Mapping Corporate Water Risk – Investigation of Baseline Water Stress for Japanese Companies

by

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Abstract

As water risk becomes more severe and noticeable in recent years, corporate water risk also receives more attention in corporate management. Realizing that water risk should be examined on a regional scale, this study started from a location perspective and examined corporate water risk of ten Japanese companies by mapping their facilities on the Aqueduct global baseline water stress map and calculating fraction of facilities that are in areas with high water risk ("number fraction"). It was found that about 40% of water-sensitive facilities both inside and outside Japan are in high-water-risk areas. Variation in number fraction values is generally weak and become stronger when number of facilities is low. As number of facilities of a certain corporation, line of business or region increases, the number fraction value approaches world average. This indicates that larger entities are able to adopt more universal water management strategies. By using different layers of water risk data provided by Aqueduct, it was observed that results vary with the chosen indicator. When seasonal variability or overall water risk is used, number fraction values drop significantly to less than 20%, especially in Japan. High number fraction values can be attributed to facilities in certain regions, but the results derived from one indicator cannot be used to predict results derived from another indicator because they all focus on different aspects of water risk. This suggests that choice of indicators should be based on specific situations. Finally, validation of number fraction as a measurement of impacts from water risk using share price fluctuation was done. The validation was not successful and the ten corporations don't show significant differences in their share price behavior with different number fractions. It was suggested that sector-specific indexes and more financial metrics be used for future analysis, which can be focusing on a bigger portfolio.

Key words: water risk, equities, facility location, Aqueduct

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Contents

1. Introduction

1.1 Water scarcity and water risk

It is widely agreed that water is a very important resource for human society. Almost all human activities – from drinking water, agricultural and industrial production, to household and recreational activities – consumes water. Beyond human society, all living things require water to survive and reproduce. The water cycle in the hydrosphere not only makes water available for all life, but also provides a way of transportation and enables the environment to clean itself after contamination. As sustainable development gains priority, the value of water resource has been recognized more and more widely. On the other hand, because water is so easily accessed and usually free of charge or quite cheap, the use of water is not properly conducted and regulated, resulting in "profligate use" [9]. In fact, contamination and shortage of available water resource has been noticed in a range of forms all over the world. For example, though it's still scientifically unclear whether the rate of global groundwater depletion is greater than the rate of natural renewal [1], regional unsustainable depletion of groundwater has been noticed and studied [2], where ground water consumption is faster than natural replenishment.

Yet over-exploitation is only one problem and groundwater is only one type of water source. Though water is identified as a renewable resource, it doesn't mean that it doesn't need any conservation or management. All of the problems mentioned before lead to water scarcity, which can be partly illustrated by total fresh water use of the world (Figure 1.1). according a report published by International Water Management Institute (IWMI) in 2007, about 1.2 billion people don't live in areas with scarce water resource. This number would be increased to 2.8 billion if economic water shortage (lack of infrastructure to get and treat water) is taken into account [28]. In short, water scarcity threatens all social and economic sectors and threatens the sustainability of the natural resources base [9].

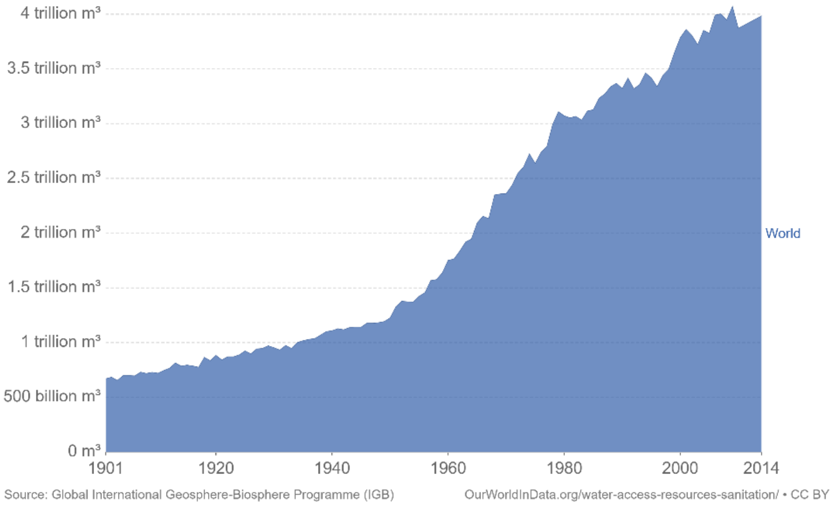

Figure 1.1 Global freshwater use over the long-run (includes freshwater withdrawals for agriculture, industry and domestic uses. Source: Global International Geosphere-Biosphere Program, retrieved from OurWorldInData)

1.2 Corporate water risk

Since water scarcity and water risk have impacts on almost every aspect of human activity, business activities, especially those that consume water such as manufacturing, transportation and research & development, are surely impacted. Presently agricultural and industrial water use account for 70% and 22% of total water use respectively [25]. Despite the fact that agriculture is the biggest water consumer and usually the first sector affected by water scarcity [9], corporate water use shouldn't be viewed as a separate issue. If water shortage occurs, industry water use has to be reduced to maintain food production.

The definition of water scarcity can be more complicated than it seems, covering stakeholders of water use, reasons of insufficient water supply (such as lack in quantity and poor quality), and impacted activities (human activities and natural ecosystems). According to Pacific Institute [10], the definition of water scarcity can be simplified to "lack of water supply in terms of volumetric abundance", which is typically measured by the ratio of human water consumption to total available water resource in a given region. "Water stress" is a more inclusive concept that refers to the inability to meet human ecological demand for water [10]. In other words, water scarcity only measures availability of water while water stress takes subsequences of water scarcity into account. Based on this, water risk is defined as "the probability of an entity experiencing a deleterious water-related event". This basic definition applies to any social sector and can be interpreted differently. For businesses, water scarcity is one part of water stress, and water stress is one of risk contributors among other non-water factors. Similar to all the other stress factors, water stress poses influence on businesses' operation and generates corporate water risk in three aspects: regulatory (management and strategies of business), physical (manufacture and distribution of products and services) and reputational (public opinions on the business). A basic framework of these concepts are shown in Figure 1.2.

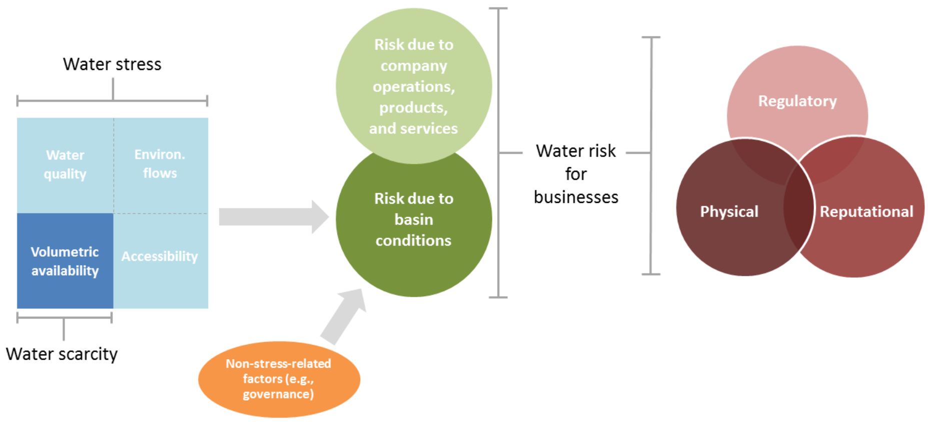

Figure 1.2 Relationship between water scarcity, water stress and water risk and their influence on businesses (source: https://pacinst.org/water-definitions/)

1.3 Regional water scarcity

While water scarcity is pervasive around the world, it is most severe in arid and semi-arid regions with inherent water shortage, especially if these regions support large, dense and rapidly-growing population and economic development [9]. People in areas with abundant water resource are more likely to conduct "profligate use" of water, which worsens the situation and also induces conflict over water allocation. This explains why water scarcity is often a regional feature, and why some corporate-level water risk research is conducted in a location-specific method. As pointed out by UN Water [9], the appropriate scale of investigating water scarcity is at local level, preferably looking at river basin and/or sub-basin. This is in line with the methodology used by Aqueduct, the basic tool used in this study.

1.4 Water-related metrics

Realizing the important role played by water risk in business activities, various water-related metrics are calculated and provided to offer insight into corporate water demand and management.

One of the most straightforward water metrics is total water use and water intensity. Total water use measures total volume of water used by a corporation. It can often be found in official sustainability reports as well as some third-party data provider like Bloomberg. Water intensity is calculated based on water use and have multiple forms. For example, water intensity per sale on Bloomberg divides total water use by total revenue to measure how much water is required to generate certain amount of sales. In addition to revenue, water intensity can also be based on assets or number of employees. However, disclosure of water use data is optional and thus not available for all companies. Its resolution is usually low, only providing annual total water use of the entire corporation. More importantly, the scope of "water use" varies across sectors and companies, which makes comparison analysis difficult to justify.

