Characteristics of Agricultural Production Structures Determined by Capital Inputs and Productivities in Contemporary China: Based on 2010 Annual Statistical Data at the Provincial Level

Yoshio Kawamura
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Working Paper Series
Studies on Multicultural Societies No.6

2012
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1. Subject of Study

Economic globalization can have advantageous or adverse effects depending on the fluidity of an industry’s input and output. In agriculture, in which land is the main medium of economic activity, land (input) has no fluidity as a resource and can be procured only at fixed locations. Meanwhile, agricultural products (output) are tradable goods with high fluidity meeting global needs, which transcend borders. In other words, agriculture is an industry whose products are affected by globalization, even though the procurement of its resources is not amenable to globalization. This makes agriculture the least adaptable industry to globalization.

Agriculture’s industrial characteristics derive from its essence, that is, production activities comprising combined factors. Namely, its production activities are restricted by the natural conditions of each region, while natural conditions (meteorological and geographical, as well as water conditions, etc.) and the quality and quantity of natural resources (land, water sources, flora, etc.) are quite unique to each region. In addition, such regional characteristics are further amplified by the region’s producers, that is, the localities and the societies around them. Thus, even if you consider only the production input system, it becomes evident that the quality of, and the means of inputting, land, labor and capital, differ from region to region.

This means it is necessary to clarify the methods of evaluating regional agriculture and establishing its development framework based on the nature of regional characteristics determined by both natural and social environments. Specifically, in the case of China, due to its very large territory and the large amount of natural and social diversity it contains, the need to clarify such methods is great. This paper presents China’s agricultural structure based on regional characteristics determined by both natural and social environments, according to 2010 annual statistical data at the provincial level, not including Beijing, Shanghai, Tianjin.

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and Chongqing.

2. **Theoretical Framework of Agricultural Development**

It is evident that agriculture, in essence, is an industry characterized by strong regional “uniqueness,” which is influenced by the natural and social environments of the region. Its industrial characteristics derive from its essence, that is, production activities comprising combined factors. Namely, the production activities are restricted by the natural conditions of each region (meteorological and geographical, as well as water conditions, etc.), which, along with the quality and quantity of natural resources (land, water sources, flora, etc.) are quite unique to each region. In addition, such regional characteristics are further amplified by its producers, that is, the localities and the societies around them. Thus, even if you look at only the production input system, it becomes evident that the quality of, and the means of inputting, land, labor and capital, differ from region to region. Jiro Iinuma’s *Nogyo Kakumei Ron* (Agricultural Revolution), a previous research work, aims at categorizing agriculture from this viewpoint.

Figure 1 shows a simplified model of the forming process of regional uniqueness according to different combinations of production elements. Here, different natural and social environmental conditions that demonstrate complicated abmodalities are theoretically dichotomized and simplified into two extreme categories. “Temperate humid regions” and “temperate dry regions” are the categories dichotomized based on natural environments, while “densely populated communities” and “thinly populated communities” are the categories dichotomized based on social environments.

Agriculture in “temperate humid regions” categorized by their natural environments is a regional form of agriculture conducted in natural environments where the harvest per unit land area will decrease if the land is left untouched during the period between seeding and harvesting without receiving labor input such as weeding, since weeds grow rapidly in such hot-humid environments. In these regions, since the increase of labor input per unit land area and the thoroughness of crop growth management directly affects the harvest volume, agriculture necessarily becomes labor-intensive and agricultural growth depends on the improvement of land productivity. Therefore, capital intensification is directed toward the improvement of land productivity, and agriculture in such regions tends to develop into capital-intensive agriculture based on fluid capital such as new species and fertilizers. If labor power is limited, the agriculture will be restricted to relatively small-scale land management.
On the other hand, the agriculture in “temperate dry regions” is a form of agriculture in a natural environment with a dry climate, with relatively fewer weeds, and no clear correlation between labor input during the period between seeding and harvesting and the harvest per land area. In these regions, since a greater area needs to be cultivated by limited labor power within the short period between seeding and harvesting, the agriculture necessarily becomes labor-saving, and agricultural growth depends on the improvement of labor productivity. Therefore, capital intensification is directed toward the improvement of labor productivity, and the agriculture there tends to develop into labor-saving agriculture based on fixed capital such as machinery. Thus, increase in the land management scale necessarily becomes the mechanism of agricultural growth.

