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Chapter 1
Comparison of Rice Production in China and Japan: Evidence from A Panel Data Analysis

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Abstract: Rice is one of the most important staple foods in the world, especially in Asia. According to the data for 2020 from the Food and Agriculture Organization (FAO), Asia accounts for 89% of worldwide rice production and 88% of global rice consumption. Of Asian countries, China and Japan play significant roles in the production and consumption of rice. China produces and consumes approximately one-third of Asia's rice in terms of quantity. Although Japan's percentage is not as large as China's, their rice productivity and quality are notable. This study uses a provincial (regional) panel data set on China's and Japan's rice production (Japonica rice) to examine cost composition and variation in rice production in the two countries. The results indicate that the cost-revenue ratio of rice production in Japan ranges from 0.96 to 1.42, while in China, it ranges from 0.64 to 0.92, suggesting Japan's rice production is economically unprofitable, and China's rice production is about to face the same issue. Building on this, the study applies DEA (data envelopment analysis) to the data set to further analyze the differences in rice production efficiency between the two countries. The results reveal that the estimated efficiency score of rice production is greater in China (0.92) than that in Japan (0.66).

1. Introduction

Rice is one of the most important staple foods in the world, particularly in Asia. According to the data published by FAO (2020), Asia accounts for

89% of worldwide rice production and 88% of global rice consumption. While rice is mainly produced and consumed in Asia, its percentage has been declining in recent years. Of Asian countries, China and Japan are significant contributors to the production and consumption of Asia rice. China alone produces and consumes approximately one-third of Asia's rice. It is also the largest rice producer globally, accounting for about 30% of the world's total production, and is the largest rice consumer, representing about 30% of global demand in 2021. Although Japan's percentage is not as large as China's, its rice productivity and quality are impressive.

Figure 1.1 shows rice and other main staple crop production in China. We can see that rice was once the first staple crop in China, no matter whether in terms of sowing area or yield. In terms of sown area of rice, the total percentage increased from about 22% in 1960 to almost 30% in 1980 and then gradually declined in recent years. Since 2000, the sown area of maize in China has grown rapidly. This is probably because of an increase in the domestic need for forage. Similarly, it can be clearly seen that the yield of maize has had a rising trend in recent years while the rice yield has tended to flatten out. However, rice production occupies less land but yields a greater output, indicating the average productivity of rice is much higher than other staple crops.

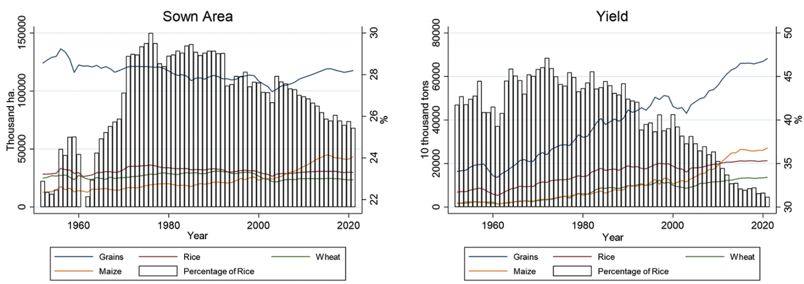

Figure 1.1 Rice production in China.
Source: The data are from the annual database of China's National Bureau of Statistics.

In fact, China's rice productivity has more than tripled in the past several decades as shown in Figure 1.2. Possible reasons are (1) the prevalence of household responsibility system and domestic market liberation (Lin 1992), (2) support of Government policy (Huang et al. 2006; Huang et al. 2013), (3) the development of high-yielding varieties (Peng et al. 2009), (4) improved crop management practices (Peng et al. 2009), and (5) increased demand for rice. However, China's rice production is currently facing several problems involving off-farm employment (Peng et al. 2009; Dong et al. 2018), such as labor transfer, a decline in arable land (Zhai and Ikeda 2000), a looming water crisis (Cai 2000; Li 2006; Li and Li 2011), and global climate change (Tao et al. 2003; Lyu et al. 2020). Consequently, Chinese rice is gradually losing its comparative advantages.

