Determinants and impacts of public agricultural research in Japan: Product level evidence on agricultural Kosetsushi

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Abstract: The public sector is an important source of agricultural research as the agricultural sector in many countries consists of a number of individual farmers who have difficulty in bearing the cost of research and development. Public institutes for testing and research called Kosetsushi help agriculture and manufacturing improve labor productivity through technology transfer activities, whereby constituting an important component of regional innovation systems in Japan. This study establishes panel data of agricultural Kosetsushi and examines whether their research activities are responsive to local needs and which type of research effort is conducive to the promotion of agricultural product innovations. Estimation results reveal variations across plants in the impacts of agricultural clusters on research on the plant conducted by Kosetsushi located in the cluster. A positive impact is observed only for vegetable while negative or statistically insignificant relationships are found for rice, fruit, and flower. The impact of research on plant breeding on agricultural product innovations also varies across plants. Policy implications of the major findings are discussed.

Keywords: Kosetsushi; Japan; agricultural extension; new variety of a plant; regional innovation systems; product innovations; technology transfer

1. Introduction
The public sector is an important source of agricultural research for several reasons. First, agricultural research requires more time than research in physical-science-based sectors as it takes time to repeat experiments through growing a number of plants and selecting a few with appropriate characteristics. Second, price elasticity of demand to agricultural products, such as staple foods, tends to be small, which implies that a demand curve is steep. Furthermore, the elasticity of supply to price of agricultural products tends to be small as it is difficult for agricultural producers to increase production within a short period of time, which implies the steep supply curve. These demand- and supply-side conditions suggest that the impact of innovation tends to be absorbed by a
great increase in consumer's surplus, leaving an increase in producer's surplus substantially small. Therefore, in agriculture it is more difficult for the private sector to appropriate the return to R&D than in other industries. The appropriation condition can be more difficult considering that the agricultural sector consists of a number of individual farmers who have no complementary assets. These supply-side and demand-side factors in innovation render the public sector a key source of agricultural research, and thus agricultural product innovations.

Public institutes for testing and research called Kosetsushi constitute an important component of regional innovation policies in Japan. Kosetsushi were initially established in the late 19th century in agriculture, textiles, and brewery (e.g., sake and soy sauce), and then gradually developed in manufacturing in general (Fukugawa and Goto 2016). An average prefecture has six or seven Kosetsushi headquarters (=318/47) in each prefecture (Appendix Table 1). Kosetsushi help small and medium-sized enterprises (SMEs) and individual farmers improve productivity through various technology transfer activities (Fukugawa and Goto 2016). They play three key roles in regional innovation systems. First, they diffuse technological knowledge through various routes, such as technical consultation and seminars for the introduction of new standards and technologies. Second, they conduct their own research, patent inventions, and license patents mainly to local SMEs. Agricultural Kosetsushi register new varieties of a plant in the same way as manufacturing Kosetsushi patent their inventions. Third, they act as a catalyst for local SMEs to develop innovative networks to external sources of knowledge, such as universities.

Regardless distinctive features in terms of regional embeddedness and research intensity, little has been known about structure and efficiency of research activities of agricultural Kosetsushi in regional innovation systems. Such tendencies contrast with an increasing research attention emerging mainly from developing countries to the design of effective agricultural extension services (Chi and Yamada 2002; Al-Sharafat et al. 2012; Cole and Fernando 2012; Hellin 2012; Issa and Issa 2013; Turner, et al. 2013; Kassem 2014; Agunga and Putra 2015; Asif et al. 2015; Elias et al. 2015; Carmen and Bautista 2016; Debnath et al. 2016). To fill this research gap, this study establishes panel data of research activities and new varieties of a plant registered by agricultural Kosetsushi and examines whether their research activities are responsive to local needs for research, research on plant breeding is efficiently transformed to agricultural product innovations, and whether research productivity varies across plants.

2. Method

This study estimates the two-way error components model described as follows.

\[
R_{plant} = \alpha + \beta \text{Clusterplant}_{i,p} + \text{Y}_{i,p} + \epsilon_{i,p} \quad (1);
\]

\[
\ln Y_{i,p} = \alpha + \beta_2 \ln R_{field} + \text{Y}_{i,p} + \epsilon_{i,p} \quad (2).
\]

R_{plant} denotes the number of researchers at agricultural Kosetsushi allocated to research on a specific plant i. Clusterplant denotes location quotients of a specific plant in a prefecture p where Kosetsushi are located. Y denotes the number of new varieties of a plant registered by Kosetsushi. Rfield denotes the number of researchers allocated to research on a specific field weighted by the proportion of R_{plant} to the number of researchers. Suffix p denotes a prefecture in which agricultural Kosetsushi are located. Suffix i denotes a type of a plant being developed (i.e., rice, flower, fruit, and vegetable). Suffix t denotes the year of registration of the new variety of a plant. Suffix q denotes a lag required for the research inputs to exert an effect on agricultural product innovations. One error component u denotes time-invariant individual effects. Another error component v denotes time effect which represents exogenous shocks to all Kosetsushi, such as a change in regulation. Last, \epsilon denotes the error term. Information of Y is collected from the Database of Seed Registration and Application, compiled by the Ministry of Agriculture, Forestry and Fisheries. As shown in Table 1, the database provides information on ten plants. Only four of them (i.e., rice, flower, fruit, and vegetable) retain the sufficient number of observations for panel analysis. The balanced panel on which the present study builds is the time-series and cross-prefectural data. Concerning Equation 2, a dependent variable includes many zeros. Therefore, a random-effects Tobit regression model is
used for estimation to analyze truncated data. Random effects model was selected as there is not a sufficient statistic allowing the fixed effects to be conditioned out of the likelihood.

