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WHICH DO YOU PREFER, ARTISANAL OR LABORATORY MADE?: QUANTIFICATION IN TRADITIONAL JAPANESE SAKE BREWING

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Abstract

How does scientific quantification come into areas where uncodified knowledge and craftsmanship are recognized as a mission-critical factor? Exploring the sake brewing process, this study examines how quantification based on science has been implemented and utilized in the traditional brewing process from the 2000s. Scientific quantification in the sake brewing process grew not from the fallen trust in experts and the need to ensure accountability, but from the expected shortage of expert supply. Substituting seasonal migrant experts with in-house workers, introducing scientific quantification into the brewing criteria, and relying on rigorous measurement obtained from award-winners presented a reasonable solution to the decreasing seasonal migrant master brewer supply. The introduction of rigorous quantification aimed to eliminate variation in sake quality and to control brewing quality at a high level that is supposed to be equivalent to the quality that can be achieved by the guidance of a top master brewer. Quantification has advanced in brewing, even though consumers still highly appreciate the uncodified knowledge that craftsmanship holds.

Keywords: sake brewery, craftsmanship, expertise, quantification, labor market

I. *Introduction*

Which kind of sake would you prefer, artisanal or laboratory brewed? Many would say artisanal is better. Expert craftsmanship has long been considered an indispensable source of delicate and sophisticated taste. However, in recent years, master craftsmanship and expertise have been extensively replaced by methods of quantification based on biotechnology in Japan's sake brewery industry.

Sake is a traditional Japanese rice wine made by fermenting rice that has been polished to remove the bran. Sake has been undergoing gradual but steady change since the 1990s in its brewing process, distribution, and consumption. Sake consumption has gradually dropped since the 1980s. Numerous local breweries used to produce local sake for local customers until the

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2000s. However, as the sake market is shrinking, the distribution channels began to diverge into two channels (Bouzdine-Chameeva et al., 2009). Breweries focusing on mass production and low prices begins to utilize mass distribution channels such as nationwide wholesalers and retailers. Some breweries began to use distribution channels such as e-commerce channels, special sake expositions, salons, and sake tourism, specialized for city markets by advertising the appeal of their high quality and high reputation.

Focusing on the changes in the sake brewing process, this paper scrutinizes how expertise formation in sake brewing has changed and how quantification based on science has advanced in sake production. This study examines how tensions over quantification based on science emerged from the combination of a skilled labor shortage, brewery competition, and consumers' trust in the sake brewing tradition.

Quantification is the act of counting and measuring observations. The concept has evolved over the centuries through the development of scientific empiricism in various areas such as astronomy, agriculture, and medical science. Quantification has been considered one of the important fundamentals behind European imperialism. Searching for explanations for the amazing success of European imperialism, Crosby argues that precise quantification, emerging between 1250 and 1300, enabled Europeans to advance their technology, to increase productivity, and to prosper (Crosby, 1997).

Quantification plays an important role not only in science and engineering, but also in other fields. One of the areas in which quantification has advanced is business management. The use of key performance indicators introduced by management accounting is a typical example of quantification in business management. Quantifying key performance indicators, such as the level of new customer acquisition and the turnover of customers, allows managers to mobilize business resources into critical activities and to streamline business processes and activities. And, without any quantification, top management would face difficulties in achieving accountability for stakeholders.

However, the downside of quantification in business management has been pointed out as well. For example, the quantification of key performance indicators cannot necessarily capture all of the important functions in a company's operations. Some important factors, such as employee morale and quality of interpersonal communication, for instance, are rather difficult to quantify. If the quantification of key performance indicators does not take into account unquantifiable but important functions, and if such quantification is used in the performance evaluation of employees to the exclusion of other considerations, it may lower the performance of the firm because the employees will focus their activities on quantified performance indicators and tend to ignore other concerns.

Quantification has increasingly permeated various areas of society. However, one area that has been regarded as unquantifiable, or at least unsuitable for quantification, is where uncodified knowledge or craftsmanship plays an important role. Artistic design, delicate pottery, blacksmith welding, and brewing are typical examples. However, scientific quantification has begun to enter into such areas. This paper aims to explore how scientific quantification has advanced by examining the sake brewery industry in Japan, in which brewers' expertise and craftsmanship are still regarded as critically important to the quality. In addition, it scrutinizes how the relationship between craftsmanship and science has changed from complementary to substitutive.

This paper explores two breweries to examine how quantification developed in brewing.

The first is a sake brewery in Iwate Prefecture (hereinafter referred to as the Iwate brewery). Iwate Prefecture is located in north-eastern Japan. Since it has good-quality water, it has been well known for sake brewing. The Iwate brewery was founded in the middle of the eighteenth century. It is one of the oldest breweries in Iwate Prefecture. Since sake brewing has been recognized as one of Japan's traditions, sake breweries emphasize their own traditional brewing process for the purpose of marketing. Thus, they are generally loath to reveal that they have introduced a scientific approach as a substitute for artisanal expertise. Therefore, we have obtained full cooperation for our research from the Iwate brewery, which has implemented scientific quantification over the past ten years, under the condition of anonymity.