“Densely populated communities” in terms of the social environment refer to communities with a very high population density. This high population density causes an excessive labor supply, resulting in low wage levels. Thus, labor-intensive economic growth is a more rational approach in these communities. In terms of agriculture, since increase in the harvest can be achieved by increasing the labor input per unit land area, the agriculture in such communities tends to be labor-saving, and agricultural growth depends on the improvement
of land productivity. Under the conditions of limited land availability and a great population, agriculture is restricted to relatively small-scale land management.

On the other hand, “thinly populated communities” refer to communities with a very low population density. This low population density causes a shortage of labor supply, resulting in high wage levels. Thus, labor-saving economic growth is a more rational approach in these communities. In terms of agriculture, since more land needs to be cultivated given the limited labor force, the agriculture in such communities necessarily becomes labor-saving, and agricultural growth depends on the improvement of labor productivity. Thus, increase in the land management scale necessarily becomes the mechanism of agricultural growth.

In these agricultural categories, the unique form of regional agriculture determined by natural and social environments of “humid region” and “densely-populated community” stands in stark contrast to the unique form of regional agriculture determined by natural and social environments of “dry region” and “thinly-populated community,” with regard to their growth mechanisms. The former regions tend to be directed towards labor-intensive agriculture, whose growth merkmal (feature) is the improvement of land productivity, whereas the latter regions tend to be directed toward labor-saving agriculture, whose growth merkmal is the improvement of labor productivity. Therefore, in terms of capital intensification, the intensification of fluid capital including the technological renovation of labor subjects generates progress in the former regions; on the other hand, the intensification of fixed capital including the technological renovation of labor generates progress in the latter regions. Hence, the key point is that agricultural growth mechanisms differ according to the natural and social environments.

3. Natural and Social Environments

The average annual temperature, temperature range, average annual humidity, humidity range, annual rainfall, and rainfall range were collected as variables of the natural environments. Descriptive statistics analysis and correlation analysis of these six variables are shown in Table 1. This table reveals the following interesting results. Heilongjiang had the lowest average annual temperature of 5.0°C, while Hunan had the highest, 24.3°C. However, the correlation coefficient of the average annual temperature and the temperature range \( r = -0.781 \) shows that the difference in the annual temperature range (the difference between the highest and lowest monthly temperature) tends to be smaller in provinces with higher average annual temperatures, and larger in provinces with lower average annual temperatures. A similar tendency can be seen with humidity. Tibet Autonomous Region had the lowest average humidity of 31.0%, and Hunan Province again had the highest of 81.0%. Once again, the correlation coefficient of the average annual humidity and its range tends to be smaller in provinces with higher average annual humidity, meaning constantly muggy
weather throughout the year, and the difference in the annual humidity range tends to be bigger in provinces with lower average annual humidity, which leads to substantial seasonal fluctuations in humidity. With regards to rainfall, which is directly related to humidity, Table 1 shows that provinces with a lot of rain experience a large amount of annual rainfall and a large seasonal variability in rainfall, whereas provinces with little rain experience a small amount of annual rainfall with little seasonal rainfall variability.

Since the six variables portraying these natural environments were found to be closely related—as shown in Table 2 in the principal component analysis, only one principal component was extracted, and the scores of this principal component were converted into an index as a climate factor. The higher the climate index, the higher the temperature and humidity, the smaller the range (i.e., the difference between the maximum and minimum values), the higher the rainfall, and the larger the range of rainfall. In other words, if the climate index of a certain province is high, this means that its temperature and humidity are high, and it has a lot of rainfall. In addition, this tendency continues throughout the year. Hainan and Fujian are typical examples of high climate index provinces. On the other hand, typical examples of provinces with a low climate index are Heilongjiang and Xinjiang Uighur Autonomous Region.

