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Hisatoshi HOKEN*

August 2010

Abstract

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In order to test the classical hypothesis of whether or not an inverse relationship between land productivity and cultivated area may be observed in developing countries, a Box-Cox transformation test was conducted for functional forms on five main crops of Buck's crop yield survey. The result of the test shows that the relationship between land productivity and cultivated areas of wheat and barley is linear and somewhat negative; those of rice, rapeseed, and seed cotton appear to be slightly positive. It can be tentatively concluded that the relationship between cultivated area and land productivity are not the same among crops, and the difference of labor intensity and the level of commercialization of each crop may be strongly related to the existence or non-existence of inverse relationships.

Keywords: farm survey, crop yield, farm management

JEL classification: N55, O12, Q12

* Research Fellow, Development Studies Center, IDE, Email: hoken@ide.go.jp

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INSTITUTE OF DEVELOPING ECONOMIES (IDE), JETRO
3-2-2, WAKABA, MIHAMA-KU, CHIBA-SHI
CHIBA 261-8545, JAPAN

Restoration of Micro Data of John Lossing Buck's Survey and Analysis of the Inverse Relationship between Yield and Farm Size in Rural China in the 1930's[Ψ]

Hisatoshi Hoken[*]

Abstract

A large scale Chinese agricultural survey was conducted at the direction of John Lossing Buck from 1929 through 1933. At the end of the 1990's, some parts of the original micro data of Buck's survey were discovered at Nanjing Agricultural University. An international joint study was begun to restore micro data of Buck's survey and construct parts of the micro database on both the crop yield survey and special expenditure survey. This paper includes a summary of the characteristics of farmlands and cropping patterns in crop yield micro data that covered 2,102 farmers in 20 counties of 9 provinces.

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[*] Research fellow, Institute of Developing Economies, Email: hoken@ide.go.jp.

I. Introduction

It has been stated that distributions of landholdings were rather unequal and increasingly polarized during the late Qing dynasty and Republican periods. This is because small farmers usually lost their own land as tenants due to unfavorable terms of trade and the high cost of credit borrowing. Tenancy farming appears to have given rise not only to social and economic inequality among farmers but also to have been related to efficiency loss and gain in agricultural production.

However, Myers [1976] utilized detailed data from a survey conducted by the Provincial Industrial Investigating Bureau of Manchuria to investigate socioeconomic structures in rural villages. Contrary to prevailing thought on the late-Qing dynasty and the Republican periods, he found that there was no trend toward social class polarization or toward more unequal land ownership or land use in Manchuria. Yanagisawa [2000] confirmed that land polarization and dispersion occurred, and land concentration by land owners had not been so strong in Northern China. Based on a household-level data set from Northeast China in the 1930's, Benjamin and Brandt [1997] showed that development of factor market had played a positive role in reducing inequality in rural China. Rawski [1989] has also indicated that commercialization and specialization of farming was gradually diffused in that period with the development of domestic industrialization and international export. These studies suggest that it is important to reconsider prevalent images of prewar China.

It is necessary to give attention to the socioeconomic structure of rural farmers in China during the late Qing dynasty and Republican periods. However, since existing micro datasets of rural households in China during those periods are extremely limited, statistical examination is still insufficient.

The purpose of this article is to clarify the characteristics of Chinese farm production in the periods mentioned using a large scale Chinese agricultural survey (called "Buck's survey"). Parts of the original micro data of Losing Buck's survey have been preserved at the Nanjing Agricultural University. In this study, a part of the micro data of the survey was restored, and by using the "yields per mow (farm area)" data, cropping patterns and land holding gaps of rural China in the 1930's could be estimated. In addition, the classical hypothesis of whether or not there is an inverse relationship between land productivity and cultivated area in developing countries was tested.

This paper is structured as follows: Section II includes brief description of the characteristics of Buck's survey and the procedures for constructing the household yields database. Section III includes descriptive statistics on cultivated area, yields of agricultural products, and cropping patterns. In addition, the relationships between land productivity and distribution of farm land are investigated. A summary of major findings and concluding remarks are presented in Section IV.

II. Characteristics of Buck's survey and procedure for restoring data

(1) Brief explanation of Buck's survey

John Lossing Buck was a professor of agricultural economics at the University of Nanking and was dean of the department until appointed as the representative of the US Department of Finance in China in 1935. In 1940, he returned to the University of Nanking. Altogether, he lived in China for almost 30 years. He obtained both his masters (1925) and doctoral (1933) degrees in Agricultural Economics from Cornell University.

As a professor of the University of Nanking, he often organized his students to carry out rural household surveys in China. Initially, they surveyed 102 farmers in Wuhu Town in Anhui province in 1922-1923. A second survey was conducted in 1922-1925, and the results were published as *Chinese Farm Economy* in 1930. This survey covered 2,866 farm families in 17 localities from 7 provinces

(Buck [1930]).

Encouraged by the success of these surveys, he carried out a joint research project known as "Land Utilization and Population in China" in collaboration with the Institute of Pacific Relations from 1929 through 1933. This survey includes what is called "Buck's survey data". It covered many rural households and not only dealt with agricultural activities of farm households but also economic activities (consumption, savings, borrowing, etc.) and living standards in rural China. The outcome of this survey was published in 1937 in three volumes with the title *Land Utilization in China* (Buck [1937a, 1937b, 1937c]).

The entire structure of Buck's survey is shown in Table 1. The survey consisted of ten types of questionnaires and can be divided into four parts: (1) survey on agriculture (farm, agricultural, marketing, and management surveys), (2) locality (locality, Hsien, and price surveys), (3) living standards (food and living standard surveys), and (4) population (population survey). Since one of the main purposes of Buck's survey was to investigate the characteristics of the agricultural system and utilization of farmland of China for agricultural policy, a large scale questionnaire survey on rural farmers was conducted covering 16,786 farms in 168 counties, and 38,256 farm families in twenty-two provinces in China. Undergraduate and graduate students of the University of Nanking were sent back to their home towns to conduct the survey[1]. About 100 families from different income groups were surveyed in each location.

[1] Since collage students and graduates of the University of Nanking at that time belonged to richer households, enumerators of Buck's survey who returned to their hometowns were likely to select relatives and neighbors as sample households. Thus, upper sampling bias may have been involved in Buck's survey. In this study, land productivity of main crops in Buck's survey was compared with other existing agricultural survey data obtained by the Chinese and Japanese governments at that time. Although the average farmland of Buck's survey was larger than that in other surveys, survey values related to land productivity of main crops were quite similar (see Hoken [2010]).

(Insert Table 1 here)

Geographical distributions of surveyed counties (hsiens) are shown in Figure 1. The dots indicate counties where one or more kinds of surveys were conducted. Red dots indicate that spreadsheets were found at Nanjing Agricultural University. From the distribution of blue and red dots, it appears that surveyed counties were not dispersed uniformly but rather somewhat concentrated on specific areas. In Shandong, Hunan, and Jiangsu provinces, the numbers of counties where Buck's survey was conducted were fourteen, thirteen, and thirteen, respectively. Only one county was surveyed in each of Ningxia and Liaoning Provinces. In addition, no surveys were conducted in four Northeast provinces. This indicates that the surveyed counties were not selected randomly and appear closely related to the political situation of the Republic China.

(Insert Figure 1 here)

(2) Restorations of original micro data of Buck's Survey

Buck's survey original data was discovered at the end of the 1990's. The preserved spreadsheets are not complete, and some were scattered, lost, or preserved by other institutes. Existing spreadsheets of seem to have been stored in package which seemed to be wrapped long ago, and most were not bound together by *hsien* (*xian*, county). Spreadsheets were not the original household questionnaire but rather interim aggregation datasheets which recorded micro data of individual farms and descriptive statistics of farm data (totals, averages, maximum, minimum, etc). Thus, we can restore the micro data from these spreadsheets.

