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Journal of Economic Structures (2022) 11:21
https://doi.org/10.1186/s40008-022-00282-8

Journal of Economic Structures

RESEARCH

Open Access

Efficiency, and economies of scale and scope in Japanese agricultural cooperatives

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Abstract

The purpose of this study is to investigate regional differences in the business characteristics of Japanese agricultural cooperatives (JAs), which have been widely criticized for depending on non-agricultural activities, contradictory to cooperative principles. We construct a panel data set over 2004–2019 from the financial statements of JAs' prefectural-level federations and use a stochastic meta-frontier cost function model, which enables the decomposition of meta-frontier efficiency into two components: technical efficiency and technology gap ratios. The operational differences between JAs in urban and rural areas are investigated by comparing their efficiency and economies of scale and scope. The main results are summarized as follows: first, the meta-cost efficiency scores of JAs in urban areas are, on average, larger than those in rural areas, which reflects the differences in technology gap ratios. Second, JAs exhibit overall economies of scale in both areas; however, the product-specific economies of scale differ between financial and nonfinancial outputs. Finally, JAs in rural areas exhibit relatively larger economies of scope than those in urban areas. These findings indicate clear distinctions between urban and rural areas in cost-reduction effects. Finally, financial activities bring higher efficiency for JAs in urban areas, while benefits from simultaneous production are larger for those in rural areas.

Keywords: Agricultural cooperatives, Meta-frontier, Efficiency analysis, Economies of scale and scope

JEL Classification: L21, L25, L31, Q13

1 Introduction

Agricultural cooperatives in Japan (JAs), nationwide organization of farm cooperatives, are present in all prefectures and have branches in numerous municipalities. Agricultural cooperatives are defined as a community of farmers who voluntarily unite to achieve economic and social goals. Therefore, their main purpose is to protect farming and ensure farmers' sustenance. Nonetheless, the Japanese government evaluates the agricultural industry as being less productive compared to other developed economies, given the influence of JAs on farmers.[1]

[1] In the 2010 Annual Report, the WTO pointed out that Japan's agriculture exhibits remarkably lower productivity compared other sectors and criticized the strong government support to this sector. Some other studies also examined these unfavorable conditions using international comparisons (Hayami 2007; Honma and Hayami 2009; Otsuka 2013).

Scholars have previously noted the presence of protectionism and interventionism to explain the lower productivity of Japan's agricultural sector, especially for rice farming. Since the 1970s, the government implemented reductions in the acreage planted for rice to prevent the oversupply of grain and maintain domestic rice prices. JAs were fierce defenders of this policy owing to their vested interest in maintaining the status quo. Moreover, JAs have been firmly against the Trans-Pacific Partnership (TPP), claiming that TPP participation would destroy Japanese agriculture. JAs emphasize that inflow of cheap foreign rice, owing to tariff abolition, will make maintaining high rice prices under the current rice acreage reduction policy difficult. Honma and Mulgan (2018) explained that JAs have been recognized as a symbol of "regulations as solid as bedrock" by the government.

Therefore, the government has been fervently promoting the organizational reform of the agricultural cooperative system to empower farmers and improve productivity. Specifically, it has attempted removing the function of the Central Union of Agricultural Co-operatives, known as JA-Zenchu, a national apex body, to audit local cooperatives and review activities such as farm management, farm product marketing, supply of production inputs, and credit and mutual insurance businesses.[2] Among these activities, marketing and purchasing are very important in terms of improving the livelihood of member farmers.

However, since the number of agricultural workers has been decreasing, JAs cannot continue to depend on farmers. The total number of regular JA members also decreased from 5.33 million in 1998 to 4.24 million in 2018. In contrast, the total number of non-regular members, comprising many non-farmers, drastically increased during the same period: from 3.70 million to 6.24 million individuals. Therefore, nonregular members now outnumber regular members by more than 2 million. Moreover, the gap between regular and nonregular members is becoming wider, especially in urban areas.[3] Therefore, non-mainstream businesses such as banking and insurance have become indispensable for many JAs, especially those located in urban areas. The ongoing JA reform aims to correct the original role of JAs by considering the overreliance on financial activities as an issue.

In Japan, many traditionally organized agricultural cooperatives have been forced to abandon their business forms. Similarly, Fulton and Hueth (2009) found that many agricultural cooperatives in Western economies have undergone profound changes, including their business forms and cooperative principles. However, in Japan, the current excessive dependence on financial business by non-farmers, especially in urban areas, is undoubtedly different from the cooperative principles of JAs. Essentially, a significant disparity in the operations for JAs between urban and rural areas can be found.

Thus, this study investigates regional differences in the business characteristics of JAs by estimating multiproduct cost functions as follows. First, we evaluate the disparity in

[2] These are referred to as multi-purpose agricultural cooperatives. Besides multi-purpose agricultural cooperatives, so-called specialized agricultural cooperatives are found, which do not necessarily focus on a specific activity but do not engage in credit business. These cooperatives are fewer than multi-purpose agricultural cooperatives and do not belong to the JA group.

[3] According to the *Statistics on Agricultural Cooperative*, released by the Ministry of Agriculture, Forestry and Fisheries of Japan, the ratio of the number of non-regular individual members to that of total individual members was 59.3% in 2018 at the national level. However, it was 81.6% in Tokyo (capital city) and 83.0% in Osaka (second largest city).

efficiency measures of urban and rural areas by employing a meta-frontier approach based on stochastic frontier analysis (SFA). The meta-frontier is considered an "envelope" cost function that encompasses groups of entities operating under different circumstances. We believe no study has hitherto applied these methods to measure the efficiency of agricultural cooperatives. Second, by using the parameters of the meta-frontier estimation results, the overall and product-specific scale economies are computed at the sample mean of urban and rural areas, respectively. Measuring product-specific economies of scale is helpful for understanding the contribution of each product to the cost of JAs. Finally, overall and product-specific scope economies are computed for investigating the potential cost-saving effects of joint production by JAs. Product-specific economies of scope exist when each product has a cost advantage for multiproduct organizations such as JAs.

The remainder of this paper is organized as follows: Section 2 briefly reviews previous studies on agricultural cooperative institutions. Sections 3 and 4 describe the methodology and data, respectively. Section 5 presents the estimation results. Section 6 summarizes the study's findings and concludes the paper with policy implications.

2 Literature review

Soboh et al. (2009) assert that empirical studies have failed to address cooperatives' objectives, as represented by the theoretical literature on cooperative performance. In contrast, Grashuis and Su (2019) highlighted that a general improvement in empirical methodologies is needed for robust analysis of the mixed objectives of cooperatives in dynamic environments. Although plenty of theoretical literature investigating cooperatives' objectives exist, the following review focuses on empirical literature investigating financial performance.

Earlier studies on US agricultural cooperative institutions have traditionally analyzed economies of scale and scope. For example, Thraen et al. (1987) examined economies of size in fluid milk cooperatives and found that processing costs decline with increases in plant volume. Schroeder (1992) estimated scale and scope economies in grain marketing and farm supply cooperatives and finding overall economies of scale and product-specific economies of scale for such as sales of grain, petroleum, feed, and others. Featherstone and Moss (1994) estimated scale and scope economies for agricultural banking and found contrasting measures of scope and scale with or without curvature restrictions on cost functions.

Similar to the other sectors, efficiency analysis is dominated by two approaches: parametric SFA and nonparametric data envelopment analysis (DEA). In accordance with SFA, the efficiency frontier is constructed based on econometric modeling in a specific functional form. Further, SFA treats deviations from the "best-practicing" frontier by comprising both random error and inefficiency. In contrast, DEA is based on the hypothesis that an efficient frontier is generated by the most efficient entities or benchmarks, and the efficiency scores of each entity are calculated relative to an efficient frontier. As the advantages of one method often represent the disadvantages of another, no commonly accepted methodology for efficiency analysis can be found.