The other brewery that this paper examines is Asahi Shuzo Co. Ltd., located in Yamaguchi Prefecture. Asahi Shuzo was the exceptional case in the sake brewing industry because it publicly announced that it had begun to utilize scientific quantification extensively in brewing.

II. *How Does Quantification Advance?*

How does quantification advance? The advancement of quantification has been discussed from various points of view. However, one focal point of the arguments has been the relationship among science, quantification, and trust.

Quantification has been implemented to frame knowledge in a universal language with numbers. Therefore, it has generally harmonized well with the advancement of science, the natural sciences in particular. However, much of the previous literature indicates that not all of our knowledge is necessarily expressed with numbers. Michael Polanyi points out that science does not present all of its contents explicitly, but includes a significant level of tacit knowledge (Polanyi, 1967). This means that publishing papers or textbooks does not necessarily convey all of the findings in science. It has been observed that seasoned expertise and tacit knowledge play an important role in science. For example, Collins and Harrison explored TEA laser development and indicated that such expertise was of significant importance in reproducing TEA laser technology (Collins and Harrison, 1975, Collins, 1999). Bruno Latour has also argued that science is inseparable from technology, as in the creation of instruments and reagents and the planning of operations (Latour, 1987).

Uncodified knowledge plays an important role not only in science, but also in research and development (R&D) in business management. Scrutinizing new R&D projects carried out by Japanese firms, Nonaka and Takeuchi found that the sharing of such knowledge among R&D department and business division personnel contributed to increased productivity of the firm (Nonaka and Takeuchi, 1995). Of course, uncodified expertise plays an essential role particularly in traditional art-and-craft industries such as pottery, porcelain, and brewing. Most expertise perceived as indispensable in such industries is acquired and developed through on-the-job training and actual experience.

Although many previous studies have indicated the importance of uncodified knowledge, not many studies have explored how uncodified knowledge is transformed into quantification. One exception is the work of Theodore M. Porter, who makes the argument that quantification advances when society's trust in the tacit knowledge of experts declines. By examining the situations surrounding accountants, actuaries, civil engineers, and army engineers, Porter effectively documents the processes through which experts' tacit knowledge has been replaced

with quantification (Porter, 1995). According to his argument, quantification proceeded when society began to question the reliability of experts and to increase its demands for accountability. Quantification is likely to proceed, for example, when communication goes beyond the boundaries of locality and community in which personal trust based on intimate social networks functions well. In such a situation, one could decrease the experts' discretion and increase the level of mechanical objectivity, both of which would contribute to a higher level of accountability, by resorting to quantification. In other words, quantification grows from attempts to develop a strategy of impersonality struggling against subjectivity in response to pressures from outside that question personal expertise and that weaken elites. However, as this paper will indicate, society's trust in experts' knowledge has not fallen; consumers still highly appreciate experts' personal uncodified knowledge in brewing.

If we consider quantification as a new technology, how quantification occurred can be explained by a discussion of the longer-term trajectories of technological change. Economic historians point out that labor-saving technological developments were dominant in the early phase of the Industrial Revolution in Britain in the eighteenth century (Ashton, 1937, Hicks, 1932). They explain the dominance of labor-saving technology by the fact that labor costs relative to capital costs were higher in Britain (Allen, 2011). This explanation indicates that entrepreneurs could make a profit by introducing labor-saving technology because the labor costs were relatively higher than the capital costs. However, questioning this explanation, Rosenberg points out that entrepreneurs could have gained a profit not only by introducing labor-saving technology but also by other means such as reducing material costs or improving labor productivity (Rosenberg, 1969). He shows how the choice of decision makers in focusing their attention on certain aspects of production played an important role in directing innovation. He argues that the entrepreneurs and inventors allocated their resources to the development of labor-saving technologies because they believed that a stable labor supply would be seriously disrupted due to strikes. In other words, he argues, the particular concerns of the time served as "focusing devices." A similar discussion has taken place in the history of science and technology field. Exploring the technological changes to the turbo jet engine, Constant notes that technological change occurs not because of functional failures of current technology but because of "presumptive anomaly" (Constant, 1980). Presumptive anomaly is defined as the expectation that the current technology will fail or function badly in the not-so-distant future. In his view, what people anticipate with the current technology plays a significant role in technological change.

This point of view suggests that quantification advances by the expectation that trust in the current practices will be dysfunctional in the future, rather than by the reality of its having already collapsed. By exploring the advance in quantification in the traditional sake brewing process, this paper aims to show that, even when faith in the credibility of experts has not fallen in a society, quantification can still be triggered by the expectation that the social systems supporting the current expert credibility will collapse sometime soon.

III. *Sake Brewing, Expertise, and Competition*

Sake is an alcoholic beverage made from the ingredients of rice, rice malt, and water, which are fermented and then strained. The origins of sake go back to the eighth century.