The titles of existing spreadsheets and the number of each volume for each title are presented in

Table 2. Titles of more than 20 volumes are shown in this table[2]. Most of existing titles do not amount to 100 volumes and are less than the number of surveyed counties. Titles contained in most volumes include: (1) "Chapter IV Table 8a & 12 Utilization of crops by amount for each use" (199 volumes) and (2) "Chapter VII Table 1 Proportion of all farm and subsidiary works performed by family and hired labor, by men, women, and children" (197 volumes). The number of counties and localities surveyed were 154 and 168 respectively (as shown in Table 1). Thus, existing volumes with these titles may contain duplication.

(Insert Table 2 here)

Using original farm micro data of the spreadsheets, a micro database of selected tables was constructed. Given constraints of time and budget in construction of the micro database, priority was placed on data relevant to implications for economic analysis and the quantity of existing original data. Thus, part of the micro database was constructed using "Table 3 Special expenditures (by size)" and "Table 13 14a 14b & Chapter IV Table 21 Yields per mow of all crop (in ton & catties) (grouped by size of farm)". The results of economic analysis using the former dataset are included in Kuribayashi [2007], and research reported in this paper utilizes the latter micro dataset to examine characteristics of productivity in agriculture.

The list of provinces and counties in the constructed micro database based on the title "Yields per mow of all crop" is shown in Table 3. To date, micro data on 24 counties of 10 provinces has been constructed from parts of the original spreadsheets. Other preserved spreadsheets of this title are under processing. Original data types of four counties were totally inconsistent with those of the

[2] The total number of titles at Nanjing Agricultural University is 98. Most contain farm level micro data, but some contain other types of data (maps, summary tables, etc.).

other 20 county datasets. Thus, the consistent 20 counties were used to construct the new micro database. Data on the cultivated area and the amount of product of every crop cultivated at each county were re-coded in this original table.

(Insert Table 3)

In constructing the database, the total list of cultivated crops was checked in detail, and coverage of each crop was confirmed. The number of crops cultivated in 20 counties totaled 377, including duplicate crops. Table 4 shows the number of cultivated crops by county. This table suggests that many kinds of crops were already being grown during the 1930's. More than 10 crops were cultivated in most counties. Looking specifically at county code 1101, it can be seen that 39 varieties of crops were cultivated, and this is larger than any other county. However, main crops such as wheat and rice were grown in many counties; and most non-grain crops were cultivated in limited localities and grown by few farmers. For simplification, crops which were grown by relatively large numbers of farmers were selected for construction of the micro database. The list of selected crops is also reported in Table 4. In total, crop data on 177 items of the 377 items (45.6 percent of total varieties) was chosen for construction of the micro database.

(Insert Table 4)

Rigorous checks on the name and arrangement of each crop for data compilation were conducted in order to assure a consistent crop yield database. As a result, the new micro database included 66 exclusive crops items. Using this database, patterns of crops cultivated at each county are described in Figure 2. The vertical axis represents the name of crops and the horizontal axis the county code.

Shaded cells indicate that relevant crops are cultivated at the county of concern. This figure shows that types of cultivated crops are strikingly diverse among counties, and special commercial crops were raised only in limited areas, despite the fact that food grains such as wheat, barley, and rice were being cultivated in almost all counties.

(Insert Figure 2 here)

In order to clarify the coverage of crops raised in surveyed counties, the numbers of counties cultivating relevant crops have been summarized in Table 5. Among 20 counties, wheat was grown in 16, barley in 15, and rice in 11. Other grains, (such as kaoliang and millet), beans, and commercial products (cotton and rape seeds) were grown in more than five counties. Forty-one crops were grown in just one county indicating that most minor crops were grown in limited localities.

(Insert Table 5)

The original questionnaire related to the table "yields per mow of all crop" consisted of five question areas: (1) "cultivated area of surveyed year", (2) "total output of surveyed year", (3) "most frequent land yield during recent ten years", (4) "normal land yield during recent ten years", and (5) "best land yield during recent ten years". Since the original dataset did not include data on the size of arable land possessed by each farmer, distributions of arable land among farmers could not be directly estimated. However, Buck [1937a: p. 274] indicated that the degree of double cropping did not differ so much among the stratums of land holdings. Thus it was appropriate to use total cultivated area as a proxy for farm land holdings of farmers.

Distribution of the Gini coefficient of total cultivated area[3] by county is shown in Figure 3. Gini coefficients were distributed symmetrically, and those of 13 counties were placed in the category from 0.3 to 0.4. Gini coefficients were over 0.4 for 5 counties. The highest coefficient for all counties was 0.504 in county code 1601. Only two counties had Gini coefficients below 0.3. In order to confirm preciseness of these estimated values, Hoken [2010] used average farmland data from the entire Buck's survey to estimate Gini coefficients of farmland among landholding strata. Estimated Gini coefficients were 0.358 for all of China, 0.381 for the wheat region, and 0.320 for the rice region. Estimated values of Gini coefficients from the original micro data are consistent with those of Buck's aggregated survey data. Thus, concentration of farmland by large farmers seems to have developed to some extent in the 1930's.

(Insert Figure 3 here)

III. Examination of the inverse relationship between land productivity and cultivated area

This section includes the following: (1) discussion of cropping patterns and farm management, (2) summary of the controversy regarding the relationship between farm size and crop yield in developing countries, (3) statistical analysis of a test of the classical hypothesis of whether or not there is an inverse relationship between land productivity and cultivated areas.

[3] The size of total cultivated area includes minor crops that were omitted from yield database construction.

(1) Characteristics of cropping patterns of surveyed counties

Conditions of agricultural production and the variation of crops were considerably different among counties. Thus, it is necessary to discuss the characteristics of cropping patterns on surveyed areas in detail. In order to examine the variations of crops and the cropping patterns, the average of total cultivated areas and the percentages of cultivated areas of each crop to total cultivated area were calculated. Crops cultivated at surveyed counties were classified into six categories: (1) grain, (2) legumes, (3) oil crops, (4) cotton, (5) root vegetables and (6) others. The results are shown in Table 6.

(Insert Table 6)

Averages of total cultivated land were strikingly different among counties. The largest of all counties was county code 1301 with an average of 73.0 *mu* per household. The smallest was 8.8 *mu* of county code 1603[4]. Caution must be exercised in comparing total cultivated lands, however, because accounting units of land areas are not necessary the same among counties. Adjustments on the units of measure of areas remain for further study due to the complexity of local units, although the numerical unit of cultivated areas was generally reported in *mu*.

Land shares of each group to total cultivated areas are also reported in Table 6. Grain accounts for more than 50 percent in every county expect for county code 1102. The proportions of other types of crops (such as legumes, oil crops, and cotton) occupied a relatively high proportion of all cultivated lands. While cultivation of grains had been dominant in rural China in the 1930's, the production of commercial crops had already developed at the time, and this is consistent with the studies of Cao [1996] and Rawski [1989].

[4] 1 *mu* is approximately 6.67are; 15 *mu* is approximately 1 hector.

To further understand diversification of crop production, the average number of crops cultivated by each household was calculated. A crop raised by a farmer was counted as "one" item regardless of the size of cultivated area[5]. Figure 4 shows that the average number of crop items cultivated by each farmer was more than three in most counties, and the numbers were concentrated on four to five items. In addition, diversification of cropping was quite advanced in some localities; specifically, more than six varieties of crops were raised in four counties.

(Insert Figure 4 here)

As described in Table 6, the percentage share of cultivated areas of staple crops such as grain to total cultivated areas was dominant. Thus, the county average of the percentage share of the top three crops to total cultivated areas by farmers could be estimated. A summary table is reported in Figure 5. The figure clearly shows that the share of the top three crops surpassed 60 percent in every county, and most percentage shares were over 70 percent. This implies that double or even triple cropping was widespread in rural China in the 1930's, and the diffusion of minor commercial crops was still limited at that time.

(Insert Figure 5 here)

Examination of cropping variation indicates the possibility that the more peasants possessed farm land, the more diverse their cropping. To confirm this prediction, coefficients of correlations between the number of crop items and the total cultivated lands by county were estimated. The

[5] When varieties of cultivated crops are calculated, "other crops" are viewed as one crop. Although this may lead to underestimation of crop variation, the share of farmers who cultivated other crops is not high. The method is thus acceptable.

distribution of the coefficient of correlations may be seen in Figure 6. Coefficients are significant at the 1 percent level of confidence and positive in all counties except for that with county code 1102 where the coefficient was not significant even at the 10 percent level of confidence. Although the numerical values of the coefficients were different among counties, they were uniformly dispersed from 0.3 to 0.7, and the level was relatively high in most counties. Thus it appears that diversification of cropping patterns and the size of land holdings were positively correlated.