There are many other water- or environment-related metrics. For example, Bloomberg monitors environmental, social and governance (ESG) performance of more than 11,500 public companies around the world [29] and develops a set of ESG indicators. However, under environment metric folder, more metrics focus on energy consumption and greenhouse gas emissions rather than water use (total water use is not including in the ESG folder). An aggregated ESG disclosure score reflects disclosure of all ESG-related information, but it is too comprehensive for water risk research. Carbon Disclosure Project (CDP) also drives environmental disclosure on climate change, water security and deforestation [30]. These data are offered to investors and companies to help them analyze their exposure to certain environmental risks.

Water-related data are also integrated with financial data to create novel water risk metrics. For example, waterBeta® is a portfolio theory-based metric owned by Equarius Risk Analytics LLC, Ann Arbor, Michigan (hereafter referred to as "Equarius"). It combines data on water use, facility location and stock volatility. It aims to separate water risk from overall risk that are denoted by financial beta and price companies' water risk.

1.5 Research objective

Though a range of metrics have been provided to measure corporate water risk, not many of them focus on location of facilities of each company. As mentioned before, it’s better to examine water risk on a regional scale. Therefore, this study chooses ten target companies, finds all of their facilities and sees how many of them are located in regions with high water risk. This is done by water risk mapping, which input location data into a water risk indicator map. After that, multiple layers of the map are used for mapping to explore what difference would be made if we focus on different aspects of water risk while mapping the facilities. Data acquisition for mapping was done in cooperation with Equarius. Finally, market performance is compared with mapping results to test if water risk mapping offers solid information on how water risk impacts companies’ financial performance.

2. Objective corporations and groups

2.1 Choice of corporations

A total of ten Japanese corporations were chosen in this study. Choices were made together with Equarius and its clients. In addition, many Japanese corporations are well-established and disclose relatively comprehensive information about their business, management strategies and location of facilities, which benefits the research. All the ten corporations are multinational Japanese companies that is based in Japan. All of them have facilities and business around the world. At the same time, Japan is their major market which contributes to the biggest part of their revenue and holds more than half of their facilities. In this way, the choices strike a balance between diversity and similarity.

The ten Japanese corporations fall in five different industry sectors. This also allows both diversity and similarity to exist. Most of them are among the top tier of respective sectors. Huge corporations have more diverse business and more public-accessible information, and are thus ideal research targets.

Large corporations and groups tend to have multiple lines of business. A line of business (LOB) is a corporate subdivision that concentrates in a single product or a family of products [13]. It is identified with in a corporation or group from an internal point of view, a different perspective with "industry" or "sector", which look at all companies in the whole market. "A family of products" refers to a relatively wide range of business that centers around some major products. For example, for an automobile company, manufacturing of vehicles and components, distribution and sales of vehicles and marketing of vehicles are all included in the automobile line of business. However, if it also provides general financial services (which is the case of Toyota), that is considered another line of business. Some of the chosen corporations mainly focus on one line of business, while some have multiple of them.

2.2 Overview of corporations

2.2.1 Toyota Motor Corporation

Toyota Motor Corporation (hereafter referred to as "Toyota") is an automobile company that was founded in 1937. It is one of major group companies of Toyota Group. Toyota is one of the largest automobile companies in the world and it became world's largest automobile company for the first time in 2008. Though Toyota also has financial services and housing-related business, vehicle and vehicle parts production and sales is its major business. According to Global Industry Classification Standard (GICS), Toyota is in automobiles & components industry group under consumer discretionary sector. In FY 2019, automobile accounted for more than 90% of Toyota's total net revenues. Thus, this study mainly focuses on the automobile line of LOB of Toyota.

2.2.2 Shin-Etsu Chemical Co., Ltd.

Founded in 1926, Shin-Etsu Chemical Co., Ltd. (hereafter referred to as "Shin-Etsu") is the largest chemical company in Japan. It ranks seventh in the latest Forbes Global 2000 diversified chemicals sector [11]. Shin-Etsu falls under materials sector in GICS. It has the largest global market share for polyvinyl chloride, semiconductor silicon, and photomask substrates [12]. Though Shin-Etsu produces a wide range of products, all of them belong to materials sector, which means that essentially Shin-Etsu only has one line of business. Shin-Etsu is a global company with a network that spreads to more than 20 countries in North America, Europe, Asia, Oceania and Latin America.

2.2.3 Mitsubishi Chemical Holdings Corporation

Mitsubishi Chemical Holdings Corporation (hereafter referred to as "Mitsubishi") was established in 2005. In general, Mitsubishi provides products and services based on chemistry. The focus of this study is the four major sub-holdings – Mitsubishi Chemical Corporation, Taiyo Nippon Sanso Corporation, Mitsubishi Tanabe Pharma Corporation and Life Science Institute, Inc.

Mitsubishi Chemical Corporation was founded in 1933. On the basis of chemical technology, it provides solutions to a wide range of business domains such as automobile, packaging, electronics, environment and energy, etc. It is classified under the materials sector – chemicals industry in GICS.

Taiyo Nippon Sanso Corporation is an industrial gas manufacturer founded in 1910. Industrial gases business is also classified under materials sector. Taiyo Nippon Sanso supplies industrial gases to multiple sectors. among which energy is a major one. Thus, Taiyo Nippon Sanso is identified as an energy LOB of Mitsubishi.

Mitsubishi Tanabe Pharma is a pharmaceuticals company that was incorporated in 1933. Life Science Institute, Inc. offers diverse solutions in three healthcare domains: health and medical ICT business, next generation healthcare, and drug discovery solutions. Both sub-holdings are classified in the healthcare sector in GICS.

Currently, the chemicals LOB accounts for about 60% of total revenue of Mitsubishi, while its energy and healthcare LOBs account for 23% and 17%, respectively. LOB-level analysis was done for these three LOBs.

2.2.4 JXTG Holdings, Inc.

Established in 2010, JXTG Holdings, Inc. (hereafter referred to as “JXTG”) manages group companies and subsidiaries whose major business is energy and metals [15]. The group is classified into the energy sector as energy is JXTG’s most important line of business. At the same time, JXTG also has a line of business in mining and metals. This study focuses on its three major core companies in these two sectors. In total, they account for more than 95% of the group’s revenue.

JXTG Nippon Oil & Energy Corporation is a petroleum company established in 1888. It accounts for about 85% of total revenue of JXTG. Its business activities include refining, marketing and sale of petroleum products, manufacture of petrochemical products and supply of electricity and hydrogen [16]. JX Nippon Oil & Gas Exploration Corporation is involved in oil and gas exploration projects around the world. It accounts for about 2% of total revenue. Both sub-holdings are classified into the energy sector of GICS.

JX Nippon Mining & Metals Corporation was founded in 1905. Its business focuses on mining, smelting, refining and marketing of non-ferrous metals such as copper and gold [17]. Products include rolled copper foils, thin film materials and fabricated products. It is classified in the materials sector.

2.2.5 Rengo Co., Ltd.

Rengo Co., Ltd (hereafter referred to as "Rengo") was founded in 1909. It is a packaging company that manufactures corrugated boxes, folding cartons, paperboard, flexible packaging products, heavy duty packaging products and other packaging-related products. Though Rengo recognizes six core business fields (the former five and overseas operations), they are all in the packaging industry. Logistic sectors and packaging machines only account for 10% of total revenue. Thus, Rengo is identified to have only one line of business, which is materials.

2.2.6 Asahi Group Holdings, Ltd.

Asahi Group Holdings, Ltd. (hereafter referred to as "Asahi") is a beverages and foods company that was founded in 1949. It's classified in the food, beverages & tobacco industry group under consumer staples sector in GICS. Its most important product is alcoholic beverages and it also produces soft drinks and foods. Unlike other corporations, Asahi divides its lines of business based on products as well as regions. In japan, business is divided into three LOBs: alcoholic beverages, soft drinks and foods. These three LOBs accounts for 40.5%, 17.2% and 5.4% of Asahi's total revenue in 2019, respectively. All of its overseas business is put into one "overseas" LOB, which contributes to 32% of total revenue [18]. In addition, 78 distribution facilities were not classified into any LOB but they were included in calculation at corporation level.

2.2.7 Suntory Holdings, Ltd.

Suntory Holdings, Ltd. (hereafter referred to as "Suntory") produces and sells alcoholic and non-alcoholic beverages. Its wine business dates back to 1899 [19]. It also produces foods, but it only makes up a small part of Suntory's business. Suntory is classified in the same industry as Asahi. According to its financial reports, its business is separated into three LOBs: alcoholic beverages (40% of revenue), foods and (non-alcoholic) beverages (51% of revenue) and others (9% of revenues). This study only looks at the former two LOBs. Similar to Asahi, facilities of the "others" LOB are included in calculation of the group.

Suntory Beverage & Food Ltd. is a public subsidiary of Suntory and it manages the foods & beverages LOB. One unique feature of Suntory is that the group is private. Therefore, share price of Suntory Beverage & Food Ltd. was used for relative analysis.