A considerable number of studies have investigated efficiency in the farmer cooperative sector using DEA. In US agricultural cooperatives, Ariyaratne et al. (2000) found that large cooperatives are fairly scale efficient. In contrast, cooperatives with more diversified output mixes are more scale efficient than specialized ones. Pokharel and Featherstone (2019) identified the existence of multiproduct scale and scope economies and reported that increasing scale and product diversification can reduce costs. Brandano et al. (2019) investigated differences in efficiency between agricultural cooperatives and conventional firms in the Italian wine industry and found that cooperatives are less technically efficient compared to their capitalist counterparts. Galdeano-Gómez (2008) used bootstrap DEA to calculate efficiency of Spanish horticulture marketing cooperatives and found that a significant increase in efficiency and environmental components is significantly influenced by labor qualifications, environmental effort, and spillover effects in the sector. Huang et al. (2013) also used bootstrap DEA to evaluate the efficiency and determinants of agricultural marketing cooperatives in China's Zhejiang Province and found that the size of financial leverage and number of board members have negative impacts on pure technical efficiency. Skevas and Grashuis (2020) investigated the determinants of the efficiency of grain marketing cooperatives in the Midwest region of the US using a bootstrap truncated regression and found the critical role of spatial spillovers.

Several studies have applied SFA to investigate these issues. Soboh et al. (2014) compared the efficiency of dairy processing cooperatives in six major European countries and found that differences in production technology and technical efficiency reflect differences in local market conditions and company characteristics. Beber et al. (2021) investigated the determinants of the technical efficiency of dairy processing firms in Southern Brazil and found that cooperatives are more efficient compared to investor-owned firms. Azumah et al. (2019) also investigated the determinants of the technical efficiency of rice farmers in Northern Ghana and reported that inefficiency is overestimated unless sample selection bias is corrected. Yoo et al. (2013) estimated the scale efficiency of rice-processing cooperatives in Korea using a translog cost function, and found that small- and medium-sized cooperatives are scale inefficient, while large rice cooperatives are scale efficient. Singh et al. (2001) investigated the efficiency of dairy cooperatives in India using both SFA and DEA and found that cooperative plants are more cost efficient than private ones. Therefore, DEA has been used more often than SFA to investigate the efficiency of agricultural cooperatives and their related institutions.[4]

There are few studies on Japan, regardless of the method used. For instance, Sueyoshi (1999) investigated the performance of 32 JA offices in one region using slack-adjusted DEA, with the main purpose being to examine the statistical differences between efficiency scores and not focusing on the political implications of the results. Yamamoto et al. (2006) analyzed the technical efficiency and total factor productivity (TFP) changes of 44 JA offices in one region by computing Malmquist indices. The TFP change pattern is driven by technical progress rather than improving technical efficiency. Harimaya and Kagitani (2019) investigated the efficiency of banking business of JAs using the input distance function under SFA and found that higher reliance on a central organization and

[4] For a more detailed description of the methodologies and empirical findings for the agricultural sector, see Bravo-Ureta et al. (2007).

credit operations leads to lower efficiency. However, no study has hitherto investigated the efficiency of JAs at the national level.

3 Methodology

3.1 The meta-frontier cost function

This study considers the business characteristics of JAs for producing multiple products. Therefore, we estimate the economies of scale and scope using the flexible translog cost function. In addition to economies of scale and scope, we evaluate the differences in the efficiency of JAs in urban and rural areas by employing the stochastic meta-frontier method developed by Battese and Rao (2002), Battese et al. (2004), and O'Donnell et al. (2008).[5] The meta-frontier is assumed to have the same functional form as the individual stochastic frontiers of different groups. Therefore, the meta-frontier cost function envelops the area-specific cost frontier.

Under the SFA framework, the cost frontier model of entity i in area j at time t is expressed as follows:

$$C_{jit} = f^j\left(X_{jit}\right)e^{v_{jit}+u_{jit}}, \tag{1}$$

where C represents total cost, and X_{it} is a vector of the output and input prices. Subscript j of function $f^j(\cdot)$ of the cost frontier indicates that individual area-specific technologies may vary across areas. Additionally, v_{jit} and u_{jit} are two mutually independent random errors, the former being independently and identically distributed as $N(0, {\sigma_v}^2)$, and the latter representing technical inefficiency. An entity's technical efficiency (TE_{jit}) is evaluated as the ratio of the minimum cost to its actual cost, reflecting the extent to which the entity's actual cost lies above the cost frontier, that is,

$$\mathrm{TE}_{jit} = \frac{f^j\left(X_{jit}\right)e^{v_{jit}}}{C_{jit}} = e^{-u_{jit}}. \tag{2}$$

The meta-frontier technical efficiency (MTE_{jit}) is also derived from the ratio of the meta-cost, expressed as $f^M\left(X_{jit}\right)e^{v_{jt}^M}$, to the actual cost, as follows:

$$\mathrm{MTE}_{jit} = \frac{f^M\left(X_{jit}\right)e^{v_{jt}^M}}{C_{jit}}. \tag{3}$$

By substituting Eqs. (1) and (2), Eq. (3) can be formulated as follows:

$$\mathrm{MTE}_{jit} = \frac{f^M\left(X_{jit}\right)e^{v_{jt}^M}}{f^j\left(X_{jit}\right)e^{v_{jit}+u_{jit}}} = e^{-u_{jit}} \times \frac{f^M\left(X_{jit}\right)e^{v_{jt}^M}}{f^j\left(X_{jit}\right)e^{v_{jit}}}. \tag{4}$$

On the right-hand side of Eq. (4), the first term is the technical efficiency of entity i in year t (TE_{jit}), as presented in Eq. (2). The second term on the right-hand side of Eq. (4) is referred to as the technology gap ratio (TGR_{ijt}). Therefore, measuring the meta-frontier

[5] Previous studies on U.S. banks found that economies of scale are more biased the further the bank is from the efficient frontier (i.e., Berger and Humphrey 1991; Berger et al. 1993; Evanoff and Israilevich 1991).

technical efficiency (MTE_{jit}) can be decomposed into group technical efficiency (TE_{jit}) and the technology gap ratio (TGR_{jit}) as follows:

$$\mathrm{MTE}_{jit} = \mathrm{TE}_{jit} \times \mathrm{TGR}_{jit}. \tag{5}$$

The stochastic meta-frontier method is often called a two-stage approach, as the group technical efficiency is estimated in the first stage, and mathematical programming and semi-parametric approaches are used for computing the meta-frontier technical efficiency in the second stage. The distance from each group frontier to the meta-frontier was defined as the technology gap ratio. However, this two-stage approach has several drawbacks. The most significant is that the meta-frontier is considered deterministic, whereas group frontiers are defined stochastic. Therefore, no statistical properties can be ascertained regarding the second-stage results. To overcome these difficulties, Huang et al. (2014) proposed a new two-step approach for estimating both the group frontiers and meta-frontier using SFA.[6] Using this approach, group technical efficiency (TE_{jit}) was estimated using the grouped data in the first stage. In the second stage, technology gap ratio (TGR_{jit}) was estimated using the adjusted cost derived from the estimation of group frontiers as the dependent variable. Therefore, meta-frontier efficiency score can be obtained by multiplying TE_{jit} and TGR_{jit}, not directly estimated. Because both TE_{jit} and TGR_{jit} are left censored at 0 and right censored at 1 in Eq. (5), MTE_{jit} is always below these two scores and ranges between 0 and 1.