(Insert Figure 6 here)

(2) Controversy on the relationship between farm size and crop yield

It has been widely argued that land productivity of agricultural products varies among landholding classes (Deolalikar [1981], Feder [1985]). This is directly related to the meaning of land redistribution and the efficiency of tenant farming. Berry and Cline [1979] have suggested that empirical studies on returns to scale of agriculture in developing countries are basically constant. On the other hand, most existing studies have shown an inverse relation between farm size and yield per cropped areas. This relationship appear to be due to the presence of a dual labor market where small farms face cheaper imputed labor costs, and this seems to induce a higher labor to land ratio on small farmers. Thus, small farmers achieve higher yields than large farmers (Feder [1985, pp. 297-298])[6]. It seems to be common view that some kinds of market failures give rise to an inverse relationship between land productivity and land holding area.

It is important to note that failure of labor market does not necessarily induce an inverse relationship, and there is a possibility that a positive relationship between land holding area and land

[6] Feder [1985] also theorized an inverse relationship in terms of the failure (underdevelopment) of the labor market due to supervision of labor and failure of financial markets.

productivity may be observed in rural areas according to the mixture of input market failure. For example, it is not easy for small farmers to obtain loans from the financial sector because their collateral is insufficient, and credit constraint is prevalent in rural areas. In contrast, large farmers can afford to invest money they have borrowed into agricultural capital to compensate for labor deficiency, and they may achieve higher productivity than the small farmers.

A debate regarding this inverse relationship would be valuable in revaluating the land redistribution policy conducted by Chinese Communist Party (hereafter, CCP) in the 1950's. If an inverse relationship was not observed in the 1930's, then the land redistribution policy might have led to a decrease in the total amount of agricultural products when conditions were such that other factors such as financial markets had not been developed to support the management of small farmers. In reality, Buck [1966] and Hoken [2010] have insisted that grain products during the end of the 1940's and the beginning of the 1950's were underestimated in order to exaggerate the achievements of CCP for agricultural development.

Examinations of the relationship in China for this period have been conducted primarily by Huang [1985] and Cao [1996]. Results of these studies are in conflict. Huang observed no clear relationship between land productivity and farm size in northern China, although small farmers were less profitable than middle and large farmers. On the other hand, Cao found a positive relationship in southern Jiangsu province. These differences may be due to differences in economic conditions of each region.

According to Cao [1996], industrialization and commercialization had been developed to some extent in southern Jiangsu areas, and opportunities for off-farm work were more abundant than in northern China. Cao also insisted that reasons for the positive relationship include: (1) the compact nature of farm land possessed by farmers under minimum level of existence, (2) deficiency of fertilizer and agricultural labor inputs, and (3) dispersion of the farm plots of small farmers. Thus, agricultural production of small farmers was less intensive than that of large farmers, and they enjoyed a lower yield than large farmers, although the total labor input of small farmers was more than that of large farmers. Both studies agree in their lack of support for the hypothesis of an inverse relationship of cropped area and yield.

Buck [1937a: pp. 278- 280] pointed out that a positive relationship between farm size and yield of agricultural products could not be observed from using aggregated survey data. In his estimation, Buck converted weights of all agricultural products into grain-equivalents, and the conversion rates of each crop were treated the same in all areas except for cotton, silk, and fuel. However, these estimation methods were arbitrary and gave rise to aggregation bias in the results. Thus, in the present study, new estimations were derived for determining the relationship between farm size and yield of each crop using the micro datasets.

(3) Empirical tests for inverse relationship

In order to test the relationship rigorously, many variables are required to estimate the production function. However, variables included in Buck's original questionnaire ("yields per mow of all crop") were limited. Thus, a simple method to verify the inverse relationship was developed which included the use of Box-Cox transformations on independent variables. A simple production function of each crop was defined as $y = \alpha + \beta g(x) + \varepsilon$, *y* represents the amount of product, and *g(x)* indicates cultivated areas. This function means that production of crop is determined just by cultivated area. If the marginal product of *y* decreases with cultivated area, crop production function would take the semi log-linear form $y = \alpha + \beta \log x + \varepsilon$. Conversely, if land productivity does not decrease with cultivated area, the function takes a simple linear form as $y = \alpha + \beta x + \varepsilon$

The two kinds of single hypotheses ($\lambda = 0$ and $\lambda = 1$) could be tested using a likelihood ratio (LR) test. In the case of the null hypothesis, $\lambda = 0$ is rejected and $\lambda = 1$ is not rejected, and the function of land productivity would take a linear form. On the other hand, if $\lambda = 1$ were to be rejected and $\lambda = 0$ not rejected, the function would take a semi log-linear form. In the case that both hypotheses were rejected, the functional form would be $y = \alpha + \beta \frac{x^{\lambda} - 1}{\lambda} + \varepsilon$. In this latter case, it would be difficult to identify the functional form of land productivity, but return of the functional form could still be determined to be increasing (if $\lambda > 1$) or decreasing (if $\lambda < 1$). The Box-Cox transformation and null hypotheses of the tests are summarized as follows:

$$g(x) = \begin{cases} \frac{x^{\lambda} - 1}{\lambda}, & if\ \lambda \neq 0 \\ \log x, & if\ \lambda = 0 \\ x & if\ \lambda = 1 \end{cases} \qquad (1)$$

Table 7 reports the proportions of cultivated area of grain crops to total cultivated areas of grain. The percentage shares of wheat and rice are strikingly high. That of rice accounts for more than 60 percent for 11 counties. The share of wheat occupies a relatively lower share than that of rice, though the frequency of counties where wheat was raised is slightly higher than that of rice. Since the percentage share of the cultivated areas of barley and kaoliang are lower than those of wheat and rice, barley and kaoliang seem to have been raised as a second or third grain crops in the surveyed areas. On the other hand, production of millet was concentrated in Gansu province (county codes 1401 and 1402), where millet appears to have been a staple food.

(Insert Table 7 here)

As shown in Table 6, except for grains, the percentage share of legumes, oil crops, and cotton were quite high. These crops were not only an important source of proteins but were also a major commercial product for farmers to obtain cash. The three main grains (wheat, rice, and barley) and the two non-grain crops (rapeseed and cotton) were used to test the relationship between cultivated area and yield.

Relations between cultivated land and output for each farmer by crop and county are shown in Figure 7. The horizontal axis refers to cultivated area, and the vertical axis indicates amount of output. All values for crop production and cultivated area were standardized by county for purposes of comparison. Clear positive correlations between the amount of production and cultivated areas may be observed in wheat and rice. Positive but not necessarily obvious correlations may be found for other crops. Shapes of the production function vary among crops and counties, and the disparity among counties is rather obvious in non-staple crops such as rapeseed and seed cotton. This is partially due to the small number of sample households that raised those crops.

(Insert Figure 7 here)

Results of estimations of the Box-Cox transformation test are summarized in Table 8, and details of these estimated results are also reported in the Appendix. Since the null hypothesis $\lambda = 0$ was rejected in almost all cases, attention was given to the linearity test of $\lambda = 1$. This table shows that the null hypothesis $\lambda = 1$ could not be rejected in wheat and barley; this case accounts for 12 out of 15 counties in wheat and 7 out of 11 counties in barley. The hypothesis was rejected in about half of the counties concerning rapeseed and seed cotton.

(Insert Table 8 here)

As seen in the Appendix, the value of a significant λ tends to be less than 1 for wheat in 9 out of

15 counties and for barley in 9 out of 10 counties. This result suggests that land productivity of those grains takes a linear form but appears to slightly decrease with the area of cultivated land. Still, λ of rapeseed and cotton seed are likely to be more than 1 as seen in 5 out of 7 counties for rapeseed and 5 out of 6 counties for seed cotton. This implies that the land productively of rapeseed and seed cotton increases with cultivated area. Results for rice show a different trend. The hypothesis is rejected in 4 counties out of 11, but the value of λ is more than 1 for 7 counties and less than 1 for 4 counties. Therefore, the function of rice tends to have a somewhat increasing form.