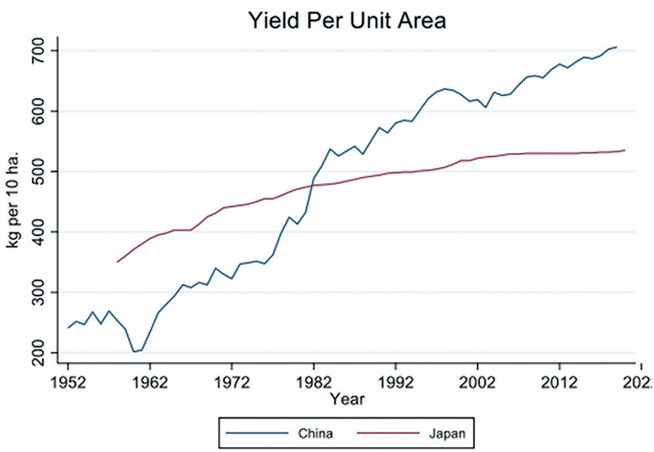

Figure 1.2 Rice productivity in China and Japan.
Source: The data are from the database of the Ministry of Agriculture, Forestry, and Fisheries of Japan.

Figure 1.3 shows the trends in the export and import of rice in China. Before 2010, China exported much more rice than it imported. Since the early 2010s, due to a slowdown in the growth of rice production and a rapid increase in rice consumption, China has changed from a net exporter of rice to a net importer. In recent decades, China has sustained a high level of rice self-sufficiency (above 97%) due to the low level of rice import in the past decades.

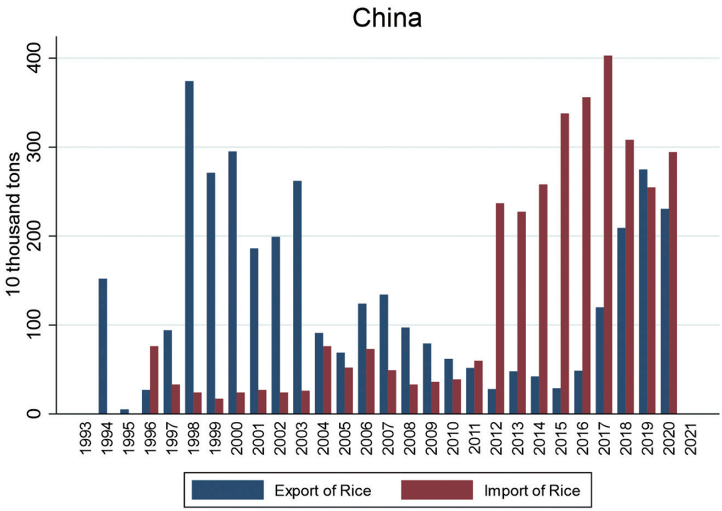

Figure 1.3 Export and import of rice in China.

Source: The data are from the annual database of China's National Bureau of Statistics.

Figure 1.4 shows rice production in Japan. We can see that both the sown area and the rice yield have declined since 1960. The percentage of rice in the total sown area declined from almost 50% in the late 1970s to about 37% recently. Meanwhile, the percentage of rice yield declined from 70% in total in the late 1970s and remains stable at 55%.

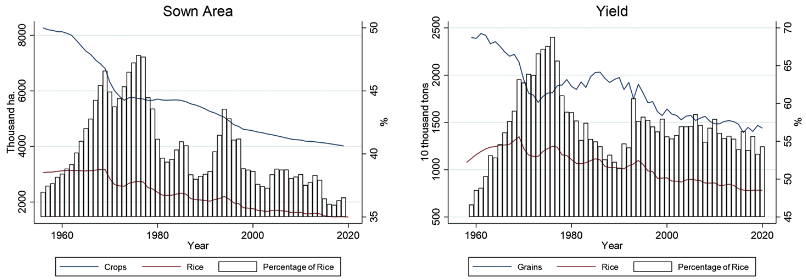

Figure 1.4 Rice production in Japan.
Source: The data are from the database of the Ministry of Agriculture, Forestry and Fisheries of Japan.

However, rice is still the most important staple food in Japan. About 20% of agricultural production is rice, and 70% of agricultural management entities grow rice. Japan's self-sufficiency rate for food is about 38% (calorie-based), but its rice is basically completely self-sufficient (98%, calorie-based). Japan implemented the Acreage Reduction Policy (Gentan Policy) since 1970, but it was abolished in 2018. Basically, it is a policy to control the amount of rice to prevent overproduction in Japan. In detail, it requires rice farmers to reduce their planted areas to avoid rice surplus and price concerns. Gradually, this may cause rice farmers to lose their enthusiasm for raising their rice productivity (See Figure 1.2). On the other hand, there are also several problems with Japan's rice production, including decreasing domestic demand and decreasing rice prices which can lead to an opportunity for exporting Japanese rice. In 2020, Japan exported $64.7 million in rice, making it the 29th largest rice exporter in the world. At the same time, Japan imported $463 million in rice, becoming the 15th largest importer of rice in the world in 2020 (OECD 2022) (See Figure 1.5). Moreover, aging agricultural labor forces, the Fukushima nuclear disaster (Shimokawa et al. 2018), global climate change (Horie et al. 1996; Nakagawa et al. 2003), and a shortage of forage rice are emerging issues in producing rice in Japan.

