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Changes in total factor productivity and its causative factors in

Japanese agriculture

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Abstract

The Japanese economy is facing a downward population trend. To maintain Japan's economic growth, it is important to improve total factor productivity (TFP), which represents technological progress in all sectors, including agriculture. The present study aims to measure chronological changes in the TFP of agricultural production. An empirical estimation was conducted to show the causative factors of TFP growth, including economies of scale, public capital stocks like irrigation facilities, and knowledge capital stocks that can be accumulated through research and development. The results demonstrate that the agricultural TFP has increased from the 1960s to the 2000s. This improvement of TFP has a positive relation with economies of scale, public capital stocks, and knowledge capital stocks. The influence of the public capital stocks and knowledge capital stocks was large in the 1960s, but economies of scale became the greatest influential factor in recent decades. Although the elasticities of the TFP growth with respect to public capital and knowledge capital were the same, the influence degree of these factors decreased, because the growth rates of these capital stocks decreased

sharply. Therefore, there is a high probability that the recent budget cuts in public capital and in the research and development field will hamper the future growth of Japanese agriculture.

Keywords: scale economies, public capital stocks, knowledge capital stocks, research and development, technological progress, public investment, Total Factor Productivity

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1. Introduction

The Japanese economy is facing a downward population trend and serious aging of its population. To maintain Japan’s economic growth, it is important to improve total factor productivity (TFP), which represents technological progress in all sectors, including agriculture.

TFP can be improved by several factors, such as economies of scale, public investment, and research and development activities. However, the national budget for public investment and

research and development has been cut since 2001. Particularly in agriculture, the total amount of public investment was reduced to less than 1/3 of the peak budget in the 1990s. This would not matter if the above factors have little effect on TFP, but it would be serious if the influence of these factors was large. Thus, it is important for empirical studies to measure the influence of these factors on TFP.

Previous studies measured TFP after the Second World War by the Laspeyres Index (Yamada, 1991). This method assumed neutral technological progress in the production technique by setting the share rate of each input factor constant. Hence, it is difficult to detect the biased technological progress that was revealed by Kuroda (1989) in Japanese agriculture.

The biased technological progress was measured by calculating the Törunkvist Index from the Input-Output (I/O) data, which showed that TFP had decreased in Japanese agriculture (Kuroda, 1985). However, this research ignored farmland as an input factor, and the I/O data used in the study omitted the wage income of the part-time farmers, who are more in numbers as compared to professional farmers. Takayama and Takahashi (2010) measured changes in the agricultural TFP by calculating the Törunkvist Index with consideration for the total amount of input factors, including part-time farmers and farmland. Their result was the opposite of Kuroda's, as they found that agricultural TFP increased since the 1960s.

Denison (1979) evaluated the causative factors of TFP growth in the US economy. Torii (2001) and Fukao and Miyagawa (2008) analyzed the causative factors in Japan. They

analyzed TFP for the entire economy. Unfortunately, there are not many empirical studies on the causative factors of TFP in Japanese agriculture.

The present study aims to measure chronological changes in the TFP of agricultural production and to show the impact of scale economies, public capital stocks like irrigation and drainage facilities, and knowledge capital stocks that can be accumulated through research and development. TFP is measured from the same data used by Takayama and Takahashi (2010), but the measurement method is devised with consideration of changes in factor share rates that can account for biased technological progress. The TFP of rice production is measured using “the cost research of rice production” (Japanese Ministry of Agriculture, Forestry, and Fishery (MAFF)). Using these TFP values, the causative factors are investigated by OLS estimation.

2. Methods

2.1 Method for measuring TFP

Supposing that the production function can be defined by an exponential function, TFP can be modeled as follows (Torii, 2001).

$$TFP = \frac{Y}{\prod_i x_i^{\beta_i}} \quad (1)$$

Here, Y is production value, x_i is the input factors, and β_i is the share rate of the i -th factor. If the production function is homogeneous, β_i corresponds to the cost share rate or relative share rate of each input factor. The relative share calculated from the I/O table is problematic

because it does not include the labor of part-time farmers in labor costs, and it does not show payments to farmland. If such miss-inclusion happens, there is a possibility of underestimation of capital in an industry where capital growth is high. Therefore, the cost share rate is commonly used in empirical studies (Fukao and Miyagawa, 2008).