2.2.8 Nippon Steel Corporation

Nippon Steel Corporation (hereafter referred to as “Nippon”) was founded in 1970. Its major business is steelmaking and steel fabrication [20], which accounts for 87% of its total revenue. Therefore, Nippon is in the materials sector. Other LOBs include chemicals, industrial machinery, construction and system solutions. These business segments are small in size compared to steelmaking, and were ignored in analysis.

2.2.9 Kurita Water Industries Ltd.

Kurita Water Industries Ltd. (hereafter referred to as “Kurita”) was established in 1949. Its main business focuses on water treatment, producing water treatment facilities and chemicals. Its facilities are used in industrial wastewater recycling. Chemicals are used to prevent problems in cooling systems and boilers and to improve production efficiency of the manufacturing processes in petrochemicals, steel, pulp and paper, and other industries [21]. Kurita also provides maintenance services of water treatment machineries. Because both chemicals and machinery LOB are related to water treatment, Kurita was put into industrials sector under GICS.

2.2.10 Sony Corporation

Founded in 1946, Sony Corporation (hereafter referred to as “Sony”) is a huge multinational conglomerate with very diversified business. While the corporation is classified into consumer discretionary sector, its major lines of business include game & network services, music, pictures, electronics (mobile communications/imaging products & solutions/home entertainment & sound), imaging & sensing Solutions, semiconductors, and financial services [22]. Since the electronics and semiconductors LOB involve factory manufacturing and are expected to be more susceptible to water risk, only these two LOBs were examined in this study. All the other LOBs were excluded from “total” of Sony.

3. Methods

3.1 Basic steps

Since this study aims to investigate water risk of corporations from the perspective of locations, this study mainly involves two steps: finding a comprehensive list of facilities of a corporation and mapping them on a water risk map. Detailed procedures are described in the following.

(1) Find all the facilities of corporation and their locations so that all the facilities can be located on a map.

Multiple business databases, such as Bloomberg, Factset and D&B Hoovers, provide corporate structure information. This study used D&B Hoovers for the following reasons: 1) it provides the most comprehensive list of sub-holdings, subsidiaries and branches (all of them are referred to as “facilities” in this paper) of a corporation including headquarter, plants, offices, research centers, marketing sites and sales facilities; 2) it provides city-level address of each facility, which is accurate enough to water risk mapping; 3) it identifies type of each facility, indicating what purpose does that facility serve (manufacturing, wholesale, financial services, distribution, etc.), which is essential to step (2).

Since corporate facility information on Bloomberg and Factset is either too vague or not as comprehensive as D&B Hoovers, they were not used to retrieve location data. However, information on corporation website and official report is sometimes also elaborate. More importantly, this information is authentic and thus trustable. Therefore, it is used to verify the information from D&B Hoovers. Detailed process of verification is shown in Figure 3.1.

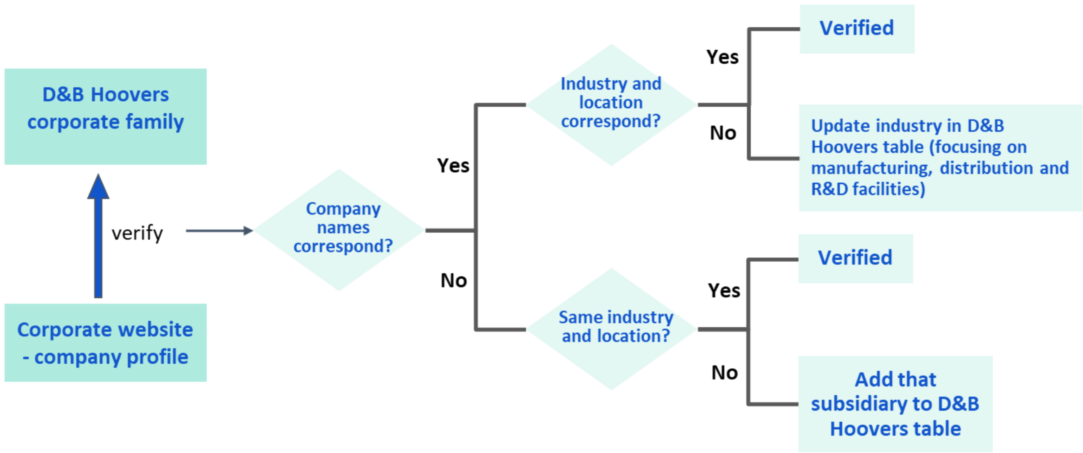

Figure 3.1 Location cross-verification process

(2) Identify facility category and line of business of each facility.

Among all the facilities, plants and research facilities are most susceptible to water risk. Other facilities, such as business offices, department stores and market research sites, are not especially water-intensive. These types of facilities only need water for daily operation and it's reasonable to assume that their water use features are similar across all companies. In other words, while water use of manufacturing facilities varies greatly across sectors, water consumption of normal offices of any company is at the same level. Therefore, similar to waterBeta® metric, this study focuses on manufacturing, distribution and research & development facilities. These are the three "categories" of facilities to consider in water risk mapping. In this study, these three categories of facilities are defined as "*water-sensitive facilities*". Because D&B Hoovers gives relatively detailed types of facilities, the three categories should be identified from them. Table 3.1 summarizes what kind of facility types are classified as manufacturing, distribution or research and development category.

Table 3.1 Classification of facility types

Categories	Example keywords in the types that are classified	Example keywords in the types that are not classified
Manufacturing	Manufacture, construction, processing, production	Engineering, repair and maintenance
Distribution	Wholesale / sales, transportation, storage and warehousing, trucking, supply	Rental, retailer, dealer, store

Research & development	Research, development, evaluation, performance, laboratory, professional, design	Business support services, consulting, programming

Apart from category, it should also be identified that how many lines of business each corporation has and which LOB each facility belongs to. This process was completed in cooperation with Equarius with information from corporation websites and D&B Hoovers.

(3) Use the World Resource Institute (WRI) Aqueduct Water Risk Atlas tool to identify the water risk level of each facility.

The Aqueduct tool provides multiple water-related metrics and returns the value of each of them for every location in an inquiry. Because corporate water risk is often measured by the ratio of human water consumption to total available water resource in a certain area, the "baseline water stress" metric was used first in this study. The tool returns both raw scores and level values from 1 to 5 to each location, indicating how risky that location is in terms of water availability. In this study, facilities that are located in level 4 ("high risk") and 5 ("extremely high risk") are deemed "*high-water-risk facility*", while the other are classified as "*low-water-risk facilities*". More detailed description of Aqueduct Water Risk tool can be found in section 3.3.

(4) Calculate fraction of high-water-risk facilities of each corporation.

With number of high-water-risk facilities and total number of water-sensitive facilities, their ratio can be calculated. This fraction serves as a basic measurement of how risky a corporation is in terms of water use. Since this fraction is derived from number of facilities, it is referred to as *number fraction* (NF) in this study.

(5) Calculate number fraction of each line of business or geographical region.

Under the corporation or group level, this study dives down to lower levels to look at what fraction of water-sensitive facilities of each line of business (LOB) or each region have high water risk. This depends on corporation structure and availability of data. If the corporation mainly focuses on one line of business, a high-level analysis would be enough. Regional number fractions were mainly calculated by dividing all facilities into "Japanese" and "overseas" ones. Although all of the ten corporations and groups are multinational, they are all based in Japan and the majority of facilities are also located in Japan. Therefore, this step adds a layer of information into the analysis, indicating potential different water management strategies in and outside Japan.

In this study, multiple indicators and aggregated scores were used to calculate number fraction. Among them, the results for baseline water stress (step 3, 4 and 5) were derived in cooperation with Equarius.

(6) Result analysis

After the number fractions of each group, each geographic region and each line of business were calculated, descriptive results were shown. On the basis of that, initial analysis on difference in NF between corporations, regions and LOBs were conducted to provide a basic picture of what kind of conclusions can be drawn from corporate water risk mapping.

In the initial analysis, all the water risk results were based on the “baseline water stress” indicator provided by Aqueduct, considering the most common definition of corporate water scarcity. However, Aqueduct actually provides 12 indicators in total as well as multiple grouping schemes to aggregate the individual metrics into overall scores (see section 3.3). therefore, after the initial analysis on baseline water stress (BWS), same analysis was done using seasonal variability (SV) as well as aggregated scores to examine the different results when different layers of water data are applied to corporate water risk mapping.

The ultimate goal of corporate water risk examination is to provide recommendations on corporate water management. To justify the recommendations, the relationship between water risk and financial performance were investigated. Share price was used as the measurement of financial performance.

3.2 D&B Hoovers

D&B Hoovers is an American business research company that provides information on companies and industries. With a data platform that leverages a commercial databased of more than 120 million business records, it offers a wide range of information including company profile, price data, financial metrics and statements, etc. This study took advantage of the “corporate family” data on D&B Hoovers. It provides a comprehensive table of all the facilities of a corporation, including offices, plants, sales bases, R&D centers and so on. Names of facilities are indented to show affiliation, which is very helpful for identifying which LOB that facility belongs to. City-level address and major business of each facility are also listed, which were used to pick out water-sensitive facilities and mapping.