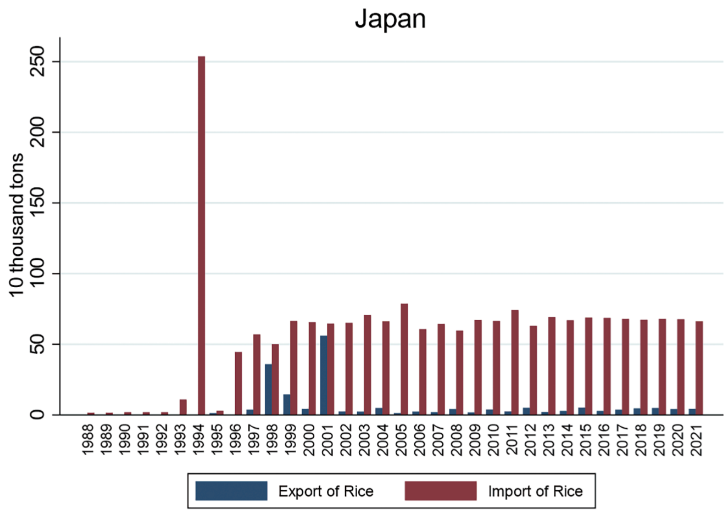

Figure 1.5 Rice import and export in Japan.
Source: The data are from the database of the Ministry of Agriculture, Forestry and Fisheries of Japan.

There is no shortage of relevant studies on the conditions and problems of rice production in China and Japan. As for China's rice production, some studies have researched conventional and hybrid rice (Xu and Jeffrey 1998; Ma and Yuan 2003), fertilizers used in rice production (Sun et al. 2019), and farm size and production cost of rice (Zhang et al. 2019). Regarding Japanese rice production, the existing literature has been mainly concerned with the effects of the Gentan policy and the production cost of rice (Kusakari 1989), farm size and the production cost of rice (Matsukura et al. 2015), and production cost and forage rice (Senda and Tsunekawa 2015; Tsunekawa 2016). But there are two questions that remain unanswered, namely: (1) How does the production cost of rice change in China and Japan, respectively? and (2) Which country is more efficient in rice production, China or Japan?

The significance of this research can be addressed as follows: first, from the perspective of China, it is important to study and learn about some successful experiences in agricultural production from developed countries such as Japan and consider the similarity of the natural endowments of the two countries. Second, Japan has abolished the Gentan policy, and the alternative option of its rice strategy is to promote the export of its agricultural products. One of the important target markets is China. Hence, it is important to compare the production cost and efficiency between China and Japan. Finally, the common issue for global agriculture is how to tackle global climate change and develop sustainable agriculture. It may require producing enough output for the market, raising revenue as high as possible for farmers, and stabilizing the market price of agricultural output. Therefore, this study aims to (1) examine the changes in the production costs of rice in China and Japan and (2) estimate and compare the production efficiency of rice between the two countries.

2. Comparisons of Rice Production Costs

This section provides a comparison of rice production costs between China and Japan, which typically consist of raw materials costs, labor costs, and land costs. It is important to note that labor costs include wages paid for family labor, and land costs include the rent paid for owned land. This study focuses on examining these inputs and chooses the category of Japonica rice as the research object. The data for China's rice production costs are sourced from the National Cost and Profit of Agricultural Products Materials Compilation and the National Bureau of Statistics, while the data for Japan's rice production costs are obtained from the database of the Ministry of Agriculture, Forestry and Fisheries of Japan.

Figure 1.6 shows the total cost of rice production per 10 acres in Chinese Yuan/ Japanese Yen. In China, the total cost of rice production per 10 acres has been found to have increased during our observation period, from 952 Chinese Yuan in 2006 to 2,190 Chinese Yuan in 2018. Conversely, the rice production cost per unit area has decreased in Japan, from 148,382 Japanese Yen in 2003 to 132,020 Japanese Yen in 2020.