From these estimations, it appears that that the relationship between land productivity and cultivated areas of wheat and barley is linear and negative, while that of rice, rapeseed, and seed cotton appears to be positive. Estimation results for wheat and barley are consistent with former studies of developing counties. However, the existence of positive relationships for rice, rapeseed, and cotton seed are not consistent with those studies but rather consistent with former studies on rural China.

Conflicting results seem to be related to the difference of labor intensity and the level of commercialization of each crop. The amount of labor necessary for the production of rapeseed and cotton seed per farm land was more than that of wheat and barley, and rice more than twice that of wheat and barley[7]. In addition, the levels of commercialization for grain crops were considerably different from others. Percentage shares of commercialized products of rapeseed and seed cotton were 61 and 37 percent; those of wheat and barley 29 and 18 percent. The share for rice was only 15 percent, although the percentage of non-commercialized rice used as payment for land tenure was 22 percent, the highest of all crops (Buck [1937a, pp. 233-239]). Accounting for this share, the level of

[7] Buck [1937a, pp. 301-303] showed that the average number of labor days required for rapeseed was 48 days and for cotton 53 days; that of wheat was 26 days, barley 28, and 40 days for millet. The number of labor days required for non-grain crops was more than that of grains. However, the average number of days for rice production was 82 days, much more than that of commercial crops.

commercialization of rice was actually more than 30 percent.

IV. Conclusion

This article reported data restoration methods of Buck's original survey preserved at Nanjing Agricultural University and included examination of the characteristics of crop yield data. Existing micro data of the table "yields of crops per farm mow of all crop" was composed of 24 counties in 10 provinces. Due to inconsistency of data forms, 20 counties with 2,102 farm households were selected. Though many crops were cultivated in these counties, most crops were raised by only a few farmers. Thus, data for main crops was selected for inclusion in the constructed micro database.

In order to test the hypothesis of whether or not an inverse relationship exists between land productivity and cultivated area, the distribution of farmland and cropping patterns was examined relative to total cultivated area as a proxy for farmland possessed by farmers. Estimations of Gini coefficients show that the distribution of farmland was relatively unequal among farmers in every surveyed county. Cropping patterns varied greatly among localities due to differences of climate and geographical features. Analysis further shows that diversification of cropping patterns was already developed in the 1930's, and positive correlations were observed between diversifications of cropping patterns and the size of land holdings.

Second, a Box-Cox transformation was used to investigate the relationship between farm land and land productivity of five crops. Results of the estimations were not the same among crops. The hypothesis of a linear relationship could not be rejected for wheat and barley, but functional forms for those crops showed decreasing trends. In contrast, the hypotheses concerning rice, rapeseed, and seed cotton could be rejected, and the yield for those crops showed an increasing trend in some counties. Differences in results appear to be related to labor intensity and the level of commercialization of each crop.

From these results, a tentative conclusion can be made that the relationship between cultivated area and land productivity were not the same among crops. The characteristics of each crop and the diversity of production patterns among land holding strata must be taken into consideration in evaluating this relationship.

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Table 1 Structure of Buck's Survey

	Number of Questionnaires Collected	Number of Hsien (Counties) Surveyed	Number of Localities Surveyed
Farm Surveys	16,786	154	168
Agricultural Surveys	272	180	272
Locality Surveys	165	165	160
Hsien (County) Surveys	179	174	
Price Surveys	1,041	106	108
Marketing Surveys	121	121	121
Farm Practice Surveys	1,874	128	125
Food Surveys	2,728	131	136
Standard of Living Surveys	429	143	150
Population Surveys	53,283	186	191

Note: The total number of counties in which the survey was conducted was 308. Population surveys included vital statistics.

Source: Buck [1937a: p. x].

Table 2 Number of Volumes Existing in Buck's Original Survey Spreadsheets

Number of Volumes	Titles of Existing Spreadsheets
199	Chapter IV Table 8a & 12 Utilization of crops by amount for each use
197	Table 16 Relation of size of farm to crop hectare per mew equivalent
187	Chapter VII Table 1 Proportion of all farm and subsidiary works performed by family and hired labor, by men, women and children
151	Table 3 Special expenditures (by size)
128	Man labor
108	Chapter IV Table 3b & 3c Number of mow of crop area devoted to various crop
108	Table 2 Savings
107	Table 7, 8a, 8c and 9 Proportion of farm area rented
106	Chapter IV Table 8b Utilization of crops by amount for each use
106	Chapter IV Table 8c Utilization of minor crops by amount for each use
106	Work table summary for table 3 b, c, d, g, 4, 5, 6, and 7 Crop and soil areas, and irrigation
105	Table 1 Credit and indebtedness
104	Table 1a, 1b, 2, 3a, 3b Farm area devoted by different uses grouped by size of farm
102	Chapter V Table 5 Amount of fertility produced on the farm
102	Table 14 Most frequent yield per mow of the by product of important crops (in quintals groups by
102	Table 5 and 6 Number, distance and size (crop area in local units) of plots and fields
102	Work table summary for Table 21 Chapter VI Crop index by size of farm
101	Chapter VII Table 4 Able-bodied men (over 15 and under 60 years of age)
100	Table 5 Size of family (farm grouped by size of farm)
99	Table 4 Number and area of graves in farms
96	Table 7a Changes in the use of fertilizers
94	Chapter IV Work table summary for table 14 (b) Crops index for average normal and best yield taking the most frequent yield as 100
93	Table 13 14a 14b & Chapter IV Table 21 Yields per mow of all crop (in ton & catties) (grouped
84	Table 1, 2, 3, 4 and Chapter VI Table 6 Amount and distribution of live stock
68	Table 1 Crop mow area per farm (Farm group by size of farm)
67	Frequency distribution of farms by number plots and fields
65	Table 19 Relation of size of farm to crop mow per labor animal unit
65	Table 6 Amount and kind of fertilizers per mow
59	Table 15 and 16 Most frequent yield of important crops by soil types and irrigations
47	Table 9, 10 ,22 and 23 Production per capita and per mow equivalent
37	Table 19 Relation of size of farm to crop hectare per labor animal unit
37	Table 6b and 6c Frequency distribution of farms by number of plots and fields
37	Table 7b Changes in the use of fertilizers
37	Work table summary, Table 3e percentage of crop area illigated by size of farm
35	Animal labor
34	Chapter IV Table 8b Utilization of crops by percentage for each use (by products)
34	Chapter V Table 6 Amount of fertility produced on the farm by size of farm
34	Table 1,2,3,4 and Chapter VI Table 6 Amount and distribution of livestock
28	Table 7b Changes in kinds of fertilizers used
25	Chapter VI Credit and indebted
22	Chapter XI Table 1 Credit and indebtedness
22	Work table summary for Table 3b, c, d, g, 4, 5, 6 and 7 Crop and soil and irregation

Note: The titles of existing spreadsheets preserved in more than 22 volumes are shown in the table.

Source: Based on the survey conducted by the author at Nanjing Agricultural University in May 2008.

Table 3 Coding for Preserved Data and Situation of Database Construction

Province	County	County Code	Database	Sample Size of
Anhwei (Anhui)	Fengyang	1001	✓	100
	Fuyang	1002	✓	99
	Ho	1003	✓	145
	Wuhu	1004	✓	100
Chekiang (Zhejiang)	Tangki	1101	✓	100
	Yuyao	1102	✓	118
Honan (Henan)	Nanyung	1201	X	
	Sinyang	1202	✓	100
Hopeh (Henan)	Kishui	1301	✓	100
	Yincheng	1302	✓	100
	Yunmeng	1303	X	
Kansu (Gansu)	Ninghua	1401	✓	100
	Wuwei	1402	✓	100
Kiangsi (Guangxi)	Nanchang	1501	✓	101
	Pengtse	1502	✓	101
	Tuchang	1503	✓	101
Kiangsu (Zhejiang)	Kwanyun	1601	✓	99
	Kunshan	1602	✓	83
	Wusih	1603	✓	112
	Yencheng	1604	✓	143
Kwangtun (Guangdong)	Chungshan	1701	X	
Shansi (Shanxi)	Ningwu	1801	✓	100
Szechwan (Sichuan)	Neikiang	1901	✓	100
	Ta	1902	X	

Notes: "✓" indicates that arrangements of the original data and construction of the database have been finished. "X" means that arrangements of original data have been finished, but construction of the database is not complete due to data format problems.