However, the modern form of sake was developed in the sixteenth century and continues as a traditional industry to this day. For purposes of making the substance of this research clearer, three points about the characteristics of sake brewing need to be outlined.

First, sake brewing is highly knowledge-intensive. One of the steps requiring a high level of expertise is the multiple parallel fermentation process. This simultaneous multiple fermentation process is defined as the two processes of saccharification and fermentation: enzymes in the rice malt turn starch into glucose, and glucose is fermented into alcohol using yeast, proceeding in parallel within manufacturing-use containers. Multiple parallel fermentation is a distinctive process, in contrast for example with how wine and beer are made. For wine, manufactured using single fermentation, the grapes themselves contain sugar, which makes it possible to ferment them into alcohol by adding yeast. Beer is manufactured through monographic double fermentation after saccharification, where the process of breaking down starch into sugar (saccharification) and the process of fermenting this sugar using yeast proceed separately. For the manufacture of sake, it is necessary to maintain a good balance between saccharification and fermentation while proceeding with the fermentation process. Furthermore, the pre-fermentation processes of rice malt production and polished rice soaking both significantly affect the quality of the sake. Including rice malt production and soaking, sake manufacturing requires an extremely high level of expertise, and it is generally said that to become a full-fledged sake brewing expert takes about ten years.

The second characteristic involves the labor market. Sake brewing labor during the winter months has traditionally been carried out by seasonal migrant workers, called *kurabito* and *toji*. *Toji* is the master brewer, who is regarded as a highly skilled craftsperson. The master gets a contract to brew sake from the sake brewery via the brokerage of a *toji* association and takes responsibility for sake brewing. *Kurabito*, the name for the brewer, is a craftsperson working at a sake brewery under the guidance of the master. *Kurabito*s are recruited and employed by the master brewer. In the wintertime, the master brewer gathers subordinates from the region where he resides to become *kurabito*s, and they travel together to the location of the sake brewery. They stay on site and devote themselves to sake brewing until springtime. After the brewing, they go back to their home regions. Thus, they are seasonal migrant workers. Although migrant and seasonally employed craftspersons used to be dominant, the proportion of seasonal migrant craftspersons has decreased over the past twenty years. The number of non-seasonal and non-migrant craftspersons who are employed as full-time workers by the sake brewery, rather than by the master brewer, has increased.

The third is related to the quality of competition. The Japan Sake Awards are held annually. This award has been the most highly esteemed quality competition in sake brewing in Japan since its start in 1911. The award provides an important opportunity for breweries to advertise their sake brewing quality. The award is a venue for master brewers to put their expert skills on display and an opportunity to boost their reputations. Approximately nine hundred sake products from throughout Japan currently compete here. Each sake is reviewed under a sensory evaluation framework by sake experts based on blind taste tests. From the competing sakes, prize-winners are recognized as excellent, and gold prize-winners are recognized as especially excellent. Approximately 30 percent of the competition entries are given the gold prize.

Some form of quantification has been utilized from the early times of sake brewing. For example, it was important for breweries to keep a record of the amount of sake produced due

to a tax on alcohol that was strictly enforced. In addition to keeping track of total production volume, breweries right along have also routinely checked several variables such as the alcohol concentration in the final product. However, in the past, these quantifications played only a marginal role in the process of brewing. Quantification was at most complementary to the expertise of the brewers. The master brewers' expertise has traditionally been recognized as an indispensable factor playing a critical role in brewing quality.

IV. *Reduced Expertise Supply and Increased Quality Variance*

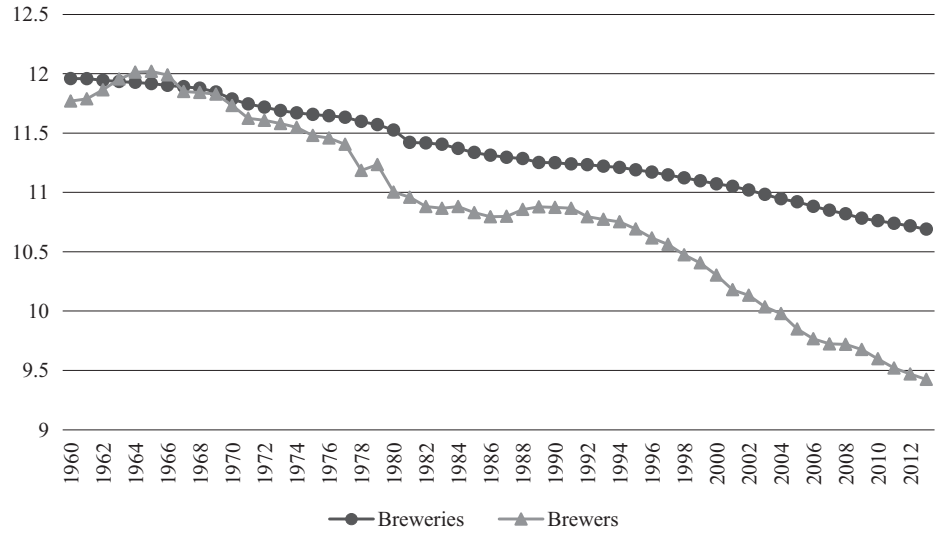
It is important for sake breweries to employ a master brewer who possesses high-quality expertise and skills. Thus, the brewery will offer better working conditions (mainly in terms of compensation) to the master brewer in order to ensure that he/she will not be lured away by a competitive brewery after winning a prize several years in a row. It is rare for a master brewer who has achieved fame to reappear on the labor market. Historically, if a brewery found a seasonal migrant master whom it employed excellent and reliable enough, it would usually offer him a better contract for the following years. This was because the master brewer's expertise played a vital role in sake brewing. It was also in a master brewer's best interests to stay contracted with the same brewery, because sake brewing is highly sensitive to the delicate conditions of a brewery such as temperature, humidity, water, and tub conditions. If a master brewer left a brewery and went to work at another, he would have to learn such conditions there and figure out the best practices on a trial-and-error basis again. Thus, if seasonal migrant master brewers change their employers often, their reputations might suffer (Fujiwara and Hori, 2009), because some might interpret their trial-and-error period as a sign of defects in their expertise.