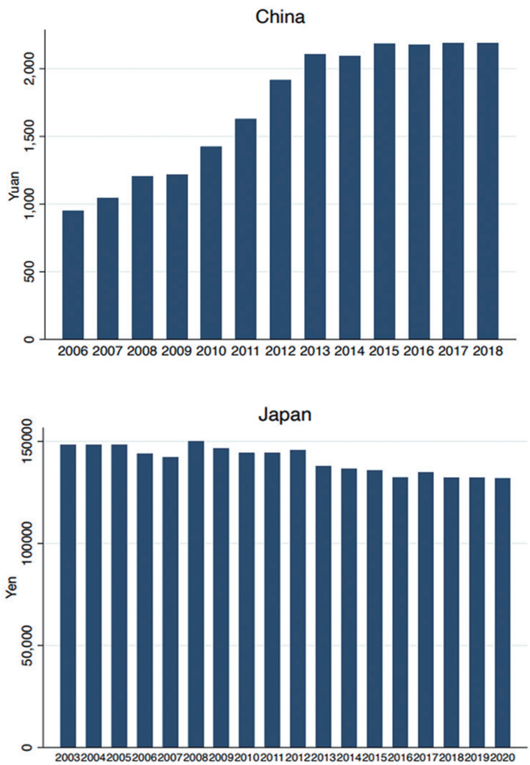

Figure 1.6 Comparisons of rice production costs (Japonica rice) between China and Japan.
Source: Calculated by the author.

Figure 1.7 shows the composition of costs and their changes in the two countries. In both China and Japan, raw material costs are mainly dominant. In China, raw materials, labor costs, and land costs have exhibited an increasing trend since 2006. Moreover, the growth rate of labor expenditure became higher and even exceeded that of raw materials during 2013–2016. Since 2017, raw material costs have still been higher than labor costs, but the gap between them has narrowed. In contrast to China, raw materials rather than labor costs are the major expense for rice production in Japan. All costs are leveling off, and especially labor costs and land costs show a similar variation with less fluctuation and a decreasing trend.

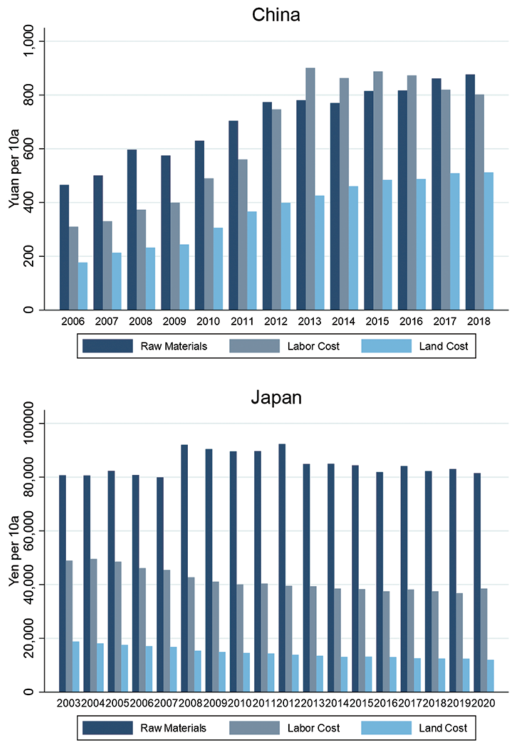

Figure 1.7 Composition changes in rice production costs between China and Japan.
Source: Calculated by the author.

Regarding labor input in rice production, family labor remains the mainstay of labor input in rice farming, both in China and Japan (see Figure 1.8). However, we can also see that family labor input has significantly decreased in both China and Japan, but employed labor input remains stable.

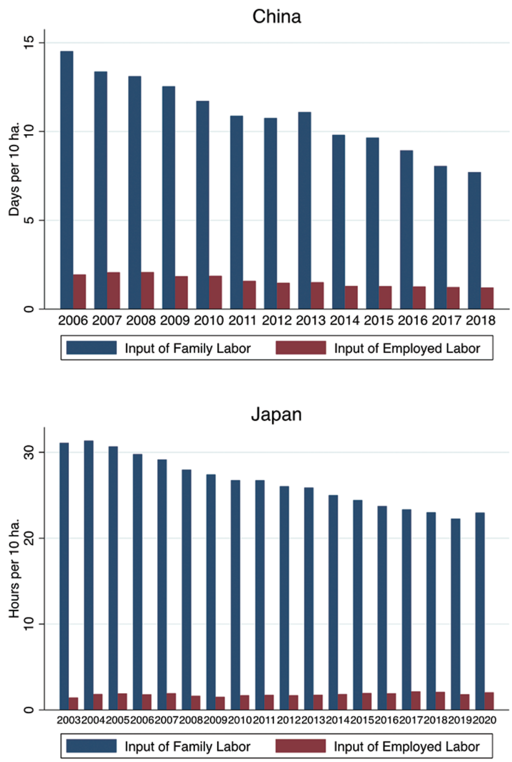

Figure 1.8 Comparison of labor input in rice production between China and Japan.
Source: Calculated by the author.