If the biased technological progress is taken into account, β_i in Eq. (1) changes annually and is defined by $\beta_i(t)$ ¹. $\beta_i(t)$ is measured by the cost data of farmland rents, wage of labor, and rate of capital depreciation. The amounts of the input factors rely on the estimation work of Takayama and Takahasi (for agriculture in general) and the cost research on rice production (MAFF).

2.2 Analysis of causative factors

The present study considered three causative factors, namely economies of scale, public capital stocks, and knowledge capital stocks. Economies of scale were represented by the

¹ When $\beta_1(t) = \bar{\beta}_1 + \gamma_1 0.5 \ln[A(t)] + \gamma_2 \ln[L(t)] + (-\gamma_1 - \gamma_2) \ln[KP(t)]$, $\beta_2(t) = \bar{\beta}_2 + 0.5\gamma_2 \ln[A(t)] + (-\gamma_2 - \gamma_3) \ln[KP(t)]$ and $\beta_3(t) = \bar{\beta}_3 + 0.5\{\gamma_1 + 2\gamma_2 + 2\gamma_3\} \ln[KP(t)]$ are assumed, Eq. (1) becomes the trans-log production function that can show the biased technological progress. In the empirical studies, the above three functions are estimated as the cost share function with the main production function by using Seemingly Unrelated Regression (SUR). In this paper $\beta_i(t)$ is directly measured as the cost share values from the statistics, so the measured TFP is flexible to biased technological progress as well as to neutral technological progress.

average farm management area of an individual farmer. The knowledge capital stocks were accumulated by investment in research and development. The public capital stocks consisted of irrigation and drainage facilities and consolidated farmland. The first and second factors are clear from the economic literature (see Kuroda, 1989 and 1995). Regarding the third factor, irrigation and drainage facilities can increase the unit-production and reduce the operation costs of water distribution. Consolidated farmland can raise the working efficiency of farm machinery. Hence, the accumulation of public capital stocks increases TFP.

The following equation was used to measure the effect degree of each factor.

$$\ln(TFP_t) = \phi_0 + \phi_1 \ln(MA_t) + \phi_2 \ln(K_t) + \varepsilon_t \quad (2)$$

Here, K is the total capital stocks, and it is assumed that $K = KG_{t-1} \cdot KK_t$ or $K = KG_{t-1} + KK_t$, where KG is the public capital stocks and KK is the knowledge capital stocks. MA is the average farm management area of an individual farmer. ϕ and ε are a parameter to be estimated and the error term, respectively. KG influences TFP with a one-year lag because of the gestation period.

The log-log equation was employed because the parameter to be estimated corresponds to the elasticity value of TFP with respect to each factor. The combination of KG and KT was used because there was strong multi-collinearity in these variables, which showed that these variables were complementary factors.

3. Data

3.1 Data on agriculture

The data for measuring TFP for agriculture in general were estimated by Takayama and Takahashi, as was mentioned above. Their work covered (i) total agricultural production, including added value and intermediate input costs; (ii) the private capital stocks related to agricultural machinery, buildings, livestock, and the stocks of fruit trees; (iii) the service costs of the private capital stocks; (iv) labor costs and labor inputs; and (v) farmland inputs. A detailed explanation of the estimation can be found in their paper.

The data for measuring TFP in rice production were based on “the cost survey of rice production” (MAFF). This survey contained almost the same kinds of variables as the data on general agriculture. The nominal values in these statistics were deflated by the index shown in the “the national accounts of agriculture and food industries” (MAFF).

3.2 Capital stocks

The knowledge capital stocks were estimated as follows based on the method of the Policy Research Institute on Science and Technology (PRIST, 1999).

$$KK_t = (1 - \theta)KK_{t-1} + IK_{t-N} \quad (3)$$

Here, IK is the investment in research and development. θ and N are the obsolescence rate of knowledge and time lags representing the time in which developed technology spread to the

commercial fields, respectively. According to the questionnaire survey conducted by the PRIST, θ was 0.075 and N was 9 years. By using these rates and its estimation of KK from 1973 to 1997, this study estimated KK from 1998 to 2006.

The data on public capital stocks were published by the Cabinet Office of Japan (in “The Japanese Social Overhead Capital Stocks 2007”). Based on these data, this study estimated KG for 2004 and 2005.