One might wonder, then, why sake brewers did not begin to employ master brewers internally until the 1990s. First, the supply of brewers from the seasonal migrant labor market had been adequate until the 1990s. This was because, though the number of seasonal migrant brewers was decreasing, the number of breweries was decreasing faster. Second, the sake brewing season starts in October and ends in April. Therefore, the labor typically needed for brewing was seasonal.

The fact that the number of seasonal migrant brewers began to decrease around the beginning of the 1990s played a critical role in this change. Figure 1 shows the number of breweries and brewers from 1960 to 2010. The number of breweries in Japan was easy to ascertain. However, since the number of seasonal migrant brewers in Japan is not on public record, this paper uses the number of brewers registered in the Southern Toji Association as a proxy. The Southern Toji Association is the largest brewers' labor union in Japan. There are approximately thirty brewers' labor unions in Japan. These unions are geographically organized, as in the north-central region on the shores of the Sea of Japan and central Hyogo and Kyoto Prefectures. The Southern Toji Association accounts for nearly 30 percent of all master brewers. Because it reflects the relative longitudinal change in the number of breweries and brewers, the data here are log2-transformed: if the number on the vertical axis is decreased by one unit, it signifies that the actual number has been decreased by one-half. Figure 1 shows that the number of breweries was constantly decreasing from the middle of the 1960s. The number of brewers followed approximately the same trend. However, the latter variable diverged from

the trend and began to drop rapidly in the 1990s.

FIGURE 1: NUMBER OF BREWERIES AND BREWERS



Source: Southern Master Brewer Association (Nanbu Toji Kyokai), 1960-2013, National Tax Agency (Kokuzeicho), 1960-2013.

Why did the number of brewers begin to drop sharply in the 1990s? One of the biggest reasons was the decrease in the number of agricultural workers. The number of agricultural workers in Japan has been declining since the 1960s, dropping by one-third from 1960 to 1990. The decreased number of agricultural workers has been attributed to advancement of mechanization in farming and new employment opportunities in the industrial and service sectors.

The decreased number of agricultural workers reduced the seasonal migrant worker supply. Rice farmers have historically been dominant within Japan's agricultural sector. The leading rice farming areas have been the northern parts of Japan such as Niigata, Akita, Fukushima, Yamagata, Iwate, and Hokkaido, because of their good water supply, large temperature difference between daytime and night, and soil conducive to good water drainage. The rice farming season usually starts in the middle of March, when the farmers prepare rice seeds, and ends in late September, when they harvest. The rice farmers typically go to breweries and work there from October until March, because farming is virtually impossible in the wintertime due to heavy snow.

The number of seasonal workers steadily decreased from the 1960s. The actual number dropped from 297,000 in 1980 to 15,000 in 2000 (Ministry of Health Labour and Welfare, 2011). The leading job opportunities for seasonal migrant workers have been in the construction and manufacturing industries. However, the decreased number of seasonal migrant workers has had a significant impact on the brewer supply because the main brewer supply was from seasonal migrant workers.

Facing a shortage of seasonal migrant brewers, brewing companies shared the thought that this would be a serious problem for sake brewing and that they should do something at the round-table talks at the eightieth anniversary of the Southern Toji Association in 1991 (Hatafuku, 1991).

Two reasons for the decreasing number of seasonal and migrating brewers were discussed at the round-table talks (Hatafuku, 1991). First, the volume of seasonal migrant labor was decreasing due to the unstable lifestyle and the physical demands of the work. Second, manufacturing firms had begun to open factories in Iwate, which provided good job opportunities for young workers.