Regarding functional form, recent studies on the empirical estimation of cost functions tend to employ the Fourier flexible form rather than the translog form.[7] However, Fourier approximation can only provide accurate results for large samples owing to its additional flexibility. As our sample size is not very large, we employ standard translog specification of the cost function.[8]

Once standard linear homogeneity restriction for input prices is imposed, cost function can be expressed as follows:

$$\begin{aligned}\ln\left(\frac{C_{it}}{p_{lit}}\right) &= \alpha_0 + \sum_j \alpha_j \ln Y_{jit} + \sum_{k\neq l} \beta_k \ln\left(\frac{p_{kit}}{p_{lit}}\right) + \frac{1}{2}\sum_j\sum_m \alpha_{jm} \ln Y_{jit} \ln Y_{mit} \\ &\quad + \frac{1}{2}\sum_{k\neq l}\sum_{n\neq l} \beta_{kn} \ln\left(\frac{p_{kit}}{p_{lit}}\right) \ln\left(\frac{p_{nit}}{p_{lit}}\right) + \sum_j\sum_{k\neq l} \delta_{jk} \ln Y_{jit} \ln\left(\frac{p_{kit}}{p_{lit}}\right) \\ &\quad + \tau t + \frac{1}{2}\gamma t^2 + v_{it} + u_{it},\end{aligned} \tag{6}$$

where C_{it} denotes the observed total cost of the Prefectural Union of Agriculture cooperatives i at time t; Y_{it} and p_{it} represent the total output and input prices, respectively; t is a time trend variable; α, β, δ, τ, and γ are the parameters to be estimated; v_{it} is a standard statistical error term independently and identically distributed as $N(0, {\sigma_v}^2)$, and u_{it}

[6] Honma and Hu (2018) measured the meta-frontier total-factor energy efficiency of 47 prefectures in Japan for 1996–2008 using a new two-step meta-frontier approach.

[7] Yu et al. (2011) employed the Fourier flexible cost function to investigate the cost structure of US agricultural and nonagricultural banks.

[8] Berger and Mester (1997) reported that the difference between the results obtained using the two methods seems negligible.

represents technical inefficiency, following the non-negative truncations of the normal distribution with mean, μ, and variance, $\sigma_u{}^2$. Further, u_{it} and v_{it} are distributed independently of each other and covariates.

As described, the meta-frontier cost function envelops area-specific cost frontier. Therefore, in the first stage, the stochastic frontier cost functions in Eq. (6) are estimated for each subgroup to measure group technical efficiency scores. The same function is then estimated using first-stage estimates to measure the technology gap ratio scores. In estimating stochastic frontier functions in the first stage, technical inefficiency u_{it} is assumed to follow the truncated normal distribution $N^+(\mu(Z_{it}), \sigma_u{}^2(Z_{it}))$. This normal distribution is truncated below at 0 and with the mode at $\mu(Z_{it})$, where Z_{it}s are exogenous variables viewed as determinants of technical inefficiency. In the second stage, as the determinants of the technology gap ratio are considered different from those of technical inefficiency, u_{it} is assumed to follow the time-varying model of Battese and Coelli (1992)[9]:

$$u_{it} = \exp\{-\eta(t - T_i)\}u_i, \tag{7}$$

where T_i is the last period in the ith panel, and η is the decay parameter. When $\eta > 0$, the degree of inefficiency decreases over time and increases over time when $\eta < 0$. The last period for firm i contains the base inefficiency level for that entity as $t = T_i$ is the last period.

In both groups, the technical efficiency and technology gap ratio scores are calculated as point estimators by Battese and Coelli (1988), defined as $E\{\exp(-u_{it}|\varepsilon_{it})\}$, where $\varepsilon_{it} = v_{it} + u_{it}$. Efficiency estimates lie between 0 and 1, with values closer to 1 representing more efficient entities.

3.2 Formulation of scale and scope economies

Using the parameters derived from each area-specific cost frontier estimation, we calculate economies of scale and scope. Both scale and scope economies can reduce the average cost per unit produced. On the one hand, economies of scale refer to cost savings because of increases in the output produced. Moreover, they mainly arise by spreading fixed costs over large volumes of output and reducing average production costs. On the other hand, economies of scope refer to cost savings owing to the production of two or more different products using the same operations and arise from the sharing or joint utilization of inputs. This leads to reductions in unit production costs.

First, overall scale economies (OSE) measure the cost implications of varying all products simultaneously while holding the product mix of products constant. OSE are defined as the elasticity of the cost function relative to a proportional increase in all outputs:

$$\text{OSE} = \sum_j \frac{\partial \ln C}{\partial \ln Y_j} - 1, \tag{8}$$

[9] Honma and Hu (2018) also employed the same approach to obtain the second-stage estimates.

where $OSE < 0$ indicates the presence of economies of scale, which implies that costs increase proportionally less than outputs. Conversely, $OSE > 0$ indicates diseconomies of scale.

Further, product-specific scale economies show how costs change when the output of one product changes and the quantities of other products are held constant. This is measured as the ratio of the average incremental cost of one product to its marginal cost:

$$\mathrm{PSSE}_j = \left\{ \left(\frac{\partial \ln C}{\partial \ln Y_j} \right)^2 - \frac{\partial \ln C}{\partial \ln Y_j} + \frac{\partial^2 \ln C}{\partial \ln Y_j^2} \right\} \frac{C}{Y_j^2}. \tag{9}$$

Because $C/Y_j^2 > 0$, we only consider the expression between parentheses in Eq. (9). Consistent with the OSE indicator, $\mathrm{PSSE}_j < 0$ implies economies of scale with respect to Y_j, while $\mathrm{PSSE}_j > 0$ indicates diseconomies of scale.

Second, overall scope economies (OSP) are measured as percentage cost savings from producing all outputs jointly, as opposed to producing each output separately:

$$\mathrm{OSP} = \frac{C(Y_1, 0, \ldots, 0) + C(0, Y_2, 0, \ldots, 0) + (0, \ldots, 0, Y_n) - C(Y_1, \ldots, Y_n)}{C(Y_1, \ldots, Y_n)}, \tag{10}$$

where $OSP > 0$ indicates the presence of economies of scope. Therefore, total joint production cost was lower than that of the separate production. Therefore, cooperatives could potentially become more cost-efficient by diversifying production activities. Conversely, $OSP < 0$ implies diseconomies of scope.

Product-specific scope economies (PSSPs) arise from cost reduction owing to the joint production of a specific output with others. Therefore, PSSP measures relative increase in cost if outputs are produced in two separate groups. Specifically, the PSSP for the *j*th output is provided as follows:

$$\mathrm{PSSP}_j = \frac{C\left(Y_j\right) + C\left(Y_{N-j}\right) - C(Y)}{C(Y)}, \tag{11}$$

where $\mathrm{PSSP}_j > 0$ implies product-specific economies of scope with respect to Y_j, while $\mathrm{PSSP}_j < 0$ indicates diseconomies of scope. The measurement of product-specific economies of scope is meaningful because the scale of all products may not change proportionally. Theoretically, overall scope economies depend on both product-specific economies of scale and scope.

