

## Production efficiency of animal feed plants using food waste in Japan

Topic: Regional Input-Output Economics - I

Author: Junji Tsuru

Co-Authors: Daigo Ushijima, Shigemi KAGAWA, Tomoaki Nakaishi

75% of feeds for livestock raised in Japan was dependent on imports in 2022 (Ministry of Agriculture, Forestry and Fisheries, 2023). In addition, feeds account for 34% of the livestock industry's operating costs for feeding cattle, 50% for milk cow, 63% for feeding pigs, and 57% (broiler management) and 48% (ovum management) for poultry farming in 2022 (MAFF, 2023). If we continue to rely on imports for livestock feed, not only will we be unable to avoid rising of food prices triggered by increased import prices of the livestock feed, but we may also be left with safety concerns due to the effects of feed additives.

Animal feed from food waste, known in Japan as "eco-feed," is important for Japanese food and livestock industries because it is expected to reduce not only food waste disposal but also feed costs and thus improve productivity in both the food and livestock industries. However, eco-feed production plants are not operationally managed well because they are generally facing challenges such as low production capacity and lack of smooth production. Therefore, it is necessary to identify the most efficient management patterns for eco-feed production plants and to provide opportunities to learn the efficient production technologies.

To our best knowledge, there are few studies that have estimated the production efficiency of eco-feed plants. One exception is early work by Nakaishi and Takayabu (2022), however, they were only able to identify the monthly production efficiency of a "single" eco-feed plant due to limitations in data availability. To provide more comprehensive policy implications, it is necessary to focus on the production efficiency of "multiple" eco-feed plants across Japan.

This study applies data envelopment analysis (DEA) to input-output data of 17 eco-feed plants in Japan to quantitatively assess eco-feed production efficiency on a plant-by-plant basis. In doing so, the most efficient eco-feed production plants and the most efficient eco-feed production methods in Japan can be identified. This study is the first comprehensive evaluation of the relative production efficiency of multiple eco-feed plants, and contributes to the sustainability of both the food and livestock industries.

First, we arranged a comprehensive input-output database for production activities of 17 specific eco-feed plants in Japan from Biomass Utilization Technology Information Database ver2.1 (Japan Center for Regional Environmental Resources, 2022), consisting of three inputs (i.e., number of employees (person), amount of biomass delivered (t), and land value (million JPY)) and one output (amount of eco-feed produced).

Second, a meta-frontier DEA framework was applied to the constructed input-output database to estimate efficiency scores, standardized in the range of 0 to 1, for 17 specific eco-feed plants. DEA is one of the frontier approaches based on linear programming to assess the relative production efficiency of multiple decision-making units (DMUs). The DMUs in this study are 17 eco-feed plants in Japan. While there is one production frontier estimated in the conventional DEA framework, the advanced framework of meta-frontier DEA employed in this study can estimate multiple group frontiers based on the food waste type used.

Third, from the estimated efficiency scores of each eco-feed plant, DMUs with an efficiency score of 1 were considered optimal plants, and DMUs with an efficiency score less than 1 were considered

inefficient plants. Through this estimation process, the cost reduction potential of each plant was identified by finding improvements in the efficiency of each toward the DMU with the optimal efficiency value.

From the results, we found that the average efficiency score among the 17 Eco-Feed plants was 0.44 and the three plants of Eco-Feed Corporation, Murata Shoten, and Aiwa Sangyo Sasagami Plant were identified as the most efficient eco-feed plants with an efficiency score of 1. In addition, the results demonstrate that improvements of production technologies in the 14 inefficient Eco-Feed plants can contribute to considerably reducing their production cost. Finally, we suggest providing technical workshops to learn cost-minimizing eco-feed production methods from the efficient eco-feed plants identified in this study and expanding the competitive eco-feed market.