Therefore, it was difficult for brewers to recruit young workers as seasonal migrant brewers. Doing so had always been important because they were the major source of candidates for master brewer. They worked and lived together with a master brewer and accumulated expertise. One of the brewers suggested, "If this trend is not stopped, it will be impossible to hold a good supply of master brewers" (Hatafuku, 1991), p. 125). Another brewer stated, "We should do something about the shortage of master brewer candidates" ((Hatafuku, 1991), p. 96).

As the supply of master brewers relative to the number of breweries decreased, the variability in the quality of master brewers became a serious problem for the breweries. The expertise and skills of master brewers vary significantly between individuals. Some master brewers are able to win a prize for years. Many of them win a prize every once in a while. Some master brewers have never won a prize at all. If the supply of master brewers continued to decline, it would make the quality of sake brewing increasingly unstable, and increase production costs as well.

V. *Internalization of Expertise*

Facing a shortage of seasonal migrant master brewers, sake brewers began to hire master brewers internally. The hundred-year anniversary of the Nanbu Toji Association published in 2014 indicated that the number of non-seasonal-migrant master brewers employed by a sake brewer as full-time workers was increasing (Sugawara, 2014). The following graph signifies the total number of brewers in the Southern Toji Association and the in-house employed brewer ratio in Japan. Since the total number of brewers in Japan was not publicly available until the middle of the 1980s, it uses the ratio collected by the Southern Toji Association as a proxy. It shows that the seasonal migrant brewers' share dropped sharply from the 1990s and fell below half in 2002.

The following figure shows the average age of brewers from 1975 to 2015. The Japan Sake and Shochu (distilled spirit) Makers Association began to survey seasonal migrant brewers' ages as distinguished from those of full-time employed brewers from 1999. This distinction by itself implies that the number of in-house brewers was increasing from the 1990s.

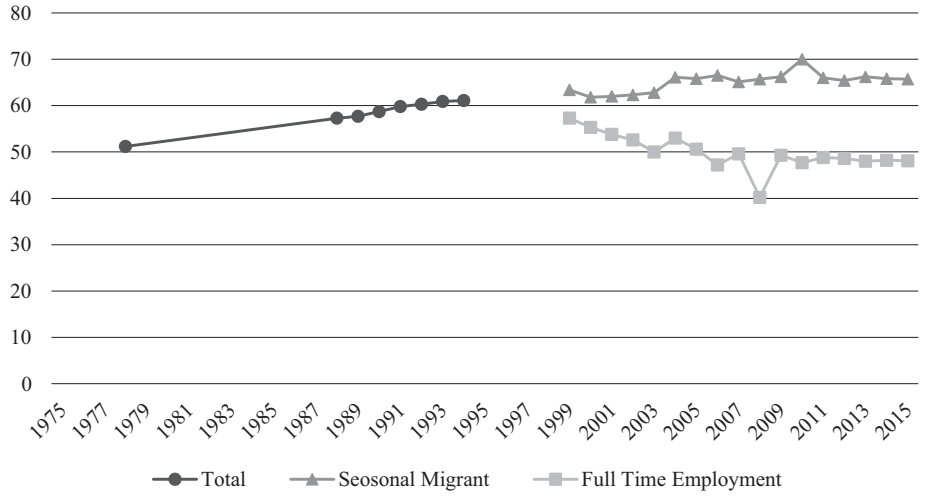
This figure demonstrates that the in-house brewers' average age was decreasing, while that of the seasonal migrant brewers was gradually increasing. This suggests that the breweries began to replace the seasonal migrant experts with younger in-house workers.

When the breweries began to contract master brewers internally, it was necessary for them to find or accumulate expertise, which they used to source from the seasonal migrating master brewers. However, this would require a certain amount of time. The expertise that the seasonal

FIGURE 2: NUMBER OF BREWERS AND SEASONAL MIGRANT BREWER RATIO

Source: National Tax Agency (Kokuzeicho), 1980, 1984-2010, Southern Master Brewer Association (Nanbu Toji Kyokai), 1960-2013.

FIGURE 3: AVERAGE AGE OF BREWERS



Source: Japan Sake and Shochu Makers Association (Nihonshuzo Kumiai Chuokai), 1975-2015.

migrant master brewers held was accumulated by long-time trial and error based on the apprentice system between seasonal migrant masters and brewers. The personnel whom the breweries sourced internally and attempted to train as potential master brewers had never been trained in the apprentice system. Thus, the challenge faced by the breweries that tried to replace the seasonal migrant master brewers with in-house personnel was how to keep the quality of skilled craftsmanship from dropping.

Sake breweries introduced on-the-job training (OJT) programs to develop the skills that master brewers were expected to have. In addition to internal OJT, it was important for the breweries to send their personnel to technical workshops organized by the Toji Association, the National Research Institute of Brewing, and the Japan Sake and Shochu Makers Association, because they were important channels through which to accumulate sake brewing expertise. However, training was not the only way of mitigating the potential loss of quality under the new arrangement. In this transition from seasonal migrant labor to internally hired labor, the breweries began to introduce science formally into the brewing process.