3.3 WRI Aqueduct Water Risk Atlas

Aqueduct Water Risk Atlas is developed by World Resource Institute (WRI), which applies the composite index approach to translate hydrological data into intuitive indicators of water-related risks [5] it also provides graphical illustration to show special variation of water risks. WRI has launched Aqueduct 3.0 in 2019, which covers data from October 2016 through October 2018. Considering the time frame of this study, Aqueduct 2.1 was used.

3.3.1 Basic concepts used for water-related metrics

The water-related metrics (“indicators”) are based on several basic concepts.

(1) Water withdrawal: the total amount of water abstracted from freshwater sources for agricultural, domestic, and industrial uses [5]. Data are acquired from Food and Agriculture Organization of the United Nations (FAO) Aquastat database.

(2) Consumptive use: the portion of water withdrawal that evaporates or is incorporated into a product and is thus no longer available for downstream use [5]. This is estimated by by multiplying water withdrawals by estimates of the portion of withdrawn water that is consumed per sector (agricultural, domestic, and industrial) [5].

(3) Available blue water: the total amount of water available to a catchment accounting for upstream consumptive uses. It is calculated by runoff plus all water inflow to the catchment from adjacent upstream catchments.

A total of 12 indicators are used in Aqueduct 2.1, which are summarized in table 3.2.

Table 3.2 Water-related metrics provided by Aqueduct 2.1 (definitions are cited from technical notes of Aqueduct [5])

Indicator	Abbreviation	Definition
Baseline water stress	BWS	Measures the ratio of total annual water withdrawal to average annual available blue water. A long time series of water supply data are used to allow users to ignore complexities of short-term water scarcity
Inter-annual variability	IAV	Measures the variation in natural water supply between years. Indicates catchment-specific variation of total blue water. Focuses on natural variation in surface water supply while ignores human influences such as diversions and infrastructure
Seasonal variability	SV	Estimates within-year variation of water supply. Similar to IAV, human influences are ignored
Upstream storage	STOR	Measures how many years of total blue water storage capacity exist upstream of or within the given catchment
Return flow ratio	RFR	Measures the ratio of non-consumptive use upstream and within the given catchment relative to the mean available blue water. Indicates reliance on water treatment infrastructure and natural features such as buffers and wetlands to maintain water quality
Upstream protected land	PROT	Measures the proportion od total blue water that originated from protected areas
Flood occurrence	FO	Measures number of floods recorded in each catchment between 1895 and 2011
Drought severity	DRO	Measures the mean severity of drought events from 1901 to 2008
Groundwater stress	GW	Measures the ratio of groundwater withdrawal relative to its sustainable level of recharge rate in a given aquifer
Media coverage	MC	Measures the number of news articles about water issues in a country relative to the total number of articles about a country
Access to water	WC	Measures the proportion of population without access to improved drinking water sources by country and coverage of drinking water infrastructure
Threatened amphibians	AMPH	Measures the percentage of amphibian species that are threatened in each catchment

Since the raw scores of the indicators are not intuitive enough for users, each indicator is normalized to a value between 0 and 5. After that, they are categorized into five levels, with level 1 being lowest water risk and level 5 being highest water risk. For example, baseline water stress is both calculated and normalized based on the ratio of total water withdrawal to total water available. An area is considered to have "high" water risk (level 4) if the ratio is higher than 40% and "extremely high" water risk (level 5) if it's higher than 80%. Different indicators have different thresholds, which are based on combination of existing literature, distribution of indicator values and expert judgement [5].

Apart from individual indicators, the 12 metrics are aggregated into aggregated water risk scores, which applies a linear weighted aggregation approach [5]. The weights of each indicator can be subjective. They also vary depending on the usage of the tool. A default weighting scheme was developed by six staff water experts of Aqueduct [5]. In addition to that, with information from corporate water disclosure reports and industry experts [5], weighting schemes for nine water-intensive industry sectors are provided in the tool. Users can also build their own weighting scheme to tailor to specific needs.

4. Results

4.1 Number fraction of corporations and LOBs

4.1.1 Basic results

After step 1 and 2, the addresses of water-sensitive facilities of each corporation are plugged into Aqueduct and number fractions were calculated. Same analysis was done for each line of business for Mitsubishi, JXTG, Asahi, Suntory and Sony.

On corporation/group level, number fraction of each of the ten corporations and groups were calculated on three geographic levels: Japan, overseas and worldwide. Because all of the ten corporations are Japanese company, more than half of their water-sensitive facilities are in Japan (except for Sony). While all corporations are multinational, they may have only a handful of facilities in many countries. Thus, granularity would be too high if geographic analysis is done on a country level, with Japan dominating the distribution. Group-level and regional-level number fraction results are shown in Figure 4.1.

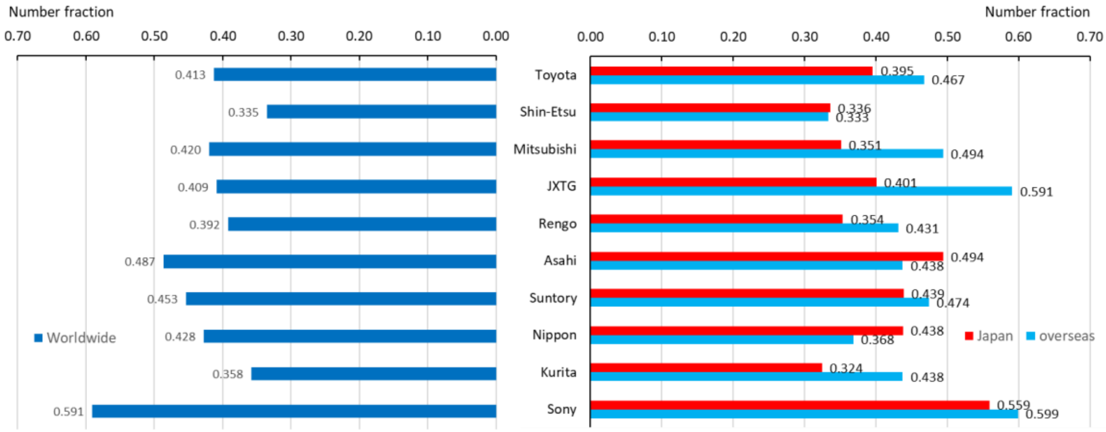

Figure 4.1 Group/corporation-level number fraction

The first observation is that the worldwide number fractions [NF(W)] of the ten corporations don't vary a lot. On worldwide level, the lowest NF is 0.335 (Shin-Etsu) and the highest is 0.591 (Sony), while all the rest fall in a range from 0.35 to 0.50.

Looking at geographic level, number fraction in and outside Japan don't have an essential difference. NF in Japan [NF(J)] ranges from 0.324 (Kurita) to 0.559 (Sony), while overseas NF [NF(O)] ranges from 0.333 (Shin-Etsu) to 0.599 (Sony). It makes sense that NF in Japan doesn't vary a lot because all the companies chosen are huge business with hundreds of or even thousands of facilities. That is to say, they all have facilities scattered throughout Japan without obvious distribution difference. Since number fractions is determined by distribution, no corporation stands out particularly. On the other hand, it is expected that overseas number fraction would have a greater variation, which is not supported by the results. The distribution of overseas facilities of the ten corporations are shown in Figure 4.2.

Figure 4.2 is a radar chart showing the proportion of overseas facilities in each continent. In general, the United States, China, the UK and Germany are countries that has most facilities for these ten companies, while other countries such as France, Belgium, India, Thailand, Australia also own quite a few facilities. Overall, facilities of the ten corporations are scattered in 70 countries across the world. In can be concluded that most overseas facilities are in Asia, Europe and North America, but from Figure 4.2 we can't say that the distribution pattern is similar enough to explain why overseas number fraction doesn't vary to an expected extent. However, the distribution pattern is still even. In other words, no corporation's overseas facilities are all in North America or Europe. Considering that the baseline water stress is prevalent across the world, it is reasonable that scattered overseas facilities result in similar number fractions.