Correspondingly, the hourly wage is rapidly increasing in China but remaining flat in Japan (see Figure 1.9). As a result, we can infer the reasons accounting for reduced labor input in China's rice production are different from those in Japan's rice production. Possible explanations for reduced labor input in China's rice production are labor migration and rising labor wages. Conversely, the reasons for reduced labor input in Japan may be attributed to the aging agricultural population and the replacement of labor with capital.

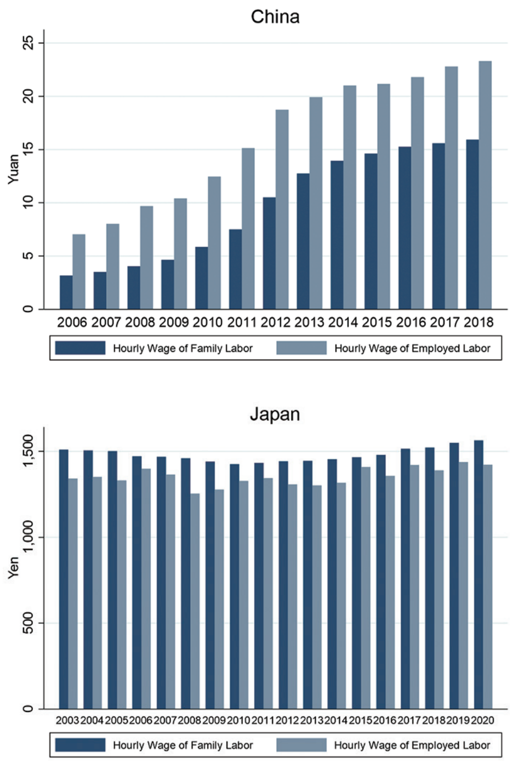

Figure 1.9 Comparison of hourly wage in rice production between China and Japan.
Source: Calculated by the author.

Concerning land rent in rice production (see Figure 1.10), we observe that both land rent of owned land and land rent of borrowed land are increasing in China, primarily due to China's rapid urbanization. However, land rent of owned land is decreasing, while the land rent of borrowed land remains flat in Japan. It is interesting to note that the land rent of owned land is higher than that of borrowed land for both countries.

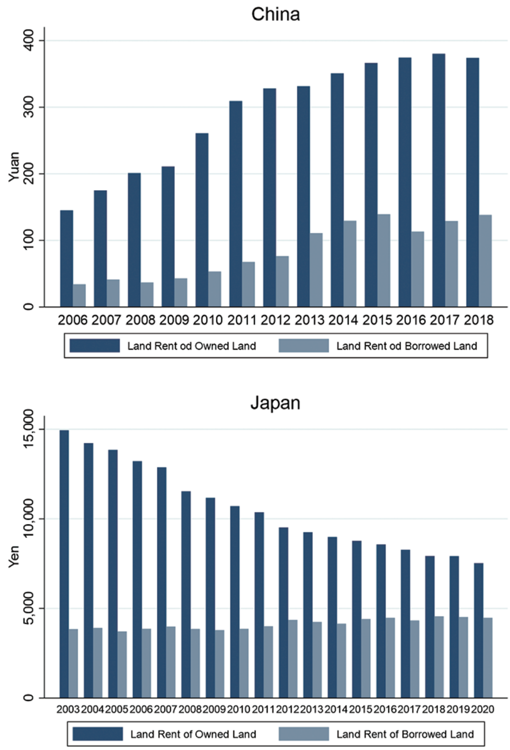

Figure 1.10 Comparison of land rent in rice production between China and Japan.
Source: Calculated by the author.

In brief, China's rice production costs have risen rapidly before leveling off, whereas Japan's production costs have decreased to four times as much as China's. In terms of cost composition, raw materials have been the main cost for both countries over the years, accounting for more than 60% in Japan and 43% in China (see Table 1.1). The share of labor cost is the largest in China (nearly 36%) while the share of raw materials is the largest in Japan. Labor wages and land rent are rising in China, while they remain level in Japan. In conclusion, China's rice production costs are primarily driven by labor expenses, while Japan's rice production costs are mainly influenced by capital and fertilizer inputs.