Name of provinces and counties in Buck's survey were recorded in the Wade-Giles system of Romanization of the Chinese language.

Table 4 Number of Crop Items Cultivated by County Code

County Code	Number of Original Crop Items	Number of Selected Crop Items	%
1001	16	11	68.8%
1002	19	12	63.2%
1003	24	8	33.3%
1004	11	5	45.5%
1101	23	15	65.2%
1102	39	11	28.2%
1202	20	11	55.0%
1301	20	8	40.0%
1302	14	6	42.9%
1401	22	11	50.0%
1402	17	9	52.9%
1501	6	1	16.7%
1502	23	7	30.4%
1503	26	15	57.7%
1601	19	8	42.1%
1602	18	7	38.9%
1603	6	3	50.0%
1604	5	4	80.0%
1801	21	8	38.1%
1901	28	12	42.9%
total	377	172	45.6%

Source: Author’s calculation.

Table 5 Number of Counties Cultivating Relevant Crops

Item	Number of Counties	Item	Number of Counties
wheat	16	greed leans	1
barley	15	sesame	1
rice	11	buck wheat	1
cotton seeds	8	white laybean	1
rape seeds	8	thymus	1
kaoliang	6	laybeans	1
millet	6	wild laybeans	1
broad bean	6	lesame	1
green beans	6	seed bottom	1
soybeans	6	multery	1
field peas	6	suger cane	1
sweet potatoes	4	barlic	1
peanut	4	vegetable spangc	1
early glutinous rice	3	eggplant	1
sesame	3	mulberry	1
winter radish	3	autragalus minenees	1
black soybean	3	red beans	1
barley,hulless	2	waten melon	1
spring wheat	2	tentil	1
late rice	2	stoames	1
prade milllet	2	brassica pekinensis	1
cotton	2	millet+black lean	1
cotton lint	2	potatoes dush	1
opium	2	resome	1
barley field peas	2	jan	1
corn	1	carrots	1
buck wheat	1	mulleny leave	1
glutinous rice	1	oats	1
early rice	1	field beans	1
late glutinous rice	1	klyacinth beans	1
hemp	1	lish notates	1
bauica	1	pearcuts	1
jelacca	1	pape seeds	1

Source: Author's calculation.

Table 6 Percentage Share of Cultivated Areas of Each Crop to Total Cultivated Areas

County Code	Total Cultivated Areas	Grain	Legumes	Oil Crops	Cotton	Root Vegetables	Others
1001	41.1	60%	15%	3%	0%	0%	22%
1002	37.2	61%	28%	0%	2%	7%	2%
1003	22.3	75%	3%	0%	19%	2%	0%
1004	29.3	70%	0%	30%	0%	0%	0%
1101	17.6	56%	0%	3%	0%	0%	41%
1102	29.4	1%	34%	3%	46%	0%	15%
1202	40.7	90%	5%	0%	2%	0%	2%
1301	73.0	85%	0%	4%	10%	0%	0%
1302	44.3	94%	0%	4%	3%	0%	0%
1401	19.2	80%	6%	0%	0%	0%	14%
1402	19.3	75%	3%	0%	0%	0%	22%
1501	20.3	100%	0%	0%	0%	0%	0%
1502	12.0	51%	4%	22%	23%	0%	0%
1503	18.2	60%	13%	22%	1%	3%	2%
1601	66.2	66%	32%	0%	0%	1%	0%
1602	37.0	82%	7%	4%	8%	0%	0%
1603	8.8	85%	0%	0%	0%	0%	15%
1604	25.3	100%	0%	0%	0%	0%	0%
1801	33.7	63%	7%	4%	0%	0%	25%
1901	32.4	54%	18%	0%	2%	21%	5%

Source: Author's calculation.

Table 7 Percentage Share of Cultivated Areas of Grain Crops

County Code	Wheat	Rice	Barley	Kaoliang	Millet	Other Grains
1001	67%	0%	8%	25%	0%	0%
1002	65%	0%	1%	32%	1%	1%
1003	21%	73%	6%	0%	0%	0%
1004	6%	92%	2%	0%	0%	0%
1101	15%	28%	33%	0%	20%	4%
1102	0%	0%	96%	0%	4%	0%
1202	36%	56%	8%	1%	0%	0%
1301	12%	88%	0%	0%	0%	0%
1302	5%	62%	32%	0%	0%	0%
1401	49%	0%	0%	3%	48%	0%
1402	50%	0%	12%	0%	38%	0%
1501	0%	100%	0%	0%	0%	0%
1502	14%	61%	25%	0%	0%	0%
1503	7%	60%	18%	0%	15%	0%
1601	53%	0%	14%	13%	0%	20%
1602	30%	61%	9%	0%	0%	0%
1603	39%	61%	0%	0%	0%	0%
1604	5%	84%	11%	0%	0%	0%
1801	5%	0%	0%	0%	0%	95%
1901	13%	67%	11%	9%	0%	0%

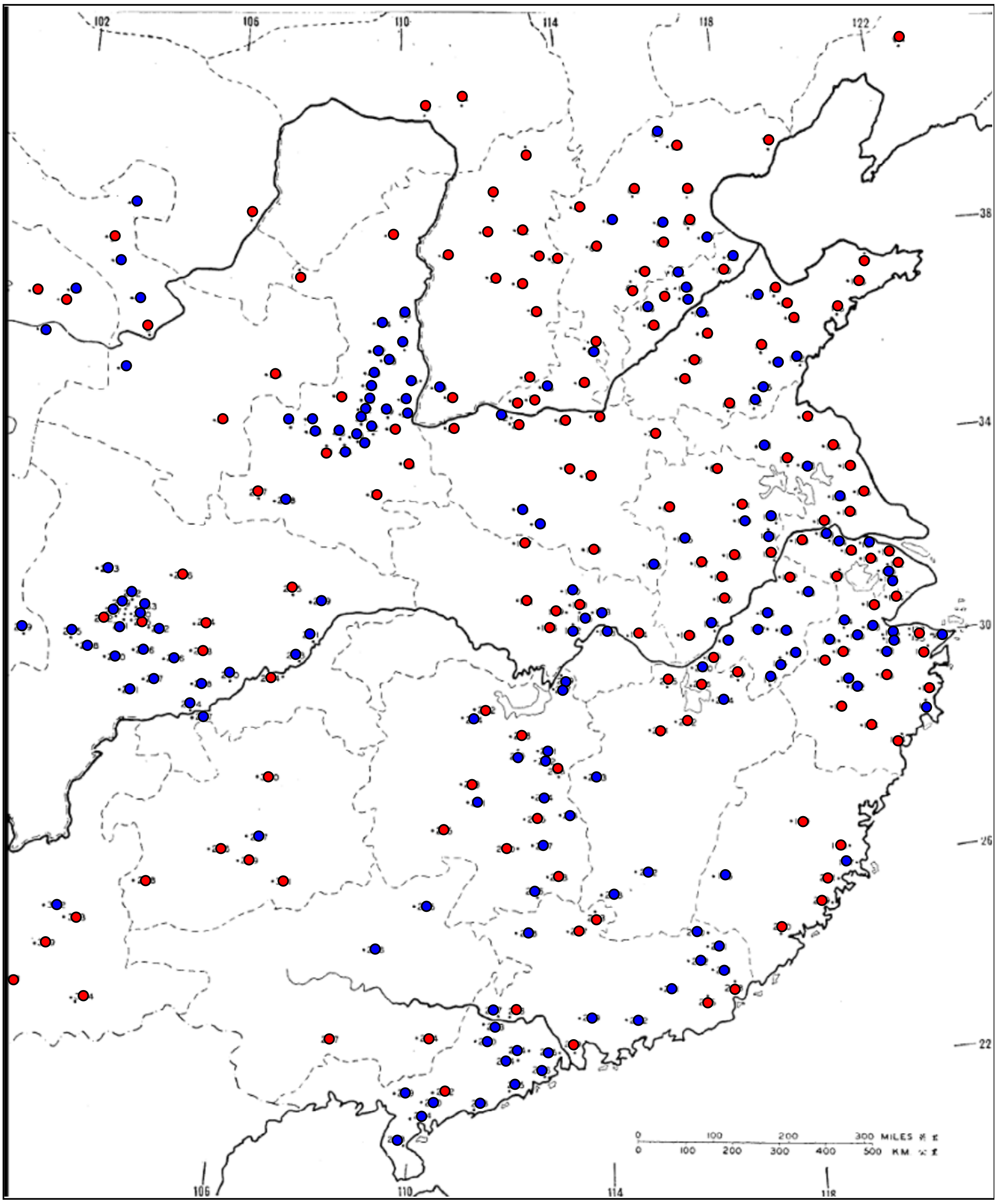
Source: Author's calculation.