4 Data

This study uses financial data from the *Statistics on Agricultural Cooperative* by the Ministry of Agriculture, Forestry and Fisheries of Japan. Specifically, we use panel data covering the period from FY2004 to FY2019. These data include annual basic financial records, namely, balance sheets and income statements of general agricultural cooperatives.[10] As

[10] There are about 700 multi-purpose agricultural cooperatives in Japan. Although there are many cooperatives that disclose accounting information through their websites, published accounts are not uniform; cost information, such as personnel expense and the total insurance business expense, needed for the cost function estimation, are not disclosed for many cooperatives. Therefore, we use aggregate data at the prefectural level.

previously explained, these data are disclosed at the prefectural level. Because JAs exist in every prefecture, the panel dataset is balanced.[11]

Considering outputs, we consider the segment assets from major businesses of general agricultural cooperatives: banking (Y_1), insurance (Y_2), and economic (Y_3), based on which prefectural-level organizations belonging to national central organizations are established. Although JAs engage in various activities, the four main businesses are banking, insurance, purchasing, and marketing. The segment assets of economic business are equal to the sum of those of the purchasing and marketing businesses.[12] Subsequently, input prices are defined as follows: the price of labor (p_1) is the ratio of personnel expenses to the number of full-time employees and directors, price of capital (p_2) is the ratio of non-personnel expenses to the value of movable and immovable capital, and the price of credit business (p_3) is the interest expenses on deposits over total amount of deposits, and the price of insurance business (p_4) is defined as the total insurance business expenses over the total assets of the insurance business.[13] The total cost (C) is the sum of the four input expenses. All monetary values are converted to 2011 constant yen values using gross domestic product (GDP) price deflator.

Regarding the inefficiency determinants, the following environmental variables were used: the key variable is the share of agriculture in prefectural GDP (AGPS). This reflects the foundation for the existence of JAs. Therefore, as the relative importance of the agricultural sector in the region reflects the performance of JAs, the coefficient of AGPS is negative. Next, the ratio of the number of regular members to that of total members (RMBR) is used to capture JA membership strength. As high RGMR suggests the strength of JA governance by full-time farmers, the RGMR has a negative coefficient. Moreover, unemployment rate (UEMR) is used to control for prefectural differences in economic conditions. The natural logarithm of total assets (LAST) is also used to control for size differences across prefectures.[14]

The summary statistics for all variables are presented in Table 1 for the urban and rural areas. We classified 47 prefectures into two regions based on whether the agricultural sector has a large share in the prefectural GDP. The urban areas comprise 20 prefectures where the primary industry share was above 1% as of 2019. Japan's three largest metropolitan areas (Tokyo, Yokohama, Nagoya, Osaka, Kyoto) are included in this group. Rural areas comprise the remaining prefectures.

As shown in Table 1, the banking business segment assets exhibit highest mean value among the three outputs in both areas. Regarding differences in financial and nonfinancial activities, a distinctive difference exists between urban and rural areas. The mean value of the segment assets of the banking business in urban areas is around 2.7 times larger than that in rural areas. The mean value of the segment assets of the insurance

[11] There are 47 prefectures, as the first level of jurisdiction and administrative division in Japan.

[12] Although we have tested the models using flow variables as outputs, such as total earnings and total profit for each business, the stable and reliable results could not be obtained.

[13] We have considered the price of economic business, as sum of expenses in purchasing and marketing businesses over the total assets of the economic businesses, as the fifth input variable. However, since the monotonicity condition does not hold, we assumed price is determined in a perfectly competitive market and is negligible.

[14] The GDP statistics and the unemployment rate were drawn from the portal site of official statistics of Japan, provided by the Ministry of Internal Affairs and Communications. All other data were from the *Statistics on Agricultural Cooperative*, the same as financial data of JAs.

Table 1 Descriptive statistics

Variables	Total		Urban area		Rural area	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Total cost (C)	114,846	101,849	112,080	60,907	116,895	123,771
Total asset of credit business (Y_1)	1,949,947	1,589,625	3,070,639	1,819,577	1,119,804	573,853
Total asset of insurance business (Y_2)	1645	1784	2478	2173	1029	1074
Total asset of economic business (Y_3)	26,485	29,124	17,569	11,620	33,091	35,712
Price of labor (p_1)	5.3762	1.0345	5.9379	1.0398	4.9602	0.8104
Price of capital (p_2)	0.1694	0.0430	0.1823	0.0413	0.1598	0.0417
Price of credit business (p_3)	0.0012	0.0009	0.0012	0.0009	0.0012	0.0008
Price of insurance business (p_4)	0.2046	0.0900	0.1764	0.0835	0.2255	0.0891
Observations	752		320		432	

All financial data are in million yen

All financial data are deflated by the Japanese GDP deflator and taken from Annual Report on National Accounts provided by Economic and Social Research Institute (ESRI)

business in the urban region is also around 2.4 times that in rural areas. Obviously, as the agricultural sector does not play a significant role in urban areas, figures may reflect the dependence on financial business for non-farmers. By contrast, rural areas largely exceed urban areas in terms of the mean values of the segment assets of the economic business.

5 Results

5.1 Efficiency scores

Table 2 presents the maximum likelihood estimates of the parameters. The results for area-specific frontiers are presented in the first and second columns. Results for the meta-frontier are shown in the third column and are estimated using the predicted values from estimation results of area-specific frontiers as a dependent variable. All results in Table 2 pertain to linear homogeneity restrictions imposed using the price of the insurance business (p_4) as a numeraire. To confirm the validity of the data splitting, the standard F test of the null hypothesis that the cost functions are the same for all samples is calculated after estimating OLS regressions by pooling data from both groups and each subgroup. The value of the F statistic is 12.0871, which is greater than the 1% critical level (1.6285). This suggests that the two groups' stochastic frontiers are not the same.

Now, we look at the estimates of the area-specific frontier models. Note that a positive (negative) coefficient for each inefficiency determinant variable indicates an inefficiency-inducing(-reducing) factor. First, the coefficient on the share of agriculture in the prefectural GDP (AGPS) is positive and statistically significant at the 1% level for urban areas. This indicates that a larger presence of the agricultural sector in urban areas does not lead to higher JA performance. Although not statistically significant, the coefficient is negative for rural areas, indicating a contrary effect. The coefficient of the ratio of the number of regular members to that of total members (RMBR) is negative and statistically significant at the 1% level for rural areas. As a high RMBR means that the ratio of the number of nonregular members is low, results suggest that non-farm members do not have a positive impact on JA performance in rural areas. Interestingly, the coefficient