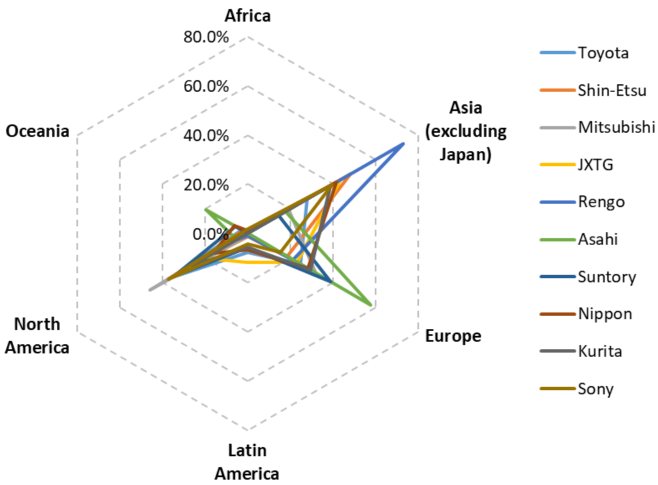

Figure 4.2 Distribution of overseas facilities

Line of business is another perspective to examine the structure of the corporations. Table 4.1 summarizes the NF results in a matrix formed by geographic regions and lines of business. Because Asahi puts all of its overseas in one separated line of business, its alcoholic beverages, soft drinks and foods LOB are all only in Japan. Blue bars in Table 4.1 provide visual illustration demonstration of NF values. For each corporation of which multiple LOB were identified, its overall NF values for each region are also shown (the "total" row) for comparison.

Table 4.1 LOB – geographic region matrix of number fraction

		Worldwide	Japan	Overseas
Mitsubishi	Total	0.420	0.351	0.494
	Chemical	0.437	0.391	0.524
	Energy	0.409	0.305	0.480
	Healthcare	0.427	0.388	0.577
JXTG	Total	0.409	0.401	0.591
	Materials	0.469	0.400	0.654
	Energy	0.402	0.403	0.500
Asahi	Total	0.487	0.494	0.438
	Alcoholic beverages		0.439	
	Soft drink		0.621	
	Foods		0.559	
Suntory	Total	0.453	0.439	0.474
	Alcoholic beverages	0.432	0.436	0.427
	Beverages and foods	0.455	0.397	0.615
Sony	Total	0.591	0.559	0.599
	Electronics	0.605	0.614	0.603
	Semiconductor	0.417	0.273	0.538

It can be observed that in most cases, NF of different LOBs on the same level are similar. It can be inferred from this that thought a corporation might develop facilities for multiple lines of business in a region, the choice of location is not obviously tied to water risk. Though different industries may have different requirements and preferences for facility locations, factors like land price, population and market situation may be more important than water-related factors in the siting process.

On the other hand, there are some LOBs that show difference in NF values. For example, the number fraction of JXTG overseas materials LOB is significantly higher than its overseas energy LOB. Similar situation can be found in three LOBs of Asahi in Japan and Sony semiconductor. One feature that these LOBs share is that their total number of water-sensitive facilities is relatively low. JXTG's materials LOB only has 26 water-sensitive-facilities outside Japan. Asahi soft drinks and foods have 66 and 34 facilities in total, respectively, which is much fewer than its alcoholic beverages LOB (239 facilities in total). Similarly, Sony semiconductor only owns 24 water-sensitive facilities worldwide, much fewer than its electronics LOB (296 water-sensitive facilities worldwide). The reason to pay special attention to quantity of facilities is that, the fewer facilities there are, the more likely this LOB's number fraction deviates from average level. Fewer in quantity means higher probability of variation. Figure 4.3 gives an example of this "probability of variation". The dark blue points on the map shows a total of 26 water-sensitive facilities of JXTG overseas materials LOB. Among these facilities, 17 are located in high-water-risk areas, which make its number fraction 65.4%. For instance, South America has an overall low fraction of high-water-risk areas, but the 4 facilities of JXTG are all located in its high-water-risk areas. If more than one hundred or even one thousand of facilities are plugged into the map, it's less likely to have such a high fraction, as the total area of high-water-risk areas (red and dark red on the map) makes up only less than half of total land area.

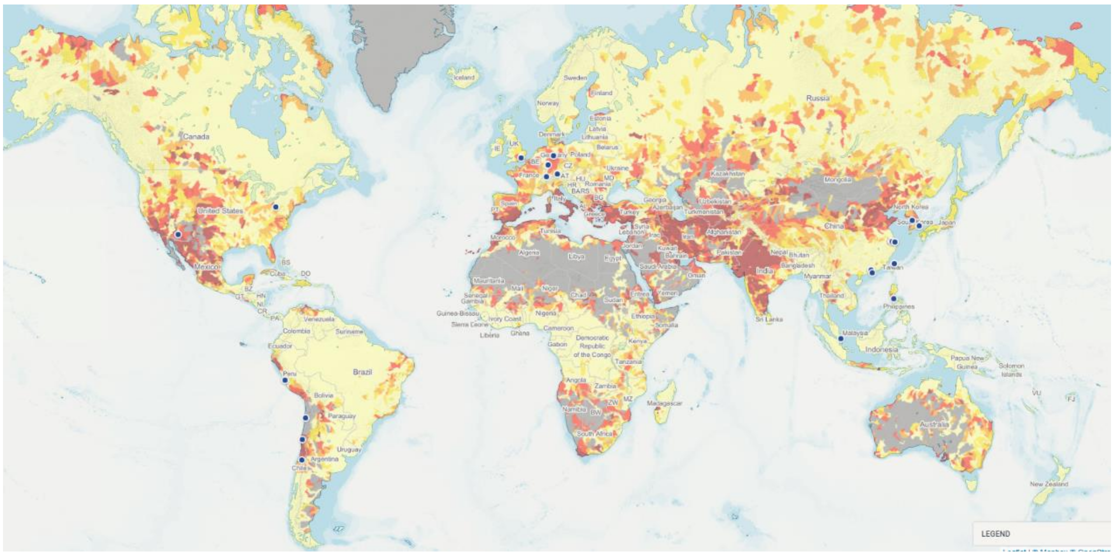

Figure 4.3 Water-sensitive facilities of JXTG overseas materials LOB

4.1.2 Observation of results

The last section gives a descriptive picture of corporate water risk mapping, indicating that number fraction based on BWS does not vary a lot either in Japan or outside Japan. The variation is a little more obvious among lines of business. This section explores what geographical factors influence number fraction and its variation.

(1) Relationship between worldwide NF and regional NF

While worldwide NF [NF(W)] does not vary a lot, it has some correlation with both NF in Japan [NF(J)] and overseas NF [NF(O)]. Figure 4.4 shows the relationship between worldwide NF and regional NF of the ten corporations. Because worldwide NF consists of regional NF, it is reasonable that generally they have a positive correlation. Furthermore, it can be concluded from the scatter plots that NF(J) has a stronger effect on NF(W). As mentioned in section 4.1, all of the ten corporations are Japanese companies and the majority of their facilities are in Japan. As a result, NF(J) has a greater weight in worldwide number fraction. In other words, compared to NF(O), NF(J) of a Japanese corporation can be used to predict its NF(W) better. This also explains why NF(W)'s variation among the ten corporations is weak. If corporations from all over the world are chosen, the variation is expected to be more obvious.

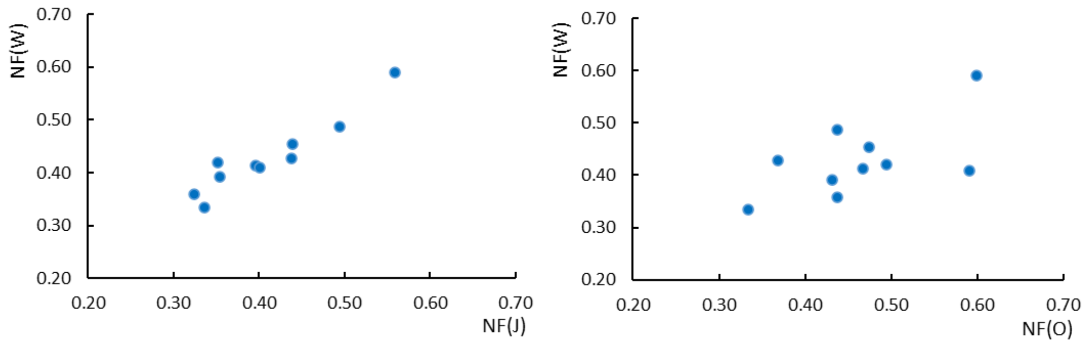

Figure 4.4 Relationship between worldwide NF and regional NF. The left figure shows relationship between NF(W) and NF(J) and the right figure shows relationship between NF(W) and NF(O)

(2) 4.2.2 NF and number of facilities

NF reflects what portion of facilities of a corporation are located in high-water-risk areas. It essentially depends on where the corporation does its business. Since all of the ten corporations are multinational, they don't feature significant different number fractions. However, it was noticed that the NF values has some relationship with number of water-sensitive facilities of each corporation, as shown in Figure 4.5.