Table 1.1 Composition in the amount of money regarding rice production between China and Japan.

Per 10 ha.	China	Japan
% of Raw Materials	43.09	60.11
% of Labor Cost	35.86	29.21
% of Land Cost	21.04	10.68
Total Cost (current LCU)	1701 RMB	140925 Yen (6921 RMB)
Cost Revenue Ratio	0.79	1.29

Source: Calculated by the author.

Moreover, to measure the efficiency of rice production expenses in relation to its earnings in the two countries, I calculated the cost-revenue ratio of rice production in China and Japan, respectively. The cost-revenue ratio of China is calculated as 0.79, while that of Japan is 1.29. From this figure alone, it seems that rice production in Japan is unprofitable. Nevertheless, we should note that the cost includes what the farmers pay themselves. Namely, the shadow costs consist of wages paid for family labor, interest paid for owned funds, and rent paid for owned land. If we subtract the shadow costs, we can obtain the cost-revenue ratio without shadow costs.

The cost-revenue ratio without shadow costs is 0.65 for China and 0.84 for Japan, suggesting producing rice is still profitable even if the ideal cost is not obtained. And the shadow cost-revenue ratio is 0.14 for China and 0.45 for Japan. This study does not focus on revenue only because revenue involves more factors such as market stocks, government subsidies, etc. Interestingly, the following figures show the revenues per 10a, which is higher in China than in Japan (see Figure 1.11).

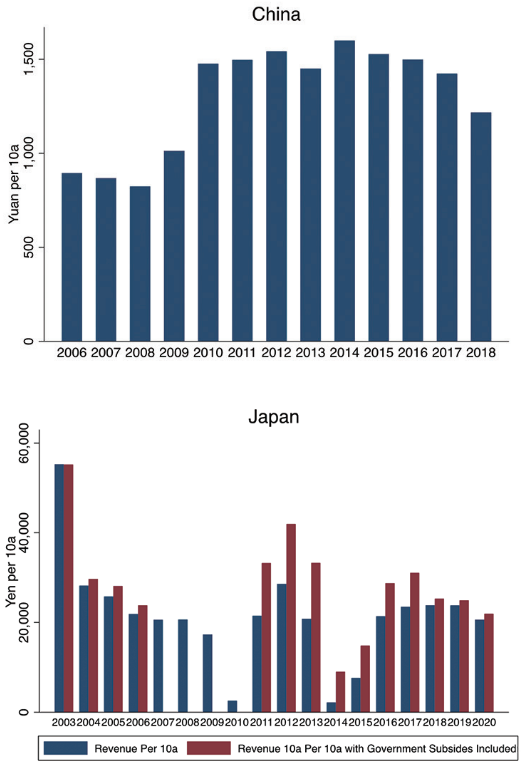

Figure 1.11 Comparison of revenue in China and Japan.
Source: Calculated by the author.

Table 1.2 reports the composition in the quantity of input uses in China and Japan. Labor input in China (on average, 100 hours) is much higher than in Japan (on average, 28 hours). Surprisingly, Japan consumes much more fertilizer input than China, with fertilizer amounts of 64.23 kg and 39.44 kg, respectively. The biggest difference between both countries is capital input. Especially, Japan consumes more than three times the capital input (2,084 RMB per 10ha) of China (316 RMB per 10ha). Rice production in China depends more on labor, while Japan depends more on capital.

Table 1.2 Composition in the quantity of input uses regarding rice production between China and Japan.

Per 10 ha.	China	Japan
Labor Input (Hours)	100.41	28.38
of which, Family Labor	88.10	26.54
of which, Employed Labor	12.77	1.83
Seeds (kg)	9.15	2.72
Fertilizer (kg)	39.44	64.23
Capital (current LCU)	316 RMB	42299 Yen (2084 RMB)

Source: The data are from the National Cost and Profit of Agricultural Products Materials Compilation, the National Bureau of Statistics, and the database of the Ministry of Agriculture, Forestry and Fisheries of Japan.

3. Measurement of Production Efficiency

This study applied data envelopment analysis (DEA), a non-parametric method, to estimate the production efficiency of rice in China and Japan. DEA was initially proposed by Charnes et al. (1978) to calculate the operation efficiency of the decision-making unit (DMU) in public programs to improve the planning and control of these activities.