Table 2 Parameter estimates of cost function

Parameter	Area-specific frontier models			Meta-frontier model		
	Urban area		Rural area			
	Coefficient	**Std. Err.**	**Coefficient**	**Std. Err.**	**Coefficient**	**Std. Err.**
α_0	11.3000***	0.0376	11.9585***	0.0852	11.2067***	0.0439
α_1	0.4014***	0.0334	0.2218***	0.0757	0.2195***	0.0265
α_2	−0.0914***	0.0125	0.1171***	0.0152	0.0031	0.0077
α_3	0.4092***	0.0314	0.6586***	0.0339	0.4970***	0.0155
β_1	0.9590***	0.0831	0.8559***	0.1059	0.9191***	0.0425
β_2	0.3088***	0.1004	0.1302*	0.0671	0.2476***	0.0400
β_3	−0.3659***	0.0322	−0.1373***	0.0470	−0.2332***	0.0159
α_{11}	0.1148**	0.0541	−0.1304	0.1170	0.1601***	0.0327
α_{12}	0.0217*	0.0128	0.0776***	0.0173	0.0385***	0.0048
α_{13}	−0.0091	0.0233	0.2692***	0.0363	−0.0135	0.0132
α_{22}	−0.0158**	0.0074	−0.0144*	0.0074	−0.0189***	0.0027
α_{23}	0.0218***	0.0079	−0.0265***	0.0091	0.0022	0.0030
α_{33}	0.0069	0.0176	−0.0530	0.0544	0.1165***	0.0121
β_{11}	1.2248***	0.2648	0.2543	0.3232	0.3116***	0.1046
β_{12}	−1.4967***	0.2402	0.1532	0.2099	−0.1751**	0.0819
β_{13}	0.0892	0.0590	−0.0311	0.1048	0.0462*	0.0266
β_{22}	1.4452***	0.2651	−0.3401*	0.1934	0.0755	0.0856
β_{23}	0.0935	0.0572	0.0188	0.0526	−0.0187	0.0175
β_{33}	−0.0898**	0.0421	−0.0003	0.0636	−0.0268	0.0174
δ_{11}	0.0913	0.0685	−0.2788**	0.1197	−0.0485	0.0377
δ_{12}	0.0202	0.0648	0.1828*	0.0952	0.0943***	0.0360
δ_{13}	−0.0227	0.0186	−0.0505	0.0369	−0.0327***	0.0081
δ_{21}	−0.1752***	0.0264	−0.0051	0.0358	−0.0451***	0.0109
δ_{22}	0.1496***	0.0304	0.0082	0.0250	0.0508***	0.0094
δ_{23}	−0.0017	0.0083	0.0168	0.0114	−0.0003	0.0034
δ_{31}	−0.1137**	0.0498	0.3269***	0.0684	0.1057***	0.0243
δ_{32}	0.0468	0.0434	−0.3128***	0.0645	−0.1012***	0.0228
δ_{33}	−0.0108	0.0145	−0.0101	0.0214	−0.0246***	0.0055
DM_{y05}	−0.1438***	0.0275	−0.1365***	0.0364	−0.1041***	0.0123
DM_{y06}	0.1009***	0.0325	−0.0937**	0.0422	0.0460***	0.0154
DM_{y07}	0.3900***	0.0570	−0.0389	0.0736	0.2286***	0.0280
DM_{y08}	0.3231***	0.0563	−0.1150	0.0754	0.1835***	0.0304
DM_{y09}	0.2344***	0.0483	−0.1578**	0.0630	0.1179***	0.0264
DM_{y10}	0.1735***	0.0353	−0.1403***	0.0498	0.0880***	0.0203
DM_{y11}	−0.0172	0.0330	−0.2986***	0.0418	−0.0674***	0.0198
DM_{y12}	−0.0341	0.0398	−0.3128***	0.0448	−0.0944***	0.0204
DM_{y13}	−0.1285***	0.0344	−0.3430***	0.0413	−0.1278***	0.0205
DM_{y14}	−0.1380***	0.0355	−0.3729***	0.0417	−0.1473***	0.0208
DM_{y15}	−0.0593*	0.0354	−0.3304***	0.0443	−0.1038***	0.0199
DM_{y16}	0.0063	0.0370	−0.2336***	0.0443	−0.0495***	0.0187
DM_{y17}	−0.1124***	0.0349	−0.3052***	0.0425	−0.1312***	0.0180
DM_{y18}	−0.4348***	0.0450	−0.0500	0.0474	−0.0916***	0.0250
DM_{y19}	−0.5686***	0.0477	−0.1344**	0.0562	−0.1727***	0.0274
Inefficiency effects						
AGPS ($\rho 1$)	0.8017***	0.0816	−0.0114	0.0228		
RMBR ($\rho 2$)	0.0001	0.0016	−0.0111***	0.0029		
UEMR ($\rho 3$)	−0.1687***	0.0317	0.0035	0.0109		

Table 2 (continued)

Parameter	Area-specific frontier models			Meta-frontier model		
	Urban area		Rural area			
	Coefficient	Std. Err.	Coefficient	Std. Err.	Coefficient	Std. Err.
LAST (ρ4)	0.0120***	0.0058	0.0473***	0.0063		
ln σ^2	− 3.7037***	0.1680	− 4.0047***	0.1363	− 3.6143***	0.2857
iligt γ	2.3079***	0.4369	− 1.1892	1.4844	2.1719***	0.3232
μ					0.2312***	0.0458
η					0.0221***	0.0028
Log likelihood	282.27		279.14		1032.23	
Observations	320		432		752	

*, **, *** denote a significant estimator at the 10%, 5%, and 1% level, respectively

ln $\sigma^2 = \ln(\sigma_v^2 + \sigma_u^2)$ and ilgt γ are the inverse logit of $\sigma_u^2/(\sigma_v^2 + \sigma_u^2)$, respectively

of the unemployment rate (UEMR) is negative and statistically significant at the 1% level for urban areas. This indicates that better regional economic conditions lead to poor JA performance in non-farming areas. Coefficients of the natural logarithm of the total assets (LAST) are positive and statistically significant at the 1% level for both areas, implying that large JAs tend to have lower efficiency.

In the meta-frontier model, coefficients related to the two error components are statistically significant at the 1% level. The estimate of the time inefficiency term, η, is positive, which implies that inefficiency decreases over time. Basically, the technology gap tends to expand over the sample period. For the other parameters, the number of significant coefficients is greater than that in the area-specific frontier models.

Table 3 presents the summary statistics of efficiency values. The left-hand side of Table 3 reports the results for the urban areas. The first columns present the technical efficiency of the group obtained from the estimation results of area-specific frontiers. The overall mean *TE* score is 0.8362, which implies that JAs in urban areas could decrease total cost by 16.4% (=1–0.8362) on average using the production technology available in the same group. Yearly mean *TE* scores tended to decrease, although they are not constant. The second column shows the technology-gap ratio. Overall mean TGR score is 0.8233, which implies that JAs in urban areas could decrease total cost by an average of 17.7% (=1–0.8233) using the best available technology. As demonstrated in the sign of the decay parameter in the meta-frontier model, the yearly mean TGR scores tend to increase over time. The third column presents the meta-frontier technical efficiency obtained by multiplying the TE and TGR scores. The overall mean MTE score is 0.6046, which implies that JAs in urban areas could decrease total cost by 31.6% (=1–0.6843) on average using the unrestricted meta-technology.

The right-hand side of Table 3 shows the results for rural areas. Relative to the results above, the first columns present group technical efficiency obtained from the estimation of the area-specific frontier. The overall mean TE score is 0.9037, implying that JAs in rural areas could decrease the total cost by 9.6% (=1–0.9037) on average using the production technology available in the same group. Therefore, JAs in rural areas exhibit, higher group technical efficiency than those in urban areas on average. The second column shows the technology gap ratio. Overall mean TGR score is 0.6964, which implies

Table 3 Estimated efficiency scores

Year	Urban area							Rural area						
	Obs.	TE		TGR		MTE		Obs.	TE		TGR		MTE	
		Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.		Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
2004	20	0.8675	0.1152	0.7970	0.1259	0.6870	0.1265	27	0.9384	0.0657	0.6545	0.1130	0.6159	0.1194
2005	20	0.8466	0.1405	0.8008	0.1238	0.6724	0.1348	27	0.9360	0.0665	0.6605	0.1115	0.6199	0.1189
2006	20	0.8296	0.1475	0.8045	0.1218	0.6636	0.1481	27	0.9338	0.0675	0.6663	0.1099	0.6237	0.1175
2007	20	0.8057	0.1622	0.8081	0.1197	0.6470	0.1552	27	0.9258	0.0725	0.6721	0.1083	0.6240	0.1187
2008	20	0.7815	0.1820	0.8117	0.1177	0.6249	0.1428	27	0.9188	0.0771	0.6778	0.1068	0.6245	0.1187
2009	20	0.8038	0.1680	0.8153	0.1157	0.6481	0.1440	27	0.9178	0.0793	0.6834	0.1052	0.6288	0.1169
2010	20	0.8524	0.1635	0.8188	0.1138	0.6927	0.1530	27	0.9130	0.0841	0.6890	0.1037	0.6307	0.1176
2011	20	0.8654	0.1552	0.8222	0.1118	0.7066	0.1467	27	0.9055	0.0884	0.6944	0.1021	0.6305	0.1182
2012	20	0.8531	0.1550	0.8256	0.1099	0.7002	0.1500	27	0.9019	0.0914	0.6999	0.1006	0.6333	0.1197
2013	20	0.8570	0.1557	0.8289	0.1080	0.7060	0.1487	27	0.8965	0.0896	0.7052	0.0991	0.6341	0.1176
2014	20	0.8548	0.1553	0.8322	0.1061	0.7058	0.1412	27	0.8904	0.0911	0.7105	0.0976	0.6343	0.1166
2015	20	0.8530	0.1370	0.8354	0.1043	0.7090	0.1353	27	0.8855	0.0945	0.7157	0.0961	0.6357	0.1175
2016	20	0.8538	0.1215	0.8385	0.1024	0.7149	0.1343	27	0.8848	0.0987	0.7208	0.0946	0.6400	0.1193
2017	20	0.8389	0.1244	0.8417	0.1006	0.7057	0.1369	27	0.8793	0.0973	0.7259	0.0931	0.6402	0.1169
2018	20	0.8068	0.1661	0.8447	0.0988	0.6798	0.1630	27	0.8706	0.1038	0.7309	0.0916	0.6379	0.1172
2019	20	0.8093	0.1590	0.8477	0.0971	0.6845	0.1572	27	0.8614	0.1028	0.7358	0.0902	0.6358	0.1188
Total	320	0.8362	0.1502	0.8233	0.1099	0.6843	0.1440	432	0.9037	0.0881	0.6964	0.1030	0.6306	0.1162