Figure 2 is a scatter diagram of the correlation \( r = 0.548 \) between the climate index and the population density (log-transformed). Figure 2 show that there exists a certain relationship between the natural environment and the population distribution. In this figure, there are no provinces that are categorized as “humid” and “thinly populated,” while eight provinces are categorized as “humid” and “densely populated,” and six are categorized as “dry” and “thinly populated.”

Table 1: Descriptive Statistics of Climate Variables and Correlations in China (Provincial Level)

<table>
<thead>
<tr>
<th>Units</th>
<th>Frequency</th>
<th>Min.</th>
<th>Max.</th>
<th>Average</th>
<th>SD</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Average annual temperature</td>
<td>°C</td>
<td>27</td>
<td>5.00</td>
<td>24.30</td>
<td>14.2704</td>
<td>5.50942</td>
</tr>
<tr>
<td>2. Temperature range (difference)</td>
<td>°C</td>
<td>27</td>
<td>12.20</td>
<td>39.30</td>
<td>25.7778</td>
<td>6.93083</td>
</tr>
<tr>
<td>3. Average annual humidity</td>
<td>%</td>
<td>27</td>
<td>31.00</td>
<td>81.00</td>
<td>63.6296</td>
<td>11.26652</td>
</tr>
<tr>
<td>4. Humidity range (difference)</td>
<td>%</td>
<td>27</td>
<td>10.00</td>
<td>42.00</td>
<td>26.4815</td>
<td>9.46804</td>
</tr>
<tr>
<td>5. Annual rainfall</td>
<td>mm</td>
<td>27</td>
<td>180.00</td>
<td>2628.20</td>
<td>848.4556</td>
<td>529.33719</td>
</tr>
<tr>
<td>6. Rainfall range (difference)</td>
<td>mm</td>
<td>27</td>
<td>64.60</td>
<td>560.60</td>
<td>202.2963</td>
<td>120.68327</td>
</tr>
</tbody>
</table>

** **Correlation coefficient is significant at the 1% level.
* *Correlation coefficient is significant at the 5% level.
Table 2: Principal Component Analysis

<table>
<thead>
<tr>
<th>Component matrix</th>
<th>Communality (after extraction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Average annual temperature</td>
<td>0.929</td>
</tr>
<tr>
<td>2. Temperature range (difference)</td>
<td>-0.780</td>
</tr>
<tr>
<td>3. Average annual humidity</td>
<td>0.764</td>
</tr>
<tr>
<td>4. Humidity range (difference)</td>
<td>-0.808</td>
</tr>
<tr>
<td>5. Annual rainfall</td>
<td>0.914</td>
</tr>
<tr>
<td>6. Rainfall range (difference)</td>
<td>0.819</td>
</tr>
</tbody>
</table>

Sums of squares of loadings after extraction = 4.212
Variance (%) = 70.205%

Figure 2: Scatter Diagram of Climate Index and Population Density

This analysis uses land-labor ratios instead of population densities, after confirming the relationship between natural environments and population distributions. The log-translated correlation coefficient ($r = -0.978$) of these factors shows them to be oriented in opposite directions, but nevertheless, they can in effect be handled as almost the same variable.
Namely, it is certain that the land-labor ratio (the land area cultivated by one agricultural worker) is low in densely populated provinces, and high in thinly populated provinces. Jiangsu has the highest population density of 7.24 persons/ha, but it has the 3rd lowest land-labor ratio of 0.75 ha/person. Henan has the lowest land-labor ratio of 0.44 ha/person, and has the 3rd highest population density of 5.73 persons/ha. Meanwhile, Tibet Autonomous Region has the lowest population density of 0.44 ha/persons and the highest land-labor ratio of 84.17 ha/person. In other words, Jiangsu is 362 times as densely populated as Tibet Autonomous Region, while the latter has 112 times more agricultural land than the former on average.

4. Relationship between the Natural and Social Environments and Agricultural Investment

In this paper, the relationship between the agricultural capital input and the distributed structures of the natural and social environments, as well as the direct influence of the agricultural capital input upon agricultural productivity are measured. Here, the formation of agricultural capital input, categorized into two groups, the input of fixed capital (machinery, etc.) and the input of fluid capital (fertilizers, agricultural chemicals, etc.) are measured using the two indexes of the capital equipment ratio (investment per agricultural worker) and the capital input ratio (capital input per agricultural land unit) respectively.