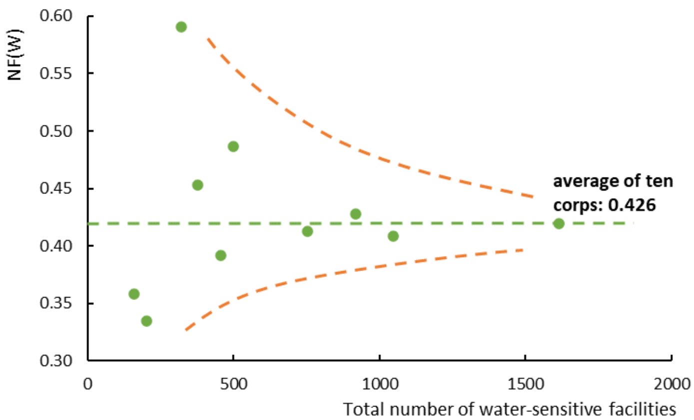

Figure 4.5 Relationship between worldwide NF and number of water-sensitive facilities

When total number of water-sensitive facilities is relatively low (<500 in this case), the NF values have more variation. The highest NF (Sony, 0.591, 320 water-sensitive facilities in total) and lowest two NFs (Shin-Etsu, 0.335, 200 water-sensitive facilities in total; Kurita, 0.358, 159 water-sensitive facilities in total) happen to fall on the three corporations with least facilities. As number of facilities goes up, variation continues to decrease and settles around 0.42. Mitsubishi has the most water-sensitive facilities (1616) and its NF(W) is 0.420. If all the facilities of the ten corporations are added together, there are 6340 water-sensitive facilities and 2703 of them are in high-water-risk areas. This gives a overall NF of 0.426, which is very close to Mitsubishi's NF. Though the sample size may not be big enough, this observation demonstrates how greater number of facilities reduce randomness in number fraction and displays a "converge pattern".

To further test this pattern, LOB-level results in Table 4.1 were mapped against respective number of water-sensitive facilities of each LOB-region pair of Mitsubishi, JXTG, Asahi, Suntory and Sony (Figure 4.6).

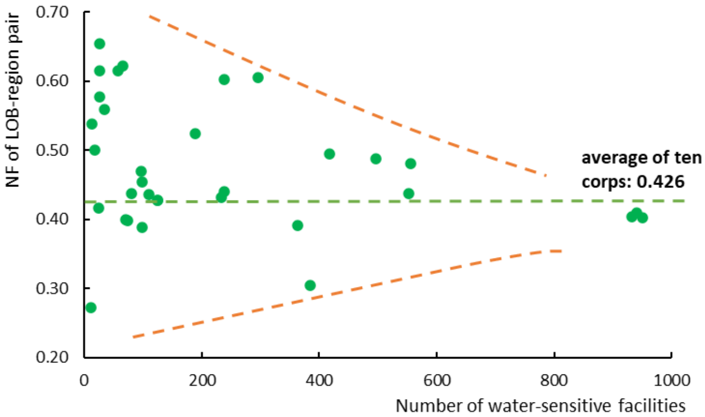

Figure 4.6 Relationship between LOB-level NF and number of water-sensitive facilities

Figure 4.6 verifies the explanation for Table 4.1 in section 4.1.1. For a certain part of a corporation, no matter if it's the entire company, a regional business portion, a line of business, or a line of business in a region (LOB-region pair), the more water-sensitive facilities it owns, the more predictable its number fraction is.

In summary, conclusion from Figure 4.4 (relationship between worldwide NF and regional NF) is more limited to this study. If companies around the world are investigated instead of Japanese companies, NF(J) (or NF of the country that the company is based in) may not be a good predictor, depending what portion of facilities are located in their base country. On the other hand, the relationship between number of facilities and number fraction is more general. It should be pointed out that the "converge pattern" suggests that NF of bigger companies is easier to predict. It doesn't mean water risk is lower for bigger companies. Small businesses or a small line of business of a big company should examine their water risk more carefully because it's more variable. Compared to small businesses, large companies may apply more universal water management strategies across LOB and regions.

4.2 Different layers of water risk data on Aqueduct

All the NF results in section 4.1 are based on the "baseline water stress" indicator. If different indicators or aggregated metrics are used, the number fractions would also change. That is to say, multiple layers are available while mapping corporation water risk. Different layer would return different results and lead to diverse conclusions. This section explores how the results would change if other indicators are used.

4.2.1 Use seasonal variability (SV)

Baseline water stress measures the ratio of total annual water withdrawal to total available water resources in a region. It intends to generally reflect if it's difficult to get enough water in a certain area. Because a long time series of water supply data are used to allow users to ignore complexities of short-term water scarcity, this indicator actually focuses on chronic water stress [5] and sacrifices variability in water availability (which is purposely put into other indicators). Many businesses are continuous, and should thus consider seasonal variation of water supply. The season variability (SV) indicator provided by Aqueduct is designed for this. It is calculated by dividing standard deviation of total blue water of twelve months by mean value of them [5]. This indicator is more related to local climate instead of water scarcity. According to results, the entire

Japan is a low-seasonal-variability area and there are literally no high-SV facilities in Japan. Figure 4.7 shows overseas NF values of the ten corporations based on SV.

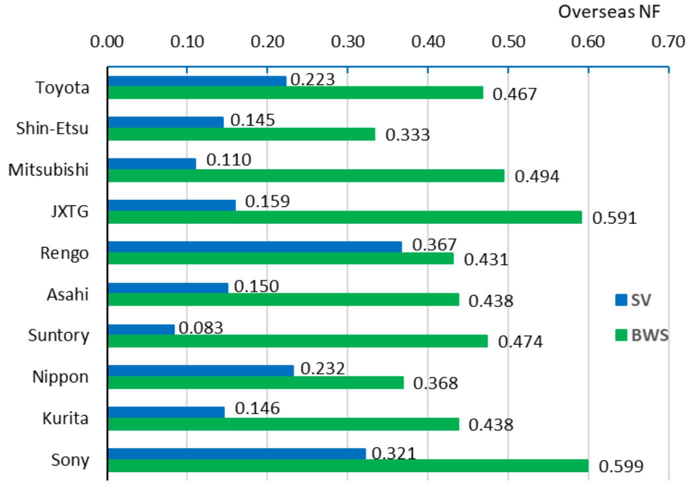

Figure 4.7 Overseas NF of the ten corporations based on BWS and SV. Because all the NF values in Japan are zero, NF(J) and NF(W) are not shown

Only overseas NFs are displayed. It can be concluded that:

1) NF based on SV (NF_{SV}) values are generally lower than NF based on BWS (NF_{BWS}). The overall NF_{SV} of the ten corporations is 0.176 (327 facilities among 1859 overseas water-sensitive facilities);

2) NF_{SV} and NF_{BWS} are not correlated. As mentioned before, SV is defined as the variability of total blue water. If a region has rich water but fluctuating resources, its SV risk is still considered high; if a region is arid throughout the year, its variation in water supply is actually low and is not considered to have high SV risk;

3) Corporations with high NF_{SV} values, including Rengo, Sony, Nippon, Toyota and JXTG, share one feature in their overseas facilities: they all have a relatively high portion of overseas facilities in South Asia and Southeast Asia countries such as India, Thailand, and Viet Nam. Due to similar climate, these countries experience significant fluctuation in water supply. Strategies such as water storage might be helpful to tackle water supply instability.

4.2.2 Use aggregated score instead of individual indicators

Aggregated score provides an idea of "overall water stress" that takes into account all of the 12 individual indicators. This section compares the NF results using aggregated score based on default weighting scheme (OWR) and those using BWS.

Figure 4.8 shows the results of worldwide NFs. NF_{OWR} is generally much lower than NF_{BWS} for all of the ten corporations. If we only look at how much water is being withdrawn from total available water resource, more regions (about 40%) are under concern. If we examine all water-related issues by looking at an aggregated score, less regions have high risks (less than 20%). This indicates that baseline water stress is an outstanding water-related problem that needs more attention.

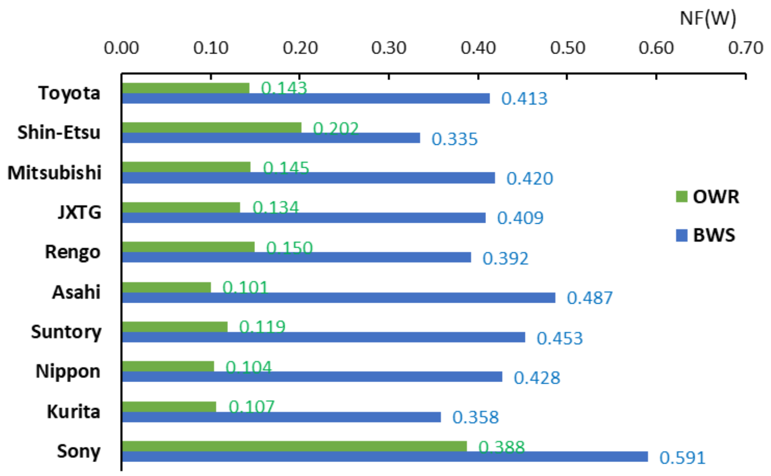

Figure 4.8 Comparison of worldwide NF values based on BWS and NF values based on overall water risk under default weighting scheme

Regional results inside and outside Japan are summarized in Figure 4.9. Similar to the results for NF(W), NF_{OWR} values are lower than NF_{OWR} values on regional level. Another similar feature with SV is that Japan has lower NFs than overseas, indicating that Japan's overall water stress is lower than average of the world. High NF_{OWR}values of Sony, Toyota and JXTG are once again due to high portion of overseas facilities in South Asia and Southeast Asia. That is to say, countries like India, Thailand and Viet Nam not only have high baseline water stress but also have high overall water risk. This can be possibly attributed to dense population and insufficient water infrastructure in those countries.