VI. *Quantification in Craftsmanship*

This section scrutinizes how scientific quantification was introduced and how it was utilized in brewing. Like the majority of brewers, the Iwate brewery had previously hired a seasonal migrant master brewer and brewers. The master brewers whom the Iwate brewery had hired were not at the top notch, as they had only won prizes sporadically. The Iwate brewery was not a regular winner of the quality award at all until 2011. Based on the fact that the seasonal migrant master brewer supply was decreasing, the Iwate brewery began to replace seasonal migrant masters' expertise with internal full-time salaried workers empowered to make the final decisions about sake brewing in 2008.

Replacing the seasonal migrant brewer with the full-time salaried worker has helped reduce the brewery's personnel expenditures as well. The brewing director of the Iwate brewery stated:

> If we hired the master brewer internally, the labor costs would be reduced. It was because the seasonal migrant master brewer costs the same as the internal full-time salaried employee, even though the seasonal migrant master brewer works only during the winter season.[1]

How was quantification implemented? Quantification in brewing significantly began early in the new century. The Iwate brewery introduced science into its brewing in 2008. Previously, the Iwate brewery had carried out scientific analysis to some extent when manufacturing sake. Specifically, they had scientifically measured the degree of density of alcohol content, acidity, amino acids, and such like. However, these measurements were carried out after the sake manufacturing process was almost complete. They used the measurements not for improving the sake's quality during the manufacturing process but for final quality checks. Compared to the importance of the master brewer's expertise, the role played by the measurements was marginal. In other words, the relationship between scientific measurement and master brewers'

[1] Interview, July 22, 2015.

expertise was complementary.

However, the Iwate brewery changed its sake brewing strategy in 2008 by introducing science, not as a complement to, but as a substitute for, the master brewer's expertise. Specifically, it began to brew sake by rigorously measuring enzyme activity in the production of rice malt and setting the values from these readings as their criteria during sake manufacturing. Carrying out rigorous enzyme measurement allowed the brewery to control and change the quality of the sake during the manufacturing process. Furthermore, it began to utilize values obtained by undertaking a component analysis of sake produced by competitors receiving prizes at the awards ceremony. In other words, it began to create sake, not based on the master brewer's expertise, but based on a number of variables obtained by component analysis of the prize-winners.

This was clearly a strategic response of the sake brewers to the master brewer shortage. If the Iwate brewery hired a seasonal migrant master brewer from the labor market, its sake brewing would significantly rely on the master's expertise. However, it would lead to unstable sake brewing under conditions where the master brewer supply was decreasing.

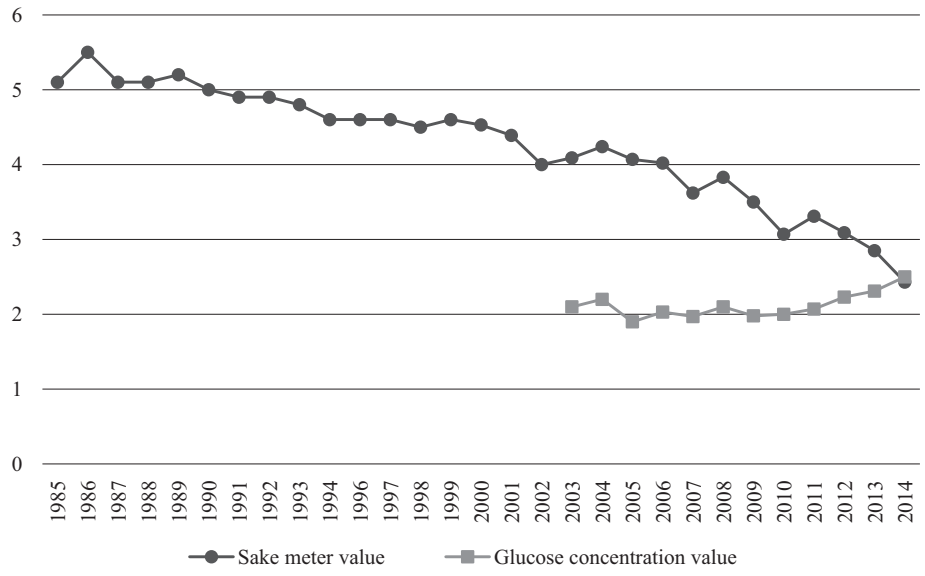
Let us explore in detail how scientific quantification is utilized in the brewing process. Quantification began to be used in coordinating the sake's taste. The National Research Institute of Brewing analyzed the award-winning sake and released some of the components' values such as glucose, ethyl caproate, isoamyl acetate, and amino acids. One of the values that the National Research Institute of Brewing has analyzed and publicly released for the average value of award-winning sake was the sake meter value. The sake meter value signifies the density of sake relative to water. This value is one of the basic measurements in classifying sakes based on their dryness, developed to help customers in selecting sake. The sake meter value does not necessarily guarantee the quality of sake at all. Consumers have generally used the sake meter value to measure to what extent a sake is dry or sweet: the lower the sake meter value is, the sweeter the sake tastes. The sake meter value has been reported since 1911. However, it did not significantly influence the brewing process until the pressure of the anticipated master brewer supply shortage intensified after 2000.