The efficiency of any DMU is obtained as a maximum of a ratio of weighted outputs to weighted inputs subject to the condition that the similar ratios for each DMU be no more than unity in this method. In more precise form, it can be expressed as:

$$\max_{\mathrm{v,u}} \theta_i = \frac{u_1 y_{1i} + u_2 y_{2i} + \cdots + u_m y_{mi}}{v_1 x_{1i} + v_2 x_{2i} + \cdots + v_n x_{ni}} \tag{1}$$

subject to

$$\frac{u_1 y_{1j} + u_2 y_{2j} + \cdots + u_m y_{mj}}{v_1 x_{1j} + v_2 x_{2j} + \cdots + v_n x_{nj}} \leq 1 \;\; (j = 1, \dots, t)$$
$$\mathrm{u}_p \geq 0 \;\; (p = 1, \dots, m) \tag{2}$$
$$\mathrm{v}_q \geq 0 \;\; (q = 1, \dots, n),$$

where y_{pi} and x_{qi} are the known outputs and inputs of the i^{th} DMU, p denotes the category of outputs and q denotes the category of inputs. u_p and v_q are the variable weights of each output and input which are called virtual multipliers and are to be determined by the solution of this problem. θ_i is the measured efficiency for the i^{th} DMU.

In this study, I treat each agricultural province/region as a DMU and adopt the output-oriented DEA model with the variable returns to scale (VRS). The output variable is the rice output per 10 acres, while the input variables are the labor input per 10 acres in agricultural production activity, agricultural fixed assets costs per 10 acres, energy costs per 10 acres, fertilizer costs per 10 acres, and seeds costs per 10 acres. All data relating to the amount are deflated to the prices of 2015. Panel data was collected across provinces in China (2006–2018) and regions in Japan (2005–2020).

4. Empirical Evidence

Unsurprisingly, the estimated results from DEA show that the average efficiency score of rice production is 0.922 in China and much higher than that of 0.721 in Japan, suggesting China's rice production exhibits greater production efficiency than Japan's rice production. However, the summary of the estimated score in Figure 1.12 shows that there is an upward trend in production efficiency in Japan while it stays at a stable level in China.

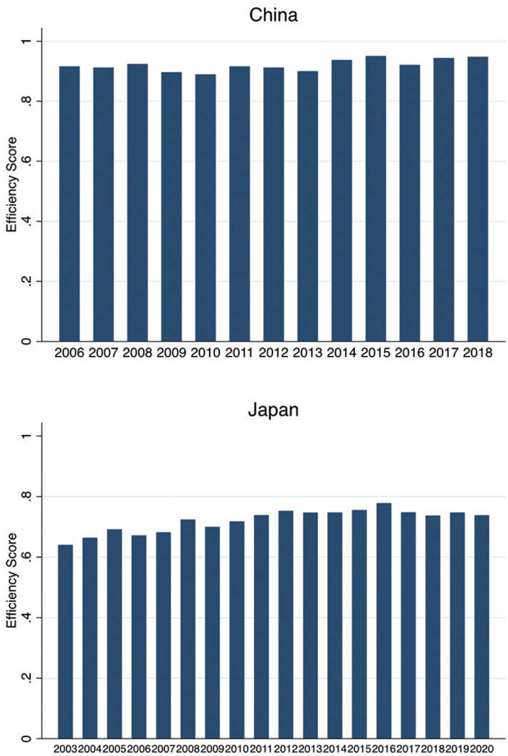

Figure 1.12 Estimated efficiency score of rice production in China and Japan.
Source: Calculated by the author.

Figure 1.13 shows the regional variation in efficiency scores in China and Japan. Initially, it was thought that regional variation is larger in China as it has a huge land area and climatic conditions are quite diversified, especially in the northern and southern regions. However, the estimated result shows that efficiency variation across regions is much larger in Japan. More specifically, rice production in the Hokkaido region is the most efficient since its farm size is much larger than other regions in Japan, followed by the Tohoku region.

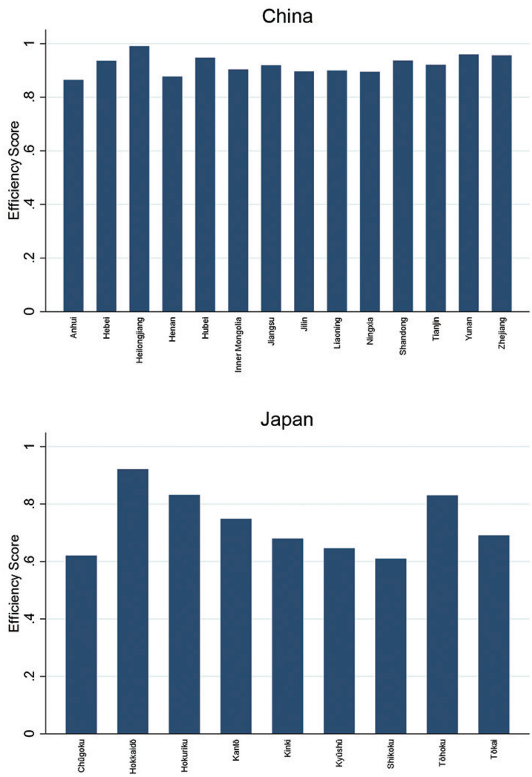

Figure 1.13 Variation in efficiency score by region.
Source: Calculated by the author.