The location quotient is defined as \( LQ_{ij} = \frac{A_{ij}}{B_j}/\frac{A_i}{B} \). \( A_{ij} \) is the agricultural production of a plant \( i \) (\( i=1…10: \) the number of plants listed in Table 2), and in a prefecture \( j \) (\( j=1…47: \) the number of prefectures). \( B_j \) is the agricultural production in \( j \). \( A_i \) is the agricultural production of \( i \). \( B \) is the agricultural production in Japan. \( LQ \) is measured by plant and by prefecture. The more specialized the production in a specific plant, the greater the location quotient of that plant. For instance, if the agricultural production is concentrated more in rice than the population mean, \( LQ_{ij} \) will be the highest in rice. Information of location quotient is collected from the Agricultural Income Statistics, compiled by the Ministry of Agriculture, Forestry and Fisheries.

Information of research effort allocation is collected from the Ministry of Agriculture, Forestry and Fisheries “the Basic Survey of Agricultural Kosetsushi”. This survey provides two types of information on the allocation of research effort by plant and research field. The survey asked agricultural Kosetsushi to divide the number of researchers to fifteen research field, as shown in Footnote 4, and nineteen agricultural outputs, as shown in Footnote 3. In other words, the number of researchers \( R \) is described as where \( xi \) denotes the effort allocated to a research field \( i \) and \( yj \) denotes the effort allocated to a plant \( j \). It should be noted that \( xi \) and \( yj \) can be decimal even though \( R \) is natural number.

Experts suggested in interviews I conducted in 2016 that \( q \) significantly varied across plants. To incorporate different lagged structures in the regression model, I have collected information of the “development lag” between commencement and completion of research projects associated with the breeding of a specific plant. Information is collected from the Annual Report of Agricultural Experiment and Research Institutes compiled by the Ministry of Agriculture, Forestry, and Fishery. This survey shows that average development lag is ten years for rice, 6.4 years for fruit, five years for flower, and 4.9 years for vegetable. An average lag between application and registration of new varieties of a plant is 2.8 years. Figure 1 shows that a lag between application and registration continued to decrease until 2011 and became longer after that. Taking an example of fruits, agricultural research inputs invested in 2000 exerted an effect on product innovations measured by registration of new varieties in 2009 (=2000+6.4+2.8), which was filed in 2006.

3. Result and Discussion

Table 1 shows estimation results of Equation 1. Table 1 reveals the absence of a statistically significant relationship, except for fruit, between agricultural clusters of a specific plant and research effort by agricultural Kosetsushi on the plant. This may have to do with organizational characteristics of agricultural Kosetsushi. Unlike manufacturing Kosetsushi there is a clear division of labor between research and diffusion at agricultural Kosetsushi. Individual farmers are normally affiliated with the Japan Agricultural Cooperatives (JA). They let JA know about problems they face in everyday operation so that JA sends requests to the diffusion arm which is organized as a part of the prefecture. The diffusion arm is organized regionally as there are different agricultural clusters even within a prefecture. The subdivisions normally have a sufficient number of staff who can deal with problems local farmers encounter, such as diseases and pests. The diffusion arm transfers local research needs to agricultural Kosetsushi. The feedback from the diffusion arm constitutes one of the key factors for agricultural Kosetsushi to design a research plan. Based on local needs and requests from the local government and the major private buyers, agricultural Kosetsushi lays out the research plan and provides feedback to the diffusion arm which engages in the provision of solutions to individual farmers. Researchers at agricultural Kosetsushi do not directly engage in personal interactions with local clients (i.e., individual farmers), which creates the biggest difference from manufacturing Kosetsushi in terms of organizational structure. Concerning the relationship between organizational features and technology transfer activities, previous studies on technology transfer organizations (e.g., university-based technology licensing offices) show that the technology transfer productivity, measured by the number of patents licensed to firms and royalty revenue, is affected not only by physical factors, such as location, but also by organizational factors, such as incentive mechanisms designed for staff of technology transfer organizations (Lach and Schankerman...
2008; Fukugawa 2009; Amico-Roxas et al. 2011; Adekunle, 2013; Hsu et al. 2015). In a similar way, the results suggest the possibility that a clear division of labor between research and diffusion makes research at agricultural Kosetsushi less responsive to local needs. It should be noted that there might have been different types of interactions between the diffusion and research arms according to plants they develop as Table 5 shows that potential impacts of organizational features are contingent on the type of a plant. Future study should collect information on the linkage between the diffusion and research arms by plant, such as vegetable and fruit which exhibit opposite results.

Table 2 shows estimation results of Equation 2. Table 2 shows that different types of research effort have different level of impacts on agricultural product innovations. Furthermore, there is a plant level variation in the way research effort exerts an effect on research outcome. In fact the development of new varieties of rice and vegetable requires agricultural Kosetsushi to arrange a broad set of research inputs (i.e., researchers) while no research effort in a specific field exerts an effect on product innovations in fruit and flower. Concerning the relationship between human resource development and technology transfer productivity, previous studies on technology transfer organizations (e.g., business incubators) show that the diversity and quality of human resources do affect the success of technology transfer organizations (e.g., the number of new firms created) but its impact is contingent on technological fields and life cycle stages of startups to which they aim to give support (Fukugawa 2013). In a similar way, the results suggest the possibility that the technology transfer productivity at agricultural Kosetsushi is contingent on plant level factors. The plant level factors would pertain not only to natural conditions, but also to economic conditions, such as appropriability. This implies that agricultural Kosetsushi play different roles in regional innovation systems according to these conditions which cannot be fully captured in the present study. Future study should incorporate detailed information to analyze the process of decision making on resource allocation at agricultural Kosetsushi.

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5. References

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