Table 8 Summary of Box-Cox Transformation Test

	Total	λ=1 reject	λ=1 not reject
wheat	15	3	12
rice	11	4	7
barley	10	2	8
rapeseed	7	3	4
seed cotton	6	3	3

Note: Null hypotheses tested at the 10% level of confidence.

Figure 1 Distribution of Counties in which Buck's Survey was Conducted



Note: Dots indicated *Hsien* (*Xian*, County) where one or more types of questionnaire surveys were conducted. Red dots indicate *Hsiens* for which spreadsheets were discovered.

Source: Kuribayashi [2007: p. 44] (Base map form Buck [1937c], Chapter 1. Map 3, p.3).

Figure 2 Distribution of Crops Cultivated in Each County

	1001	1002	1003	1004	1101	1102	1202	1301	1302	1401	1402	1501	1502	1503	1601	1602	1603	1604	1801	1901
wheat	■	■	■	■	■		■	■	■	■			■	■	■	■	■	■		■
barley	■	■	■	■	■	■	■		■		■		■	■	■	■		■		■
rice			■	■			■		■			■	■	■		■	■	■		■
cotton seeds		■	■			■		■	■				■	■		■				
rape seeds				■	■	■		■	■				■	■		■				
kaoliang	■	■					■			■					■					■
green beans	■	■					■						■	■						■
soybeans	■	■	■				■							■	■					
millet		■			■	■				■	■			■						
field peas		■					■			■	■			■						■
broad bean						■							■	■		■			■	■
sweet potatoes		■	■												■					■
peanut			■		■	■	■													
early glutinous rice								■	■									■		
sesame	■													■					■	
winter radish		■			■									■						
black soybean										■				■					■	
barly,hulless														■		■				
spring wheat											■								■	
late rice					■			■												
prade milllet										■	■									
cotton							■													■
cotton lint			■					■												
opium										■	■									
barley field peas											■				■					
buck wheat					■															
glutinous rice				■																
early rice								■												
corn															■					
late glutinous rice								■												
hemp	■																			
bauica	■																			
jelacca	■																			
greed leans	■																			
sesame	■																			
buck wheat		■																		
white laybean					■															
thymus		■																		
laybeans					■															
wild laybeans					■															
lesame					■															
seed bottom					■															
multery					■															
suger cane					■															
barlic						■														
vegetable spangc						■														
eggplant						■														
mulberry						■														
autragalus minenees						■														
red beans							■													
waten melon							■													
tentil										■										
stoames										■										
brassica pekinensis										■										
millet+black lean										■										
potatoes dush											■									
resome											■									
jan														■						
carrots															■					
mulleny leave																	■			
oats																			■	
field beans																			■	
klyacinth beans																			■	
lish notates																			■	
pearcuts																				■
pape seeds																				■

Note: Shaded cells indicate that crops were cultivated in respective counties.

Figure 3 Distribution of Gini Coefficients on Total Cultivated Area

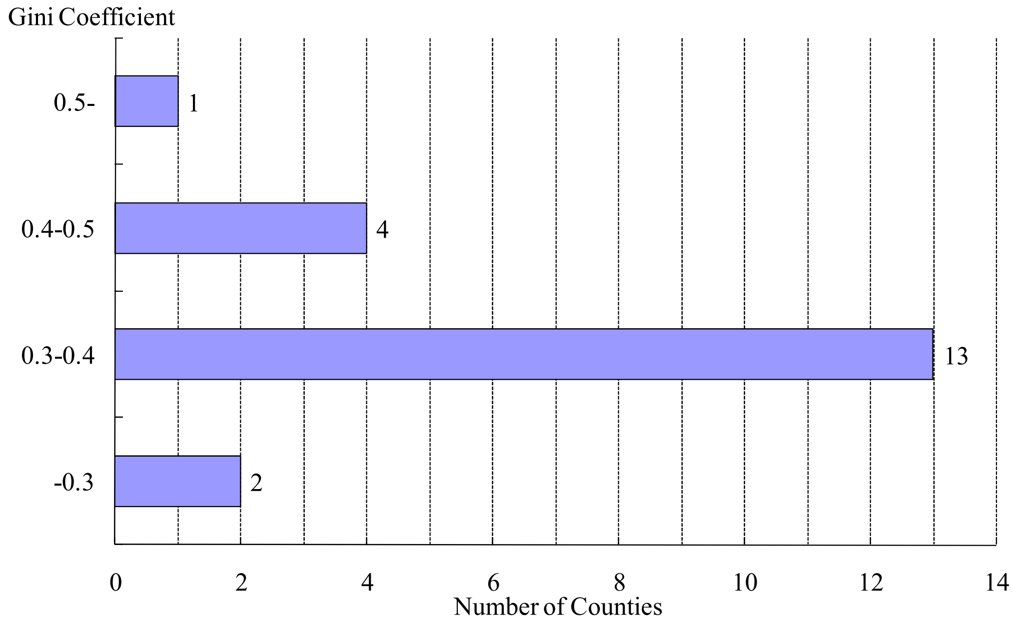


Figure 4 Average of Crop Items Cultivated by Farmers

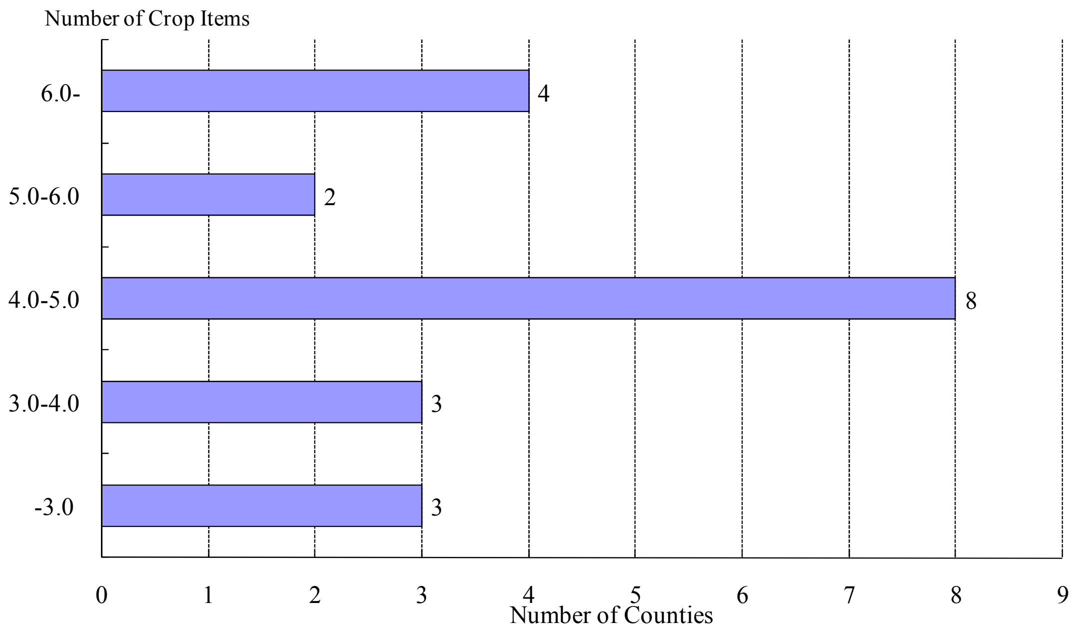


Figure 5 Distribution of Percentage Shares of Cultivated Areas of Top Three Crops to Total Cultivated Areas