that JAs in rural areas could decrease total cost by an average of 30.4% (=1–0.6964) using the best available technology. Contrary to the TE scores, JAs in rural areas have, on average, a smaller technology gap ratio than those in urban areas. As in the third column, the overall mean MTE score is 0.6306. Basically, JAs in rural areas could decrease the total cost by 36.9% (=1–0.6306) on average using the unrestricted meta-technology.

Hence, the fact that the mean TE score is larger than the mean TGR score for both areas indicates that inefficiency with respect to the meta-frontier is primarily due to the technology gap, rather than operating inefficiency. In comparing each area, the overall mean TE score for rural areas is larger than that for urban areas. For the MTE score, JAs in urban areas exhibit higher efficiency than those in rural areas on average, which reflects the superior TGR score of the former. The large difference in the TGR scores between urban and rural areas is considered to be due to the difference in the composition of regular members and non-regular members. Since JAs in urban areas excessively dependent on financial business for non-farmers, the results suggest that financial business has a greater positive impact on efficiency improvement: closer to the meta-frontier.

To assess the significant differences between the medians of these two groups, the Kruskal–Wallis test was employed. The null hypothesis of the test is that the mean ranks of the groups are the same. For the overall scores, the p-values of the Chi-square statistic are below 0.01 in all. Regarding yearly scores, the tests on the TE scores show significant differences for 7 years; the p-values of the Chi-square statistic are below 0.01 or 0.05 prior to 2009 and 2017. The tests on the TGR scores show significant differences at the 1% level in all years. Finally, the tests on the MTE scores show significant differences for 7 years, and the p-values of the Chi-square statistic are below 0.05 or 0.1 from 2011 to 2017.

5.2 Economies of scale

Table 4 shows the results for the overall and product-specific economies of scale. Measures are computed using the parameters derived from the results for the meta-frontier models and are calculated for the overall and yearly sample means, respectively. Regarding OSE estimates for the overall sample mean, the estimated values are statistically significant and below 0 for both urban and rural areas. The absolute value for rural areas (−0.3706) is larger than that for urban areas (−0.2280), which indicates that JAs in rural areas exhibit greater overall economies of scale than those in urban areas. As presented in Eq. (8), OSE assumes a proportional increase in cost resulting from a simultaneous proportional increase in all outputs. The results suggest that the heterogeneity of output component is relatively high for urban areas reflecting dependence on financial business for non-farmers. All yearly estimates are also statistically significant and below 0 for both areas, and these fluctuations are quite similar; the overall economies of scale tend to increase over time.

For the product-specific economies of scale for the banking business, $PSSE_1$, the estimated value for the overall sample mean is statistically significant and is below 0 for urban areas (−0.0563). The value for rural areas (0.0611) is greater than 0, which indicates diseconomies of scale, although this value is not statistically significant. Consistent results are obtained for the yearly estimates; that is, JAs in urban areas exhibit statistically significant product-specific economies of scale for the credit business in all years

Table 4 Scale economies estimates

	Urban area				Rural area			
	OSE	$PSSE_1$	$PSSE_2$	$PSSE_3$	OSE	$PSSE_1$	$PSSE_2$	$PSSE_3$
2004	− 0.2238***	− 0.0492*	− 0.0344***	− 0.1320***	− 0.3706***	0.0659	− 0.0141**	− 0.1326***
2005	− 0.1840***	− 0.0579**	− 0.0313***	− 0.1331***	− 0.3706***	0.0531	− 0.0103	− 0.1306***
2006	− 0.2302***	− 0.0502*	− 0.0284***	− 0.1318***	− 0.3755***	0.0694	− 0.0088	− 0.1323***
2007	− 0.2513***	− 0.0448*	− 0.0253***	− 0.1314***	− 0.3958***	0.0815*	− 0.0063	− 0.1325***
2008	− 0.2212***	− 0.0514**	− 0.0224***	− 0.1326***	− 0.3648***	0.0678	− 0.0043	− 0.1313***
2009	− 0.2254***	− 0.0539**	− 0.0215***	− 0.1320***	− 0.3681***	0.0639	− 0.0039	− 0.1319***
2010	− 0.2350***	− 0.0559**	− 0.0245***	− 0.1303***	− 0.3804***	0.0606	− 0.0062	− 0.1331***
2011	− 0.1886***	− 0.0637**	− 0.0234***	− 0.1325***	− 0.3331***	0.0446	− 0.0060	− 0.1313***
2012	− 0.1929***	− 0.0656**	− 0.0264***	− 0.1315***	− 0.3355***	0.0420	− 0.0084	− 0.1320***
2013	− 0.1766***	− 0.0655**	− 0.0226***	− 0.1329***	− 0.3163***	0.0396	− 0.0063	− 0.1303***
2014	− 0.1881***	− 0.0667**	− 0.0240***	− 0.1318***	− 0.3229***	0.0390	− 0.0071	− 0.1312***
2015	− 0.2260***	− 0.0621**	− 0.0272***	− 0.1289***	− 0.3579***	0.0486	− 0.0105	− 0.1330***
2016	− 0.2750***	− 0.0553**	− 0.0329***	− 0.1228***	− 0.4095***	0.0621	− 0.0152**	− 0.1332***
2017	− 0.2584***	− 0.0577**	− 0.0349***	− 0.1244***	− 0.3931***	0.0590	− 0.0157**	− 0.1334***
2018	− 0.3011***	− 0.0239	− 0.0795***	− 0.1215***	− 0.4349***	0.1303**	− 0.0645***	− 0.1333***
2019	− 0.2790***	− 0.0234	− 0.0858***	− 0.1248***	− 0.4116***	0.1330**	− 0.0715***	− 0.1334***
Total	− 0.2280***	− 0.0563**	− 0.0303***	− 0.1303***	− 0.3706***	0.0611	− 0.0116*	− 0.1328***

***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively, using the Wald test

except for 2018 and 2019. In contrast, the estimates for rural areas are greater than 0 in all years and are statistically significant in 2007, 2018, and 2019. The results suggest that the marginal product of the banking business brings significant cost-saving effects only for JAs in urban areas.