Table 3 shows the correlations of these four agricultural investment indexes. These correlations indicate that agricultural investment in China can be represented along two axes. One is the axis of “fixed capital equipment ratio—fluid capital equipment ratio—fixed capital input ratio”; the other is the axis of “fluid capital input ratio—fixed capital input ratio—fluid capital equipment ratio.” The first axis shows that the level of capital input (fixed capital and fluid capital) to the average agricultural worker is related to the fixed capital input to agricultural land, whereas the second axis shows that the ratio of the capital input (fixed capital and fluid capital) to agricultural land is related to the fluid capital input to the average agricultural worker. Besides, it is noteworthy that these two axes do not function independently, but the fluid capital equipment ratio and the fixed capital input ratio serve as common denominators of these two axes.

Figure 3 shows the results of path analysis (standardized regression analysis), which tested the relationship between these capital investments and the natural and social environments mentioned above. The results indicate the following three points.

(1) The social environment (land-labor ratio) has a direct influence on the capital input ratio (investment in land units), but no significant direct influence on the capital
equipment ratio (investment in labor units) is observed. Provinces with a low land-labor ratio—or densely populated regions—are characterized by large capital inputs (both fixed and fluid capital). On the contrary, the provinces with a high land-labor ratio—or thinly populated regions—have small inputs of fixed and fluid capital.

(2) Only the fixed capital equipment ratio, or the fixed capital input to labor units, has a direct influence on the natural environment (climate factor), but does not have an influence on the fluid capital equipment ratio. In addition, it does not have a direct influence on the fixed capital input ratio or the fluid capital input ratio. In other words, dry provinces have a large fixed capital input, while humid provinces have a relatively low fixed capital input to labor units. This may be indicative of the progress of agricultural mechanization in the former provinces.

(3) The fixed capital input ratio and the fluid capital input ratio, which indicate the capital investment in the land, are strongly correlated. This correlation is strongly related to the fluid capital equipment ratio, which shows the fluid capital input to the labor power; however, no significant relationship with the fixed capital equipment ratio is observed. In other words, the fixed capital equipment ratio has a relatively strong correlation with the fluid capital equipment ratio, but does not have a significant correlation with, or is independent of, other capital input.

Table 3: Correlation between Capital Inputs and Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Frequency</th>
<th>Min.</th>
<th>Max.</th>
<th>Average</th>
<th>SD</th>
<th>Correlation Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fixed capital equipment ratio</td>
<td>10,000 kw/10,000 persons</td>
<td>27</td>
<td>1.29</td>
<td>6.65</td>
<td>3.2552</td>
<td>1.43732</td>
<td>1</td>
</tr>
<tr>
<td>2. Fluid capital equipment ratio</td>
<td>10,000 t/10,000 persons</td>
<td>27</td>
<td>0.05</td>
<td>0.38</td>
<td>0.1974</td>
<td>0.09223</td>
<td>0.464* 1</td>
</tr>
<tr>
<td>3. Fixed capital input ratio</td>
<td>10,000 kw/10,000 ha</td>
<td>27</td>
<td>0.05</td>
<td>9.58</td>
<td>2.3547</td>
<td>2.52731</td>
<td>0.510** 0.252 1</td>
</tr>
<tr>
<td>4. Fluid capital input ratio</td>
<td>10,000 t/10,000 ha</td>
<td>27</td>
<td>0.00</td>
<td>0.51</td>
<td>0.1442</td>
<td>0.13951</td>
<td>0.268 0.414* 0.875** 1</td>
</tr>
<tr>
<td>5. Land productivity</td>
<td>100 million yuan/10,000 ha</td>
<td>27</td>
<td>0.01</td>
<td>5.68</td>
<td>1.6332</td>
<td>1.47434</td>
<td>0.242 0.357 0.846** 0.933** 1</td>
</tr>
<tr>
<td>6. Labor productivity</td>
<td>100 million yuan/10,000 persons</td>
<td>27</td>
<td>0.72</td>
<td>4.25</td>
<td>2.2344</td>
<td>0.94073</td>
<td>0.333 0.747** 0.240 0.371 0.534** 1</td>
</tr>
</tbody>
</table>