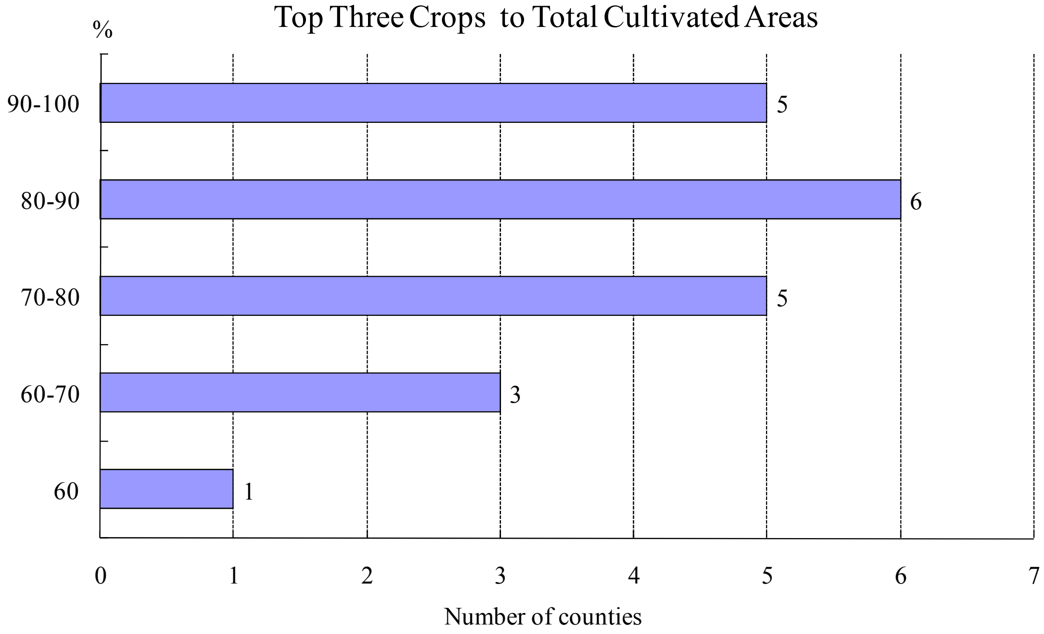


Figure 6 Distribution of Coefficients of Correlations between Cultivated Land and Number of Crops Cultivated

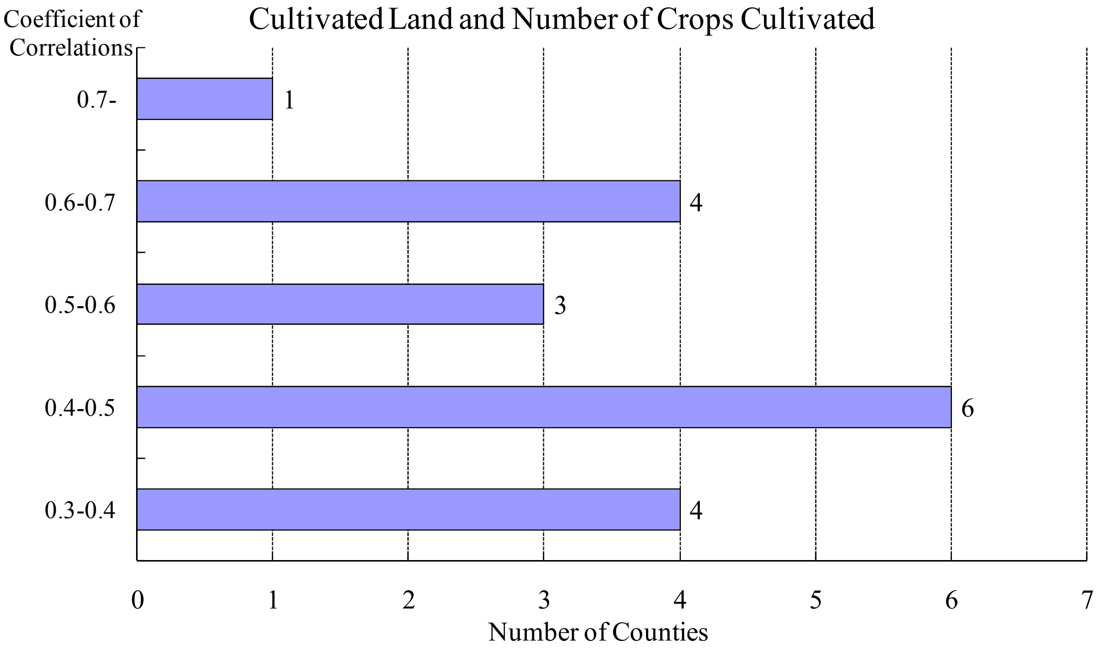
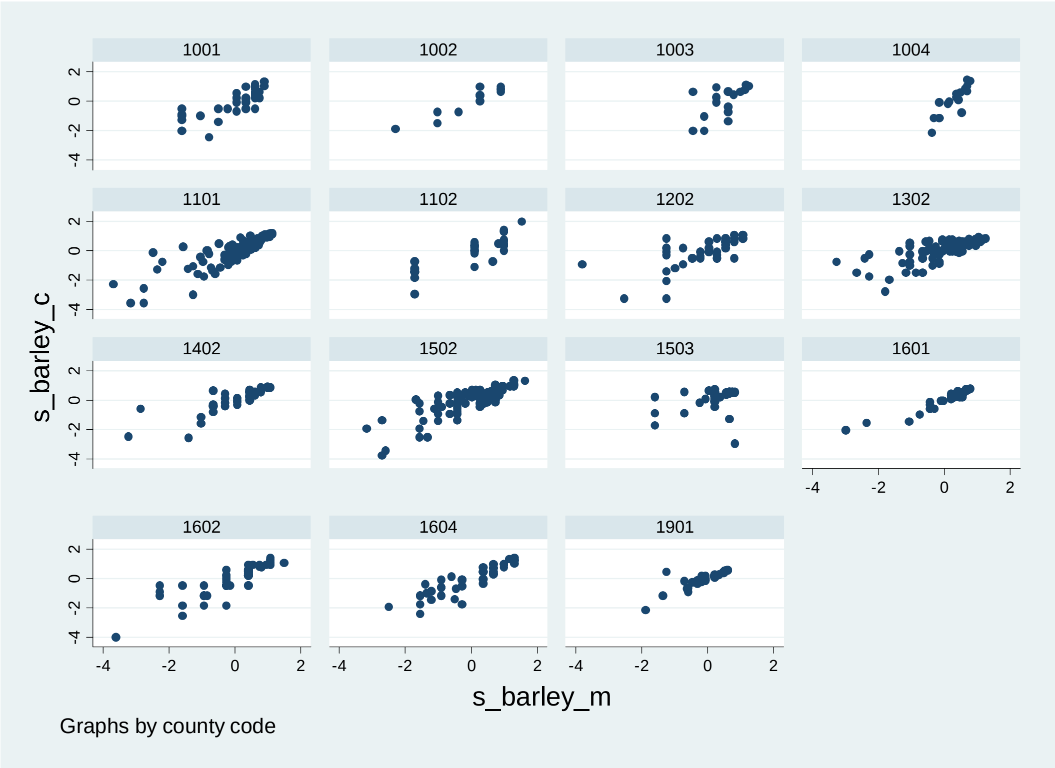


Figure 7 Plot of Crop Production and Cultivated Area (Normalized)