The estimates of the product-specific economies of scale for the insurance business, $PSSE_2$, at the overall sample mean are statistically significant and below 0 for both urban and rural areas. Absolute value for urban areas (− 0.0303) is larger than that for rural areas (− 0.0116). All yearly estimates are also statistically significant, and below 0 for urban areas. Yearly estimates for rural areas are less than those for urban areas, while almost all of them are not statistically significant. Therefore, according to $PSSE_1$ estimates, the insurance business's marginal product leads to greater cost reductions for JAs in urban areas.

In sharp contrast to previous two financial-related measures, estimates of the product-specific economies of scale for the economic business, $PSSE_3$, at the overall sample mean are statistically significant and below 0 for both urban and rural areas. Moreover, absolute value for rural areas (− 0.1328) is larger than that for urban areas (− 0.1303). All yearly estimates are also statistically significant and below 0 for both areas, but the estimates for rural areas are less than those for urban areas for 6 years. However, estimates for rural areas are greater than those for urban areas every year since 2015. These results imply that the marginal product of the purchasing business has greater cost-saving effects for JAs in rural areas.

To summarize, JAs exhibit overall economies of scale for both urban and rural areas, and the product-specific economies of scale show distinctive differences between financial and nonfinancial activities. Marginal products of banking and insurance businesses generate a larger cost reduction effect for JAs in urban areas, whereas those of economic

Table 5 Scope economies estimates

	Urban area				Rural area			
	OSP	$PSSP_1$	$PSSP_2$	$PSSP_3$	OSP	$PSSP_1$	$PSSP_2$	$PSSP_3$
2004	1.8504***	0.9928***	0.9845***	1.0283***	2.6061***	1.2021***	1.1821***	1.2196***
2005	1.2157***	0.7302***	0.7509***	0.8127***	2.0545***	1.0132***	0.9882***	1.0157***
2006	1.4592***	0.8211***	0.8293***	0.8834***	2.5926***	1.1678***	1.1736***	1.2210***
2007	1.8841***	0.9595***	0.9396***	0.9664***	3.0979***	1.2871***	1.3170***	1.4158***
2008	1.3586***	0.7384***	0.7286***	0.7615***	1.9408***	0.9170***	0.9033***	0.9386***
2009	1.4161***	0.7749***	0.7664***	0.8176***	2.1253***	0.9941***	0.9893***	1.0254***
2010	1.3741***	0.7807***	0.7831***	0.8608***	2.1309***	1.0335***	1.0304***	1.0490***
2011	0.9769***	0.6090***	0.6362***	0.7175***	1.5761***	0.8471***	0.8289***	0.8273***
2012	0.3857***	0.3872***	0.4417***	0.5626***	0.8008***	0.6255***	0.5806***	0.5386***
2013	0.8352***	0.5529***	0.5899***	0.6779***	1.3919***	0.7873***	0.7636***	0.7521***
2014	0.8139***	0.5519***	0.5888***	0.7121***	1.5567***	0.8436***	0.8251***	0.8224***
2015	0.9662***	0.6347***	0.6602***	0.8027***	1.5328***	0.8596***	0.8385***	0.8372***
2016	1.1591***	0.7430***	0.7626***	0.9213***	2.4047***	1.1708***	1.1717***	1.1846***
2017	1.4543***	0.8537***	0.8673***	0.9945***	2.9950***	1.3470***	1.3489***	1.3652***
2018	0.8313***	0.6576***	0.7260***	0.8531***	1.8484***	0.9666***	0.9666***	1.0393***
2019	0.9491***	0.7090***	0.7845***	0.8798***	1.7494***	0.9258***	0.9300***	0.9968***
Total	1.1399***	0.6967***	0.7144***	0.8047***	1.9863***	0.9864***	0.9787***	0.9984***

*** indicates significance at the 1% level, using the Wald test

businesses generate a larger one for JAs in rural areas. These findings reveal the regional differences in the business characteristics of JAs: what kind of business they mainly use.

5.3 Economies of scope

Table 5 reports the results for overall and product-specific economies of scope. Consistent with Table 4, measures are calculated for the overall and yearly sample means, respectively. Examining the OSP estimates for the overall sample mean, the estimated values are positive and statistically significant for both urban and rural areas. The value for rural areas (1.9863) is much larger than that for urban areas (1.1399), which indicates that JAs in rural areas exhibit greater overall economies of scope than those in urban areas. The yearly estimates are also statistically significant and above 0 for both areas, and the values for rural areas are larger than those for urban areas in all years. Therefore, the cost-saving benefits from the simultaneous production are relatively large for JAs in rural areas.

Regarding product-specific economies of scope for the banking business, $PSSP_1$, the estimated values at the overall sample mean are statistically significant and above 0 for both areas. Contrary to the $PSSE_1$ estimates in Table 4, the value for rural areas (0.9864) is larger than that for urban areas (0.6967). Moreover, all yearly estimates also show the same results: the values for rural areas are larger than those for urban areas. Therefore, the cost-reducing effect of the simultaneous production of the banking business is relatively large for JAs in rural areas.

Estimates of the product-specific economies of scope for the insurance business, $PSSP_2$, at the overall sample mean are also statistically significant and above 0 for both areas. Similar to the $PSSP_1$ estimates, value for rural areas (0.9787) is larger than that for urban areas (0.7144). Moreover, the yearly estimates are also statistically significant and demonstrate the same tendency. The values for rural areas are larger than those for urban areas overall. The results indicate that JAs in rural areas have a greater cost-reducing effect from the simultaneous production of the insurance business as well as the banking business.

The estimates of the product-specific economies of scope for the economic business, $PSSP_3$, at the overall sample mean are above 0 for both urban and rural areas. Consistent with the previous two financial-related measures, the value for rural areas (0.9984) is larger than that for urban areas (0.8047). Moreover, the yearly estimates are also statistically significant and are above 0 for both areas, and the values for rural areas are larger than those for urban areas in all years, except for 2012. As previously described, economic business is crucial for JAs to improve the livelihoods of member farmers. The results indicate that JAs located in rural areas exhibit a greater cost-reducing effect from the simultaneous production of their core businesses.

In summary, JAs in rural areas exhibit relatively larger overall economies of scope than those in urban areas.[15] Additionally, results for the product-specific economies of scope show the same tendency; unlike the product-specific economies of scale wherein JAs in rural areas exhibit larger product-specific economies of scope for all measures. These results imply the differences in business that members of agricultural cooperatives use in urban and rural areas. Thus, while nonregular members in urban areas use only financial and insurance businesses, many regular members of in rural areas use all of the business.

6 Conclusions

This study investigated the cost structure of JAs by employing a new two-step stochastic meta-frontier approach with multiproduct cost frontier functions. This approach allows for technological heterogeneity among the different groups. Hence, we divided Japan's 47 prefectures into two groups based on their agricultural sector shares in the prefectural GDP. As in other countries, JAs aim to protect farming and sustenance of their members. However, their current activities have been criticized owing to the role played by increased financial businesses for non-farmers. There are many cooperatives that rely too much on banking and insurance businesses, especially those located in urban areas. Therefore, this study highlights the operational differences between JAs in urban and rural areas by investigating their efficiency and economies of scale and scope. The main findings of our empirical analysis are as follows:

First, for the determinants of inefficiency, non-farm members do not have a positive impact on JA performance in rural areas. JAs in rural areas are significantly more efficient than those in urban areas in terms of the TE obtained from each grouped data. In contrast, for the MTE score, JAs in urban areas exhibit higher efficiency than those in rural areas, reflecting the superior TGR score of the former. Next, JAs in rural areas exhibit greater overall economies of scale than those in urban areas; however, some differences between financial and nonfinancial activities in product-specific economies of scale. Although the banking business's marginal product generates a larger effect for JAs

[15] Although no indication was found in the regional differences, Schroeder (1992) found that significant economies of scope exist for all of the products investigated, while product-specific scale economies exist for all products except one output.

in urban areas, that of the economic business generates a larger effect for JAs in rural areas. Finally, JAs in rural areas exhibit relatively larger overall economies of scope than those in urban areas. Moreover, the cost-reducing effect of the simultaneous production of each business is also greater for JAs in rural areas.