** Coefficient is significant at the 1% level.
* Coefficient is significant at the 5% level.
Figure 3: The Structure of Agricultural Productivity in 2010 China (Path Analysis)

5. Agricultural Investment and Agricultural Productivity

The above Table 3 clearly shows the relationship between capital input and productivity. Before examining this relationship, attention should be paid to the productivity figures. As for land productivity, Tibet Autonomous Region has the lowest value of 100 yuan/ha, while Jiangsu has the highest of 56,800 yuan/ha. The difference between these values is huge: the highest being 568 times the lowest. As for labor productivity, Guizhou has the lowest value of 7,200 yuan/person, while Jiangsu again has the highest of 42,500 yuan/person. Thus the highest value is 5.9 times the lowest. This difference is smaller than that with regard to land productivity. There is a relatively strong correlation ($r = 0.534$) between land productivity and labor productivity, and provinces with a high land productivity tend to have a high labor productivity, while provinces with a low land productivity tend to have a low labor productivity. In this regard, the results of the descriptive statistics show that the difference is
remarkable in the case of land productivity.

More importantly, land productivity, which shows great differences, has a very strong correlation with the level of capital input to land units, that is, the fluid capital input ratio \( r = 0.933 \) and the fixed capital input ratio \( r = 0.846 \); however, significant correlation between land productivity and the level of capital input to labor units (the fixed capital equipment ratio and the fluid capital equipment ratio) cannot be observed. On the other hand, labor productivity strongly correlates with only the fluid capital ratio \( r = 0.747 \), and does not have a significant correlation with the fixed capital equipment ratio. Theoretically, the level of fixed capital input to labor units, that is, the fixed capital equipment ratio, is important as a factor exerting a direct influence upon the improvement in labor productivity. This is true with indexes that indicate mechanization. However, in reality, the level of fluid capital input to labor units, not the level of the fixed capital input to labor units, determines the labor productivity. This shows the characteristics of agricultural investment in contemporary China.

Figure 3, which measures the direct influence of agricultural investment upon agricultural land and labor productivity, shows the following two points.

1. Land productivity is strongly determined by the fluid capital input ratio, which strongly correlates with the fixed capital input ratio. In other words, land productivity is strongly and directly affected by the fluid capital input per land unit. This phenomenon shows that land productivity correlates with the fixed capital input per land unit. On the other hand, no statistically significant direct influence of the capital equipment ratio (fixed capital and fluid capital), which shows the capital investment in labor power, upon land productivity is observed.

2. Compared with land productivity, labor productivity is relatively less affected by capital investment. The fluid capital equipment ratio is the only element that has a direct influence upon labor productivity, and high labor productivity is achieved in provinces with a high fluid capital equipment ratio, which shows the fluid capital input per unit of labor power. However, the fixed capital equipment ratio does not determine labor productivity. In other words, this indicates that contemporary China is not at a stage where the investment in machinery, etc., serves to improve labor productivity, but rather in a situation where investment in fluid capital such as fertilizers and agricultural chemicals boosts labor productivity. \( R^2 \) of the land productivity is 0.866, demonstrating almost complete interpretability, whereas \( R^2 \) of the labor productivity is 0.540, demonstrating relatively weak interpretability. These indicate that the axis of agricultural growth in contemporary China is the improvement of land productivity by inputting mainly fluid capital such as fertilizers.
and agricultural chemicals, which results in the improvement of labor productivity, rather than the improvement of labor productivity by directly inputting mainly fixed capital such as machinery.