One of the component values that attracted great attention was the glucose concentration value, which has been disclosed since 2003. The glucose concentration value signifies the sugar content in 100 ml of sake, which is positively correlated with a sake's sweetness. The higher the glucose concentration value is, the sweeter the sake tastes. The following curve illustrates the average sake meter value and glucose concentration value of award-winning sakes from 1985 and 2003, respectively.[2]

This figure shows that award-winning sakes have generally been sweeter. This trend has been widely shared with sake business practitioners. Therefore, it has been important for brewers to make their sake sweeter. In this light, the glucose concentration value has played an important role because it provides an important data source for in-house brewers for their scientific quantification in brewing.

[2] The competition was not held in 1995. From 2001 to 2011, the Annual Japan Sake Awards classified two types of sake based on the percentages of the usage of Yamadanishiki, which is a dominant type of rice in sake brewing. The one is sake whose Yamadanishiki ratio is less than 50%; the other is with more than 50%. The award divided the competition into two categories. This figure shows the sake whose Yamadanishiki usage is more than 50%, which is dominant in terms of the number of entries.

FIGURE 4: AVERAGE SAKE METER VALUE AND GLUCOSE CONCENTRATION VALUE



Source: Iwano et al., 1994; Okazaki et al., 2000; Sudo et al., 2010; Fujii et al., 2015.

Traditionally, seasonal migrant master brewers would evaluate the flavor and taste and decide the timing of the individual processes such as rice dipping treatment, steaming, cooling, malting, and maturing, based on their five senses and their experience (Sugawara, 2014). However, scientific quantification allows the control of sweetness by measuring the enzyme activity of rice malt. The enzyme activity of rice malt is closely related to the taste of sake because one of its components is glucoamylase. A higher glucoamylase value means a higher glucose concentration value.

With quantification, one can increase the glucose concentration value to an appropriate level by adding exogenous enzyme if the glucose concentration value is not high enough (Taguchi and Ito, 1994). If the enzyme activity value is insufficient, one can calculate how much exogenous enzyme should be added to obtain an appropriate enzyme activity value achieved by the prize-winning sakes. Now, even without use of the five senses and the expertise obtained through experience, it has become possible to make sweet sake by measuring the enzyme activity of rice malt and adding exogenous enzyme in the fermentation process. One of the in-house brewers stated:

> We checked the current glucose concentration and added glucoamylase powder in order to attain an amylase concentration ratio of 2.3, which was the target ratio. If we did this, it made it easier for us to be awarded in the competition.[3]

The relationship between glucoamylase and glucose concentration value has long been known among brewers. However, it was not utilized in the brewing process until quantification

[3] Interview with the in-house master brewer, conducted on July 21, 2015.

advanced in more recent years.

By introducing scientific quantification, the full-time employee became capable of controlling the glucose concentration value, even without much experience in brewing. Obviously, this utilized science, not just for the final check, but also for controlling and changing the sake's flavor. In other words, in contrast to the Iwate brewery's reliance on the intuition and experience of a master brewer until 2007, from 2008, the master brewer was replaced with the brewing company's own full-time employee, and greater emphasis was placed on quantification as an alternative to the master brewer's expertise.

How did the increased use of science change the quality of sake at the Iwate brewery? It improved it dramatically. For the years from 2000 through 2010, the Iwate brewery received a gold prize only twice from the Annual Japan Sake Awards. However, it has received gold prizes for five consecutive years running from 2011. An in-house brewer who has filled the role of master brewer since 2008 said, "Up until then, sake production was carried out in a somewhat vague manner based on the seasonal migrant master brewers' seat-of-the-pants approach."[4] The change was due to the expected shortage of seasonal migrant brewers and the brewery's inability to win a gold prize more than occasionally. By substituting science for expert skills, the Iwate brewery has achieved steady, high-quality brewing.

Scientific quantification has a strong impact on the quality of sake brewing. However, as mentioned above, the majority of breweries hesitate to advertise that they have replaced the craftsmanship and expertise of the master brewer with scientific quantification, because craftsmanship has been one of the important appeal points in marketing. Therefore, it is difficult to quantify to what extent quantification has influenced sake brewing quality.

However, a brewery located in Yamaguchi Prefecture, Asahi Shuzo Co. Ltd., explicitly disclosed that it utilized scientific quantification extensively. Asahi Shuzo Co. Ltd. was founded in 1948 in Yamaguchi Prefecture. As did other breweries, Asahi Shuzo also employed master brewers from the seasonal migrant labor market. However, it decided to discontinue that practice and began to train in-house personnel in order to brew sake internally in 1999. When the existing master brewers resigned, Hiroshi Sakurai, the president of Asahi Shuzo, realized that it had become difficult for the firm to engage master brewers because the labor supply was shrinking. The president said that the seasonal migrant master brewers were aging and the job was becoming less attractive to young people (President Inc, 2014). After the in-house brewing group decided not to rely on seasonal migrants' expertise and began to make use of sake brewing textbooks, the sake the team brewed attained superior quality to the sake that had relied on the master brewers' seat-of-the-pants approach. Therefore, the group decided to utilize scientific quantification and strict numerical value controls for the long term (President Inc, 2014).