In conclusion, the empirical findings suggest differences in the presence of distortions in JA business characteristics with respect to the effects of the simultaneous activities of financial and nonfinancial businesses. In terms of cost-reducing effects, clear distinctions between local and urban areas are found, and the benefits from simultaneous production are relatively small for JAs located in urban areas. Hence, our results have important policy implications in that a JA reform should consider regional variations.

Finally, further research is needed to propose concrete measures to address the current issues faced by JAs. Although the overreliance on financial activities is identified as an issue, our results do not clarify whether JAs' nonfinancial activities are highly productive and indispensable. Certainly, economic businesses, such as purchasing activities, are important to supply member farmers with factors of production at low prices; however, this activity might be easily conducted by other suppliers. Moreover, although this study uses aggregate data at the prefectural level because of limited availability, further investigation based on data of individual JAs is also needed, even though the data would be incomplete and not be at the national level. Aggregated data may not be consistent with the concept of efficiency measurement. Despite these limitations, our empirical findings provide new insights into the current characteristics of agricultural cooperatives in Japan.

Received: 15 February 2022 Revised: 11 October 2022 Accepted: 12 October 2022
Published online: 25 October 2022

References

Ariyaratne CB, Featherstone AM, Langemeier MR, Barton DG (2000) Measuring x-efficiency and scale efficiency for a sample of agricultural cooperatives. Agric Resour Econ Rev 29(2):198–207
Azumah BS, Donkoh SA, Awuni JA (2019) Correcting for sample selection in stochastic frontier analysis: insights from rice farmers in Northern Ghana. Agric Food Econ 7:1–15
Battese GE, Coelli TJ (1988) Prediction of firm-level technical inefficiencies with a generalised frontier production function and panel data. J Econom 38(3):387–399
Battese GE, Coelli TJ (1992) Frontier production functions, technical efficiency, and panel data: with application to paddy farmers in India. J Prod Anal 3:153–169
Battese GE, Rao DP (2002) Technology gap, efficiency, and a stochastic metafrontier function. Int J Bus Econ 1(2):87–93
Battese GE, Rao DP, O'Donnell CJ (2004) A metafrontier production function for estimation of technical efficiencies and technology gaps for firms operating under different technologies. J Prod Anal 21:91–103
Beber CL, Lakner S, Skevas I (2021) Organizational forms and technical efficiency of the dairy processing industry in southern Brazil. Agric Food Econ. https://doi.org/10.1186/s40100-021-00195-3
Berger AN, Humphrey DB (1991) The dominance of inefficiencies over scale and product mix economies in banking. J Monet Econ 28(1):117–148
Berger AN, Mester LJ (1997) Inside the black box: what explains differences in the efficiencies of financial institutions. J Bank Finance 21(7):895–947
Berger AN, Hancock D, Humphrey DB (1993) Banking efficiency derived from the profit function. J Bank Finance 17(2/3):317–347
Brandano MG, Detotto C, Vannini M (2019) Comparative efficiency of agricultural cooperatives and conventional firms in a sample of quasi-twin companies. Ann Public Coop Econ 90(1):53–76
Bravo-Ureta BE, Solis D, Moreira LV, Maripani JF, Thiam A, Rivas T (2007) Technical efficiency in farming: a meta-regression analysis. J Prod Anal 27:57–72
Evanoff DD, Israilevich PR (1991) Productive efficiency in banking. Econ Perspect 15:11–32
Featherstone AM, Moss CB (1994) Measuring economies of scale and scope in agricultural banking. Am J Agr Econ 76(3):655–661
Fulton M, Hueth B (2009) Cooperative conversions, failures and restructurings: an overview. J Coop 23:1–11

Galdeano-Gómez E (2008) Productivity effects of environmental performance: evidence from TFP analysis on marketing cooperatives. Appl Econ 40(14):1873–1888
Grashuis J, Su Y (2019) A review of the empirical literature on farmer cooperatives: performance, ownership and governance, finance, and member attitude. Ann Public Coop Econ 90(1):77–102
Harimaya K, Kagitani K (2019) Performance of agricultural cooperative banks in Japan: difference between stock and flow output variables. Agric Financ Rev 80(1):38–50
Hayami Y (2007) An emerging agricultural problem in high-performing Asian economies. World Bank Policy Research Working Paper, 4312
Honma M, Hayami Y (2009) Japan, Republic of Korea, and Taiwan, China. In: Anderson K (ed) Distortions to agricultural incentives: A global perspective, 1955–2007. World Bank, Palgrave Macmillan, London and Washington, DC, pp 67–114
Honma S, Hu J-L (2018) A meta-stochastic frontier analysis for energy efficiency of regions in Japan. J Econ Struct 7(1):1–16
Honma M, Mulgan GA (2018) Political economy of agricultural reform in Japan under Abe's administration. Asian Econ Policy Rev 13(1):128–144
Huang Z, Fu Y, Liang Q, Song Y, Xu X (2013) The efficiency of agricultural marketing cooperatives in China's Zhejiang province. Manag Decis Econ 34(3/5):272–282
Huang CJ, Huang TH, Liu NH (2014) A new approach to estimating the metafrontier production function based on a stochastic frontier framework. J Prod Anal 42:241–254
O'Donnell CJ, Rao DP, Battese GE (2008) Metafrontier frameworks for the study of firm-level efficiencies and technology ratios. Empir Econ 34(2):231–255
Otsuka K (2013) Food insecurity, income inequality, and the changing comparative advantage in world agriculture. Agric Econ 44(S1):7–18
Pokharel KP, Featherstone AM (2019) Estimating multiproduct and product-specific scale economies for agricultural cooperatives. Agric Econ 50(3):279–289
Schroeder TC (1992) Economies of scale and scope for agricultural supply and marketing cooperatives. Rev Agric Econ 14(1):93–103
Singh S, Coelli T, Fleming E (2001) Performance of dairy plants in the cooperative and private sectors in India. Ann Public Coop Econ 72(4):453–479
Skevas T, Grashuis J (2020) Technical efficiency and spatial spillovers: evidence from grain marketing cooperatives in the US Midwest. Agribusiness 36(1):111–126
Soboh R, Oude-Lansink A, Giensen G, Van Dijk G (2009) Performance measurement of the agricultural marketing cooperatives: the gap between theory and practice. Rev Agric Econ 31(3):446–469
Soboh R, Oude-Lansink A, Giensen G, Van Dijk G (2014) Efficiency of European dairy processing firms. NJAS-Wagening J Life Sci 70–71:53–59
Sueyoshi T (1999) DEA nonparametric ranking test and index measurement: slack-adjusted DEA and an application to Japanese agriculture cooperatives. Omega 27(3):315–326
Thraen CS, Hahn DE, Roof JB (1987) Processing costs, labor efficiency, and economies of size in cooperatively-owned fluid milk plants. J Agric Coop 2:40–56
Yamamoto Y, Kondo K, Sasaki J (2006) Productivity and efficiency change for agricultural cooperatives in Japan: the case of the dairy-farming region in Hokkaido. Jpn J Rural Econ 8:58–63
Yoo CK, Buccola S, Gopinath M (2013) Cooperative pricing and scale efficiency: the case of Korean rice processing complexes. Agric Econ 44(3):309–321
Yu Y, Escalante CL, Deng X, Houston J, Gunter LF (2011) Analysing scale and scope specialization efficiencies of US agricultural and nonagricultural banks using the Fourier flexible functional form. Appl Financ Econ 21(15):1103–1116

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