6. Development Direction in Agricultural Productivity

Figure 4 shows the changes in land productivity and labor productivity from 2005 (2004) to 2010 (2009) in 27 provinces. In these 27 provinces, in 2005, the average land productivity was 9,900 yuan/ha, and the average labor productivity was 12,300 yuan/person; and in 2010, the average land productivity was 16,300 yuan/ha, and the average labor productivity was 22,300 yuan/person. Therefore the nominal growth rates were 1.71 in land productivity and 1.83 in labor productivity. Since the price index increased by 1.18 during this period, the real growth rates were 1.45 and 1.55 respectively.

In Figure 4, the line which connects the intersections of the average land productivity and the average labor productivity for 2005 and 2010 shows the agricultural progressive trend line of the whole of China determined by both of these productivities. If a line connecting the average intersections for 2005 and 2010 for each province represents the agricultural progressive trend line of the province, a province whose agricultural progressive trend line lies on the X-axis (land productivity axis) side of the overall agricultural progressive trend line with a gentler slope than that of the overall agricultural progressive trend line is achieving land-productivity-oriented growth, whereas a province whose agricultural progressive trend line is located on the Y-axis (labor productivity axis) side of the overall agricultural progressive trend line with a steeper slope than that of the overall agricultural progressive trend line is achieving labor-productivity-oriented agricultural growth.

In Figure 4, Jiangsu, Shandong, and Henan are as typical provinces that have sought land-productivity-oriented agricultural growth. In Jiangsu, in 2005, land productivity was 35,600 yuan/ha and labor productivity was 21,000 yuan/person; in 2010, land productivity was 56,800 yuan/ha and labor productivity was 42,500 yuan/person. The nominal growth of land productivity was 1.60 (real growth, 1.36) whereas the nominal growth of labor productivity was 2.02 (real growth, 1.71). The increase rate of land productivity was a little lower than the average for the 27 provinces, and the increase rate of labor productivity is a little higher than the average. Nevertheless, since both the land productivity and the labor productivity are at high levels, the slope of the agricultural progressive trend line is steep. This steep slope, compared with the average agricultural progressive trend line determined by the 2005 to 2010 average, shows an orientation to land productivity rather than labor productivity, which shows that the province has taken the land-productivity-oriented agricultural growth route. The same trend can be seen in two other provinces, Shandong and Henan. This land-productivity-improvement-oriented trend accompanied by an improvement
in labor productivity reflects the growth axis of Chinese agriculture, which aims at the improvement of capital input centered on such fluid capital as fertilizers and agricultural chemicals, rather than the improvement of labor productivity by directly inputting fixed capital such as machinery.

However, Figure 4 also shows that there are provinces that obviously deviate from the general growth trend of Chinese agriculture. In other words, at least four provinces, namely Inner Mongolia Autonomous Region, Jilin, Heilongjiang, and Xinjiang Uighur Autonomous Region, are seen to have developed an agricultural growth pattern that is clearly labor-productivity oriented. For example, the land productivity of Inner Mongolia in 2005 was 900 yuan/ha, while its labor productivity was 15,300 yuan/person; in 2010, its land productivity was 1,600 yuan/ha and its labor productivity was 28,100 yuan/person. Its nominal growth of land productivity was 1.78 (real growth 1.51), whereas the nominal growth of labor productivity was 1.84 (real growth 1.56), which shows an increasing tendency similar to that of the average of the 27 provinces. However, since the land productivity itself is at a low level, its agricultural progressive trend line has an almost vertical slope, which shows that it has taken the labor-productivity-oriented agricultural growth route. The other three provinces mentioned show almost the same tendency.

Figure 4: Scatter Diagram of Land Productivity and Labor Productivity (2005 - 2010)
The point is, all the provinces that take the labor-productivity-oriented agricultural growth route belong to the category determined by the respective natural and social environments of “dry region” and “thinly-populated community.” It is necessary to recognize that the growth mechanism in these areas is probably different from the growth mechanism developed in areas determined by the respective natural and social environments of “humid region” and “densely-populated community.” Most probably, these provinces have an agricultural growth mechanism that differs from the agricultural growth whose axis is the improvement of the land productivity based on fluid capital input, but aims at the improvement of labor productivity by directly inputting fixed capital. The important point is, the agricultural growth mechanism differs from region to region according to their natural and social environments.
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