Specifically, Asahi Shuzo introduced component analysis equipment to measure various values such as amino acids and enzymes in the brewing processes at its analysis laboratory. Based on the data obtained by the component analysis, the brewing group made delicate adjustments to the fermentation conditions. In the malted rice production process, the amount of evaporation from steamed rice is strictly controlled for the quality control of rice malt by introducing weight sensors. The brewery began to control primary material rice cultivation processes as well as introducing sensors to detect soil temperature and humidity (Nikkei

[4] Interview with the in-house master brewer, conducted on May 15, 2015.

Veritas, 2014). The president articulated the fact that "we have no seasonal migrant master brewer. We invested in introducing analysis and sensor equipment to rigorously examine components and processes for intensive quality control" (Nikkei MJ, 2014). "We try to brew good-quality sake, which would be awarded gold prizes by the National Research Institute of Brewing, not by the craftsmanship and spirit of master brewers but by systematically controlled routines" (Nikkan Kogyo Shimbun, 2014).

As described above, quantification technology was introduced to compensate for a skilled labor shortage. Sake brewed by quantification technology began to win the annual competition. However, unlike Asahi Shuzo, most breweries do not publicly announce that they utilize quantification technology for their brewing. This is because, while it has become important for breweries to utilize quantification, their customers still put a high level of trust in craftsmanship for sake brewing. The tension between quantification and consumers' preference still exists. Therefore, sake breweries emphasize their own traditional brewing process for the purpose of marketing. Quantification has achieved positive results in the quality competition. However, it is still less appreciated by consumers.

VII. *Conclusion*

Exploring the sake brewing process, this study has examined how quantification has been implemented in the traditional brewing process since the start of the new century. Sake breweries began to employ master brewers internally and to introduce scientific component analysis into the brewing process.

The previous literature argues that quantification advances when credibility of expertise falls. As reviewed above, Porter found that the pervasiveness of quantification in accounting, insurance, and civil engineering did not grow out of the inherent nature of scientific activities (Porter, 1995). He showed, rather, that quantification prevailed in areas where experts were losing their credibility and companies had to adopt a strategy to cope with pressures to ensure accountability from outside.

However, decline in credibility was not the main factor promoting quantification in sake brewing. The majority of the sake breweries have not publicly admitted that they have introduced science into the traditional brewing process. Instead, they still emphasize their exquisite craftsmanship as a marketing strategy, which implies that they believe sake consumers still put high reliance on the master brewer's expertise.

Quantification in the sake brewing process grew not from the fallen trust in experts and the need to ensure accountability, but from an expected shortage of experts. The shortage of expert supply from the labor market was occurring from the changes in the nature of work. The income gap between agricultural workers and industrial workers was increasing. Therefore, the number of agricultural workers was decreasing. As a result, the number of seasonal migrant workers was diminishing. This reduced the brewing labor supply.

Replacing seasonal migrant experts with in-house workers, introducing quantification into the brewing criteria, and relying on rigorous measurement obtained from competition winners presented a reasonable solution. The introduction of science aimed to eliminate variation in sake quality and keep the brewing quality at the high level expected to be achieved through the direction of a top master brewer. If asked, "Which would you prefer, artisanal or laboratory-

made sake?" many people would answer that artisanal would be better. The notion that the expertise of master brewers is an indispensable source of good-quality brewing still exists. However, the case of sake brewing suggests that quantification supported by the laboratory would yield better results, not only in response to the expertise shortage, but also in quality. In the annual Japan Sake Awards, where the judges evaluate sakes based on a blind taste test, the sakes made with quantification have increasingly won.

This paper has examined how the relationship between craftsmanship and quantification based on science can move from complementary to substitutive by examining the sake brewery industry in Japan. It discussed how the implementation of scientific findings in this industry was promoted, not by decreased credibility of experts' authority, but by a decreased supply of a high-quality skilled workforce. This presents another route toward prevailing scientific quantification in society. Since our research focuses on a single case study of a traditional industry, and although further investigative research is required, we consider our results a contribution to the analysis of factors leading to the substituting of science for expert knowledge. Furthermore, as one direction of future research, it is important to build on the present studies to explore the effects of quantification. Some seasonal master brewers have predictably been critical of quantification, as it can neglect very delicate and unquantifiable but important aspects in brewing. Some experts have pointed out that the diversity of award-winning sakes has diminished since quantification has advanced. It is possible to suppose that many brewers have focused on the quantified points and ignored other uncodified aspects. It is important for future research to explore the relationship between quantification of processes and diversity of products.

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