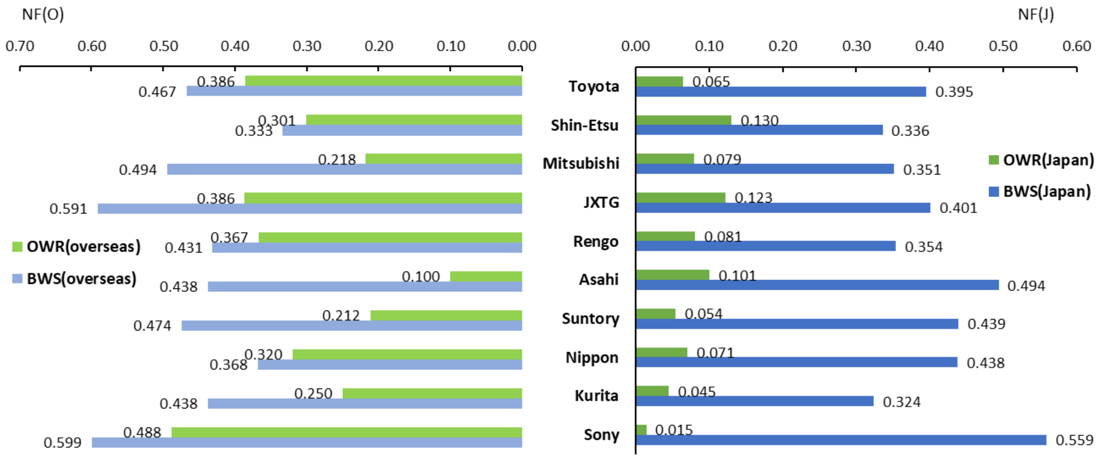

Figure 4.9 Comparison of regional NF values based on BWS and NF values based on overall water risk under default weighting scheme

The relationship between NF_{OWR} and NF_{BWS} were also plotted, as shown in Figure 4.10.

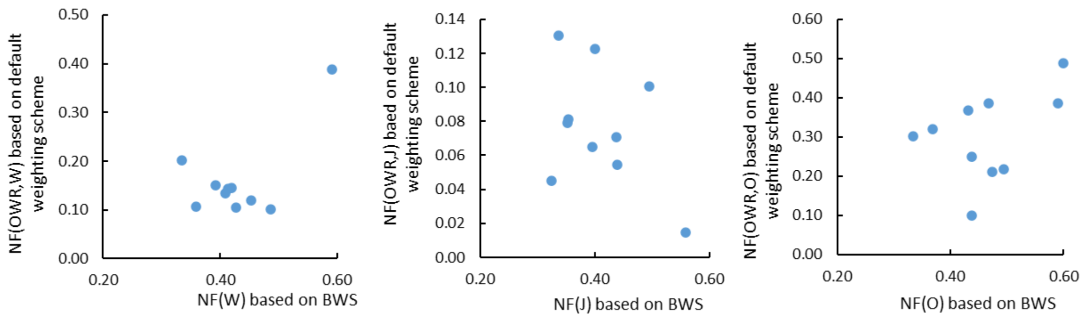

Figure 4.10 Relationship between NF_{OWR} and NF_{BWS} on worldwide (left) and regional (middle for Japan and right for overseas) level

Based on the scatter plots, the relationship is very weak and almost shows no pattern, especially in Japan. Since baseline water stress is only one of the twelve indicators, it is reasonable that it only reflects part of water risk information. In other words, regions with high baseline water stress do not necessarily have high overall water risk, and vice versa. Nevertheless, as illustrated by the former analysis, regions like South Asia and Southeast Asia do have high values in both metrics. This demonstrates that use of indicators and detailed water management strategies requires deeper assessment of each corporation's situation.

4.3 Compare mapping results with market performance

So far, all the results are based on Aqueduct Water Risk Atlas. Although Aqueduct strives to balance every aspect of water risk and provide a corresponding comprehensive assessment as well as individual factors within it, it is pointed out in its technical notes that human judgement input is necessary in the model due to lack of appropriate historical data [5], which makes the indicators subjective to some extent. Therefore, validation of results is necessary.

From a corporate water risk perspective, through the impacts on manufacturing and research & development, water risks affect companies' business activities. It then generates certain impacts on companies' market performance. While there are lot of financial metrics reflecting business performance, share price is the most commonly used one. Generally speaking, fluctuation of share price is driven by demand and supply of a certain stock [23]. In the long run, share price is tied to investors' expectations of future earnings and dividends [24]. Both understanding can be related to water risk. If a company's business is impacted by short-term water risk, its performance such as revenue and profit may drop, which leads to fewer demand of its stock and a drop in its share price. If this short-period disturbance caused by water stress happens repeatedly, investors would view this firm as a high-risk business with unstable performance. Though they may not identify where the instability comes from, this would still lower their expectations of future earnings and dividends and reduce the share price. Thus, this study uses share price fluctuation as an external performance indicator to validate the mapping results.

4.3.1 Price data of stocks and index

Daily closing prices and daily change rate of price of the ten stocks were obtained. Since stocks are traded in the market and its fluctuation is influenced by the fluctuation of the whole market, if we only look at the price change rate itself, too much information is taken into account. Therefore, index price change was used to benchmark stock price changes. The index should be able to reflect the major market the stocks are traded in and thus show a similar trend with the stock prices (representativeness). Because all of the ten corporations are Japanese companies with international business, Nikkei 225 index and MSCI World Index were chosen. Both indexes are widely used benchmark for Japan market and world market, respectively. They were tested for their similarity in trend with the ten stocks. Pearson correlation coefficient (PCC) was used to measure this similarity. Results are shown in Table 4.2.

Table 4.2 Representativeness of indexes

Stock	PCC with Nikkei 225	PCC with MSCI World
Toyota	0.79	0.30
Shin-Etsu	0.74	0.30
Mitsubishi	0.73	0.31
JXTG	0.55	0.23
Rengo	0.43	0.19
Asahi	0.59	0.24
Suntory	0.44	0.20
Nippon	0.69	0.30
Kurita	0.62	0.25
Sony	0.60	0.28

Apparently, PCC values with Nikkei 225 index are higher than those with MSCI World. Though the ten corporations are all multinational, Japan is still the most important market of them. In addition, the price data obtained are from Tokyo Stock Exchange and are in Yen. Therefore, Nikkei 225 better reflects the market behavior and serves as a "background" of price fluctuation. Price data acquisition was completed in cooperation with Equarius.

4.3.2 Performance measurement and analysis procedure

In this study, daily stock price change rates are compared with daily index price change rates by subtracting index price change rate from stock price change rate. The difference is defined as *daily stock performance (DSP)*:

$$daily\ stock\ performance = CR_s - CR_i$$

where CR_s is the daily stock price change rate and CR_i is the daily index price change rate. No matter if the change rates themselves are positive or negative, as long as this difference is positive, it indicates that the stock outperforms the index on a certain day. Time frame was set from July 2, 2013 to Dec 31, 2019. The start date was chosen due data availability of Suntory (no data before that date). The end date was not set at present to avoid strong impact of the COVID-19 pandemic on stock prices.

After daily stock performance values of each day are calculated, the lowest DSP of each month was picked out to demonstrate the risk of that month. This step was done due to two reasons. On one hand, water risks tend to be seasonal and affects business activities relatively fast. On the other hand, the impacts don't normally become noticeable to the market within merely one day. Thus, while shorter time frame is more appropriate, daily data gives too high resolution and may include a lot of other factors that can influence share price other than water risk. Hence, the lowest DSP – the worst performance – of each month was used to reflect fluctuation of market performance. This monthly lowest DSP is defined as *monthly risk indicator (MRI)*:

$$monthly\ risk\ indicator = \min\ (DSP\ values\ of\ a\ given\ month)$$

4.3.3 Results of stock performance

Before plotting results of MRI values, the distribution of DSP values was observed. As expected, DSP of all of the ten stocks are normally distributed and centered around zero. Figure 4.11 shows the distribution of DSP of Toyota.

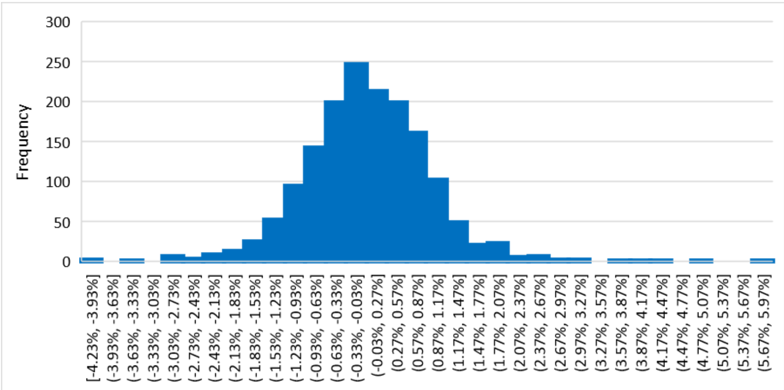

Figure 4.11 Distribution of DSP values of Toyota

Though sometimes Toyota outperforms Nikkei 225 index by nearly 6% and sometimes it is outperformed by the index by 4%, generally the DSP values are close to zero, indicating that normally a stock behaves similarly with its market index. All the other stocks show the same pattern.