In addition, the findings from Table 1.3 reveal the differences in the factors influencing rice production efficiency between China and Japan. The results indicate that the land rent of owned land has a positive and significant effect on rice production efficiency in China, while it has a negative and significant effect in Japan. This could be attributed to the fact that increasing the size of farms can enhance rice production efficiency in Japan, but it could have the opposite effect in China due to differences in labor and capital allocation per unit acreage between the two countries.

Interestingly, the shadow cost-revenue ratio has a significant and negative effect on rice production efficiency in Japan only. This suggests that farmers in Japan may not have sufficient motivation to improve their production efficiency, as they may already be earning enough money and see little need to work harder to increase efficiency in their rice production.

Table 1.3 Rice production efficiency and its determinant.

VARIABLES	China	Japan
Wage of family labor	0.036	-0.001
	(-0.033)	-0.01
Wage of employed labor	-0.045	0.004
	(-0.03)	-0.003
Land rent of owned land	0.0259**	-0.001***
	(-0.012)	(0.000)
Land rent of borrowed land	0.012	-0.001*
	(-0.011)	(0.001)
Shadow cost -revenue-ratio	-3.703	-18.860***
	(-27.65)	(6.017)
Constant	90.050***	93.390***
	(2.704)	(9.057)
Observations	120	157
Number of dmu	14	9
R-squared	0.144	0.485

Note: Standard errors in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

5. Conclusion

This study compared the rice production between China and Japan by decomposing the production costs and estimating production efficiency in rice production. From the decomposition analysis of rice production costs, we find that the cost-revenue ratio (with shadow cost included) in Japanese rice production is much higher than that in Chinese rice production. However, if the shadow cost is excluded, the gap between the two countries becomes much less. Moreover, the shadow cost-revenue ratio is much larger in Japan than in China. It implies that while the costs of producing rice in China are lower, Japanese rice production is not completely unprofitable once its self-payments are subtracted.

There are several possible reasons accounting for the higher cost-revenue ratio in Japan's rice production than in China's rice production. One possibility is that it is due to most input prices being much lower in China than in Japan. Especially, labor wages are far lower in China's rice sector than that in Japan's rice sector, and China adopts an intensive labor input way of producing rice compared with Japan. Hence, even though China's rice sale prices are lower than Japan's rice sale prices, production costs are relatively lower in China than in Japan.

Another possibility is that China is producing rice more efficiently than Japan, which could also make its cost-revenue ratio lower than Japan's. To verify this point, we conducted a DEA method to estimate the rice production efficiency for the two countries. The results from the DEA reveal that the estimated efficiency score of rice production is greater in China (0.92) than that in Japan (0.72). Thus, regardless of variety or quality, China produces rice much more efficiently than Japan. The reasons behind this are that in China, regarding the policy and food self-sufficiency aims, the scarce input resources in rice production resulting from the structural transformation and the changes in the dietary structure make its rice production more efficient. Furthermore, the low shadow cost-revenue ratio stimulates its peasants to produce rice efficiently to acquire more profits. However, in Japan, the acreage reduction policy (or Gentan policy), the decreasing domestic demand for rice, the export disadvantage of rice, and the high shadow cost-revenue-ratio make the motivation for promoting rice efficiency less urgent. Hence, even though Japan's mechanization level is much higher than China's, its production efficiency is relatively lower.

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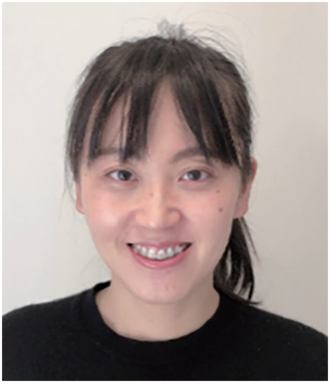

Chapter 1. Comparison of Rice Production in China and Japan: Evidence from a Panel Data Analysis

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