(1) Wheat

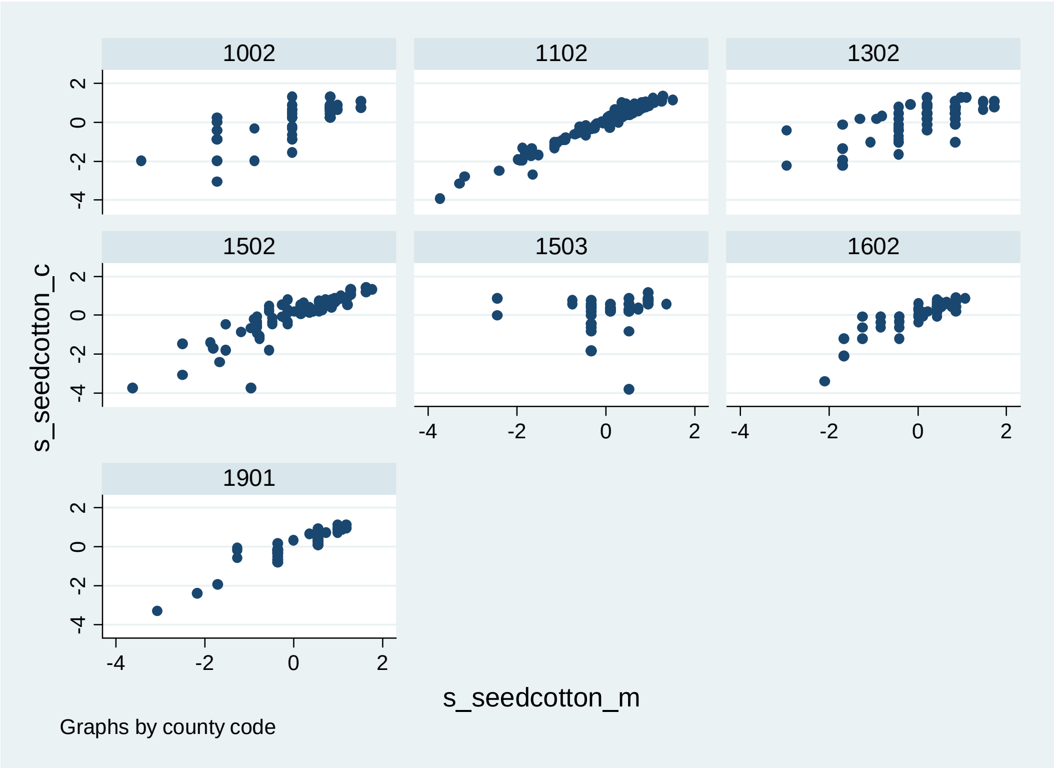
(2) Rice

(3) Barley



(4) Rapeseed

(5) Seed cotton



Appendix Results of Box-Cox Transformation Test (Detail)

(1) Wheat

county	λ	z		null hypothesis	LR	
1001	0.843	10.090	***	λ=0	77.28	***
				λ=1	3.32	*
1002	0.675	6.910	***	λ=0	38.55	***
				λ=1	10.09	***
1003	0.897	9.130	***	λ=0	66.46	***
				λ=1	1.06	
1004	0.840	8.150	***	λ=0	49.86	***
				λ=1	2.28	
1101	0.979	7.400	***	λ=0	43.18	***
				λ=1	0.02	
1202	1.008	6.050	***	λ=0	35.57	***
				λ=1	0.00	
1301	1.409	4.180	***	λ=0	17.30	***
				λ=1	1.55	
1302	0.841	3.700	***	λ=0	18.47	***
				λ=1	0.44	
1401	0.978	10.420	***	λ=0	74.24	***
				λ=1	0.06	
1502	1.180	4.470	***	λ=0	25.80	***
				λ=1	0.49	
1503	0.964	1.420		λ=0	2.07	
				λ=1	0.00	
1601	0.887	19.510	***	λ=0	148.17	***
				λ=1	5.84	**
1602	0.996	8.130	***	λ=0	54.19	***
				λ=1	0.00	
1603	1.026	6.570	***	λ=0	37.86	***
				λ=1	0.03	
1604	1.367	5.680	***	λ=0	21.27	***
				λ=1	2.30	
1901	1.127	9.720	***	λ=0	71.27	***
				λ=1	1.24	

(2) Rice

county	λ	z	null hypothesis	LR
1003	0.876	10.900 ***	λ=0	103.03 ***
			λ=1	2.26
1004	1.111	29.740 ***	λ=0	243.27 ***
			λ=1	8.65 **
1202	0.900	4.420 ***	λ=0	20.54 ***
			λ=1	0.23
1302	1.422	13.150 ***	λ=0	142.51 ***
			λ=1	16.97 ***
1501	1.122	8.910 ***	λ=0	76.42 ***
			λ=1	0.97
1502	0.877	6.560 ***	λ=0	38.21 ***
			λ=1	0.82
1503	0.827	7.960 ***	λ=0	50.56 ***
			λ=1	2.65
1602	1.187	8.700 ***	λ=0	70.39 ***
			λ=1	2.01
1603	1.130	2.890 **	λ=0	10.29 ***
			λ=1	0.11
1604	1.093	26.040 ***	λ=0	283.43 ***
			λ=1	4.96 **
1901	1.106	41.880 ***	λ=0	273.61 ***
			λ=1	15.33 ***

(3) Barley

county	λ	z	null hypothesis	LR
1001	0.389	1.390	λ=0	2.01
			λ=1	3.88 **
1002	0.899	2.540 **	λ=0	5.17 **
			λ=1	0.08
1003	0.726	0.910	λ=0	0.99
			λ=1	0.10
1004	1.024	1.430	λ=0	3.08 **
			λ=1	0.00
1101	0.688	5.100 ***	λ=0	25.79 ***
			λ=1	4.60 **
1102	0.796	2.300 **	λ=0	6.64 *
			λ=1	0.32
1202	0.452	1.400	λ=0	1.90
			λ=1	2.65
1302	0.782	3.780 ***	λ=0	15.25 ***
			λ=1	1.03
1402	0.749	4.390 ***	λ=0	17.79 ***
			λ=1	1.98
1502	1.074	4.750 ***	λ=0	25.49 ***
			λ=1	0.11
1503	2.539	1.510	λ=0	4.53 **
			λ=1	1.58
1601	0.715	9.650 ***	λ=0	49.79 ***
			λ=1	11.79 ***
1602	0.725	3.750 ***	λ=0	14.70 ***
			λ=1	1.84
1604	0.601	1.920 *	λ=0	3.68 *
			λ=1	1.55
1901	0.990	5.600 ***	λ=0	26.98 ***
			λ=1	0.00

(4) Rapeseed

county	λ	z		null hypothesis	LR	
1004	1.085	23.200	***	λ=0	197.49	***
				λ=1	3.31	*
1101	0.380	1.990	**	λ=0	3.69	**
				λ=1	9.55	**
1102	1.670	5.040	***	λ=0	25.26	***
				λ=1	4.49	**
1301	1.195	2.400	**	λ=0	7.34	*
				λ=1	0.16	
1302	1.751	3.320	***	λ=0	15.99	***
				λ=1	2.64	
1502	0.229	1.490		λ=0	2.27	
				λ=1	18.77	***
1503	2.154	2.100	**	λ=0	6.41	**
				λ=1	1.68	
1602	0.806	2.850	**	λ=0	8.80	**
				λ=1	0.44	

(5) Seed cotton

county	λ	z		null hypothesis	LR	
1002	0.889	2.790	**	λ=0	10.69	***
				λ=1	0.12	
1102	1.106	14.090	***	λ=0	119.30	***
				λ=1	1.82	
1302	1.121	3.190	***	λ=0	10.74	***
				λ=1	0.12	
1502	1.316	7.400	***	λ=0	54.16	***
				λ=1	3.31	*
1503	-0.763	-0.900		λ=0	0.77	
				λ=1	2.99	*
1602	2.096	6.650	***	λ=0	54.89	***
				λ=1	15.50	***
1901	1.333	7.650	***	λ=0	46.89	***
				λ=1	3.95	**

Note: *** Significant at 1% level, ** significant at 5% level, and * significant at 10% level.