With 78 MRI values (78 months from July 2013 to December 2019) of each corporation, the data were compared with NF values. Figure 4.12 shows the relationship between average MRI of 78 months and respective NF values.

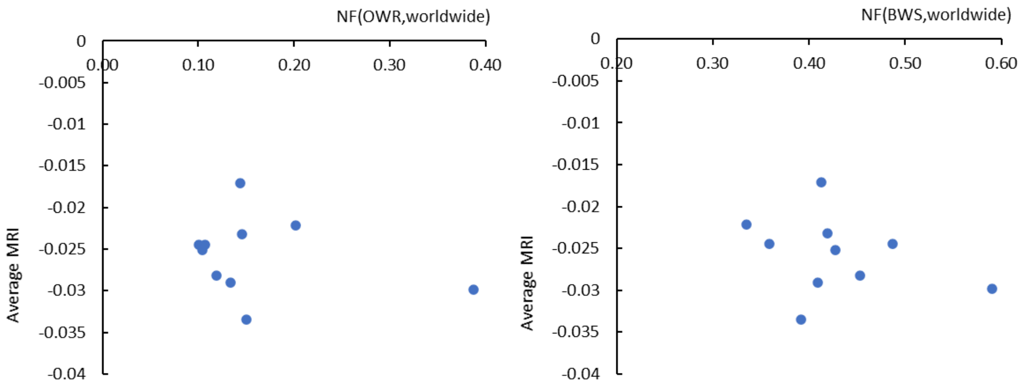

Figure 4.12 Relationship between average MRI and worldwide NF based on overall water risk (OWR, left) and baseline water stress (BWS, right).

It is expected that corporations with higher NF are subject to higher risks and thus have lower MRI values. However, no obvious correlation can be observed from the figures. MRI is not related to NF_{OWR} or NF_{BWS}. Even though Sony's NF values are significantly higher than other corporations, its average MRI is not the highest.

To further examine whether different NF values leads to significant difference in MRI values, TukeyHSD test was used. TukeyHSD test is a post-hoc statistical test of ANOVA test. Same with ANOVA, it accepts a continuous variable as the dependent variable and a categorical variable as the independent variable, which includes more than 2 categories. While ANOVA only tells us if there is a significant difference in the dependent variable among the categories, TukeyHSD provides pairwise results. Comparison results are denoted by p values, with lower p value indicating more significant difference between two categories. Figure 4.13 shows the relationship between p value of each pair and the absolute value of difference of worldwide NF values of each pair. Ten corporations form 45 pairs, so there are 45 points in each plot.

Since lower p value denotes greater difference, it was expected that the points would show a downward trend – higher difference in NF values are expected to lead to more significant difference in MRI. However, no such trend is observed in either plot and the points are almost evenly scattered. Even if two corporations have relatively large difference in NF, their MRI values may still be statistically similar, indicating similar market performance. Conversely, two corporations with very close NFs may have quite different market performance. Based on current results and choice of corporations, MRI value derived from price change is not a successful way to validate materiality of number fraction.

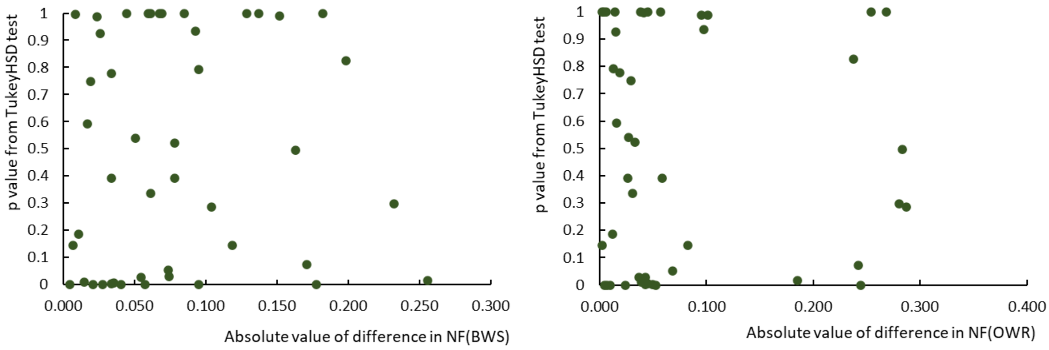

Figure 4.13 Relationship between pairwise p value and the absolute value of difference of worldwide NF values of each pair. NF values in the left plot are based on BWS and those in the right plot are based on OWR

5. Discussion

This study examines corporate water risk from a location perspective, using number fraction of high-water-risk facilities as an indicator of overall water risk of a company. While multiple layers of water-related data and multiple levels of analysis (geographic regions and lines of business) returns some valuable information, there still exist some limitations in this method.

5.1 Subjective scoring scheme

Although many Aqueduct indicators are based on objective data, subjectivity still exists. For example, aggregated score relies on grouping scheme, which boils down to weights of each individual indicator. Because of a lack of historical data on exposure to water risk [5], the weighting schemes are not validated by research on actual impacts of those indicators. This is the very reason Aqueduct provides results for every individual indicator and even allows users to create their own weighting scheme. In real world analysis, both individual indicators and aggregated scores are necessary because they give difference aspect of information that are not directly correlated (as shown in the analysis of Figure 4.10).

5.2 Limitation of number fraction

Number fraction was used throughout this study, but it may not be an ideal measurement of distribution of facilities. While number of facilities is straightforward, what financially matters is he economic output, or revenue, generated by each facility. Since the size of each facility is no the same, the actual "economic output fraction" may be either higher or lower than number fraction. Number fraction was used in this initial study because no company discloses data with such high resolution at facility level. Even so, future studies can move down to regional level (revenue from each continent, for example) and calculate "average economic output per facility" of each region. This may help increase the accuracy of number fraction and approach the real economic output fraction.

5.3 Validation of corporate water risk mapping

The validation using price change in this study is not successful, which demonstrates the difficulty of getting data that exactly reflect gain or loss generated by water risks. This partly explains why Aqueduct has been focusing on objective measurements and expert opinions instead of consequences of water risks.

The validation can be improved in at least two ways. First, choice of indexes can be sector-specific. This study chose Nikkei 225 based on the fact that it is more correlated with stock price trends and reflects the market better than a global index. While consistent index seems to make DSP and MRI more comparable, it fails to consider intrinsic differences between sectors. Some sectors are inherently more volatile than others. If a stock in such sector shows greater fluctuation in share price, it doesn't necessarily mean that this corporation is more susceptible to water risks. Hence, industry-specific indexes can be used to address inherent sector differences and only keep company-specific volatility in DSP and MRI values. For example, for Asahi and Suntory, Nikkei 500 Foods index can be used because both corporations are in food and beverages industry.

Second, other financial metrics, such as fixed asset turnover and inventory turnover, can be used for validation. Fixed asset turnover calculates the ratio of net sales to fixed assets of company and measures its efficiency to generate revenue from its fixed assets such as plants, property and equipment [26]. Inventory turnover indicates how many times a company sells and replaces its inventory in a given period. It is directly related to distribution facilities (especially storage houses). Both metrics are more detailed measurements of certain aspect of a company than share price. Since fixed assets and related manufacture and distribution activities are involved, they may contain some information on impacts of water risks. In addition, only ten corporations were examined in this study. This "portfolio" can be expanded in future analysis.

6. Conclusions

By mapping corporate water risk with Aqueduct baseline water stress indicator, it was found that about 40% of water-sensitive facilities both inside and outside Japan are in high-water-risk areas. Variation in NF values is generally weak and become stronger when number of facilities is low because smaller sample size allows greater probability of variation. The more facilities, the closer NF values are to world average. This indicates that larger entities are able to adopt universal water management strategies while smaller ones should pay more attention to unique water risks. NF(W) can be predicted by NF(J), but this conclusion is based on the fact that more than half of all facilities are in Japan. It may not be extrapolated to other companies with even more scattered facilities around the world.

NF results vary with the chosen indicator. When seasonal variability (SV) or overall water risk (OWR) is used, NF values drop significantly, especially in Japan. High NF values can be attributed to facilities in certain regions, but the relationship between results derived from different indicators is hard to find because they all focus on different aspects of water risk.

Validation of NF as a measurement of impacts from water risk using share price fluctuation was not successful. The ten corporations don't show significant differences in their share price behavior. It is suggested that sector-specific indexes, more financial metrics be used for future analysis, which can be focusing on a bigger portfolio.

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