4. Results

4.1 Estimations of TFP

Figure 1 shows the estimations of Eq. (1). The estimations based on the data of Takayama and Takahashi using the Törunkvist Indexes are provided in the figure for reference. The estimations of this study and of Takayama and Takahashi correspond well through the mid-1980s, but they differ in 1989 and 1990. After 1991, the lines are separate from each other, but the growth rates are almost identical. If these two years are ignored, the estimations of this study correspond to the estimations of Takayama and Takahashi. Actually, Japanese economies experienced a bubble burst in 1989. Because of the strong impact of the bubble burst, production in most industries decreased in Japan. Thus, there may be some disturbances in both production and input factors. Considering these disturbances, the estimations of this study appear to be reasonable.

Figure 2 shows the TFP of rice production. The TFP of entire agriculture was plotted again in this figure for comparison. As is shown in this figure, the TFP of rice production fluctuated more sharply than the TFP of entire agriculture. In general, Japanese rice is planted from April to October, and climatic fluctuation within a half year tends to be higher than climatic fluctuation in an entire year. This is the reason for the high fluctuation of the rice production TFP. Although this difference was found, the two TFPs experienced the same chronological changes on average.

<Insert Fig. 1 and 2 >

4.2 Causative factors of the increase in TFP

Table 1 shows the estimation results of Eq. (2). The dummy variables, D73-75 and D90-93, took a value of one during 1973 to 1975 and 1990 to 1993, respectively, and zero otherwise. These variables were used to consider the jump in the data mentioned above. D91+D93 was the dummy variable in 1991 and 1993 for the damage from the cold weather in these years.

Most of the estimation coefficients, except for that of MA, were significant as compared to the t-statistic value at the 1% level of error. In addition, the adjusted R-squared values of all the equations were high, and most of the Durbin-Watson statistics did not show serial correlation.

<Insert Table 1>

The elasticity of TFP with respect to MA was 0.9 for general agriculture and 0.35 for rice production. These results indicate that economies of scale exist in agricultural production. The elasticity with respect to K ranged from 0.03 to 0.13, which showed a significant effect of these variables on TFP. These results show the importance of improving management scale and public capital and of investing in research and development.

Figures 3 and 4 show the contribution degree of each factor calculated from the A-1 and R-1 models for every decade. For agriculture as a whole, the knowledge capital stocks greatly influenced the growth of TFP in the 1960s. The public capital stocks had the next highest degree of influence. In the case of rice production, the most influential factor was the public capital stocks, and the knowledge capital stocks were the next most influential. In the 1960s, an increase in the capital stocks played an important role.

However, the influence of public capital and of knowledge capital decreased in both figures in the 1970s. This is because the growth rates of public capital and knowledge capital decreased after 1970, even though the elasticity itself did not change. The decrease in the contribution degree of the public capital was particularly drastic in the 2000s because the budget for public investment, which is the main driver of the accumulation of public capital, was cut after 2001.

In contrast, the average management scale became more influential after the 1970s. The average management scale explains 70% of the TFP growth in the 2000s.

< Insert Figures 3 and 4 >

5. Discussion and conclusions

The present study measured chronological changes in the TFP of general agricultural production and of rice production. An empirical estimation was conducted to show the causative factors of the TFP growth, including economies of scale, public capital stocks like irrigation facilities, and knowledge capital stocks that can be accumulated through research and development.

The results demonstrated that the agricultural TFP has increased from the 1960s to the 2000s. This improvement of TFP has a positive relation with scale economies, public capital stocks, and knowledge capital stocks. The influence of the public capital stocks and knowledge capital stocks was great in the 1960s, but the influence of scale economies became the highest in recent decades. Although the elasticities of TFP growth with respect to public capital and knowledge capital were the same, the influence degree of these factors decreased, because the growth rates of these capital stocks decreased rapidly.

During the calculation period of this study, the growth rate of public capital was positive.

However, if one considers the drastic decrease in public investment in the 2000's, one sees that public capital will soon decrease. Hence, there is a significant possibility that TFP in agricultural production could decrease in the near future. Of course, an increase in the management scale of farmers could counter the downward pressure on TFP in Japan. Even so, in light of the slow pace of the increase in management scale in Japan until now, accelerating the growth of the management scale may be more difficult than increasing public capital and knowledge capital.

In 2010, the Japanese government introduced the direct payment policy in agriculture. This policy targets most farmers, including small-scale farmers, and the budget for this policy was raised through a cut in agricultural public investment. Considering the causative factors of TFP growth, the budget for the direct payment policy should be secured in other ways, and the scheme of the direct payments should be changed. For example, this policy could be more effective if it did not target small-scale and part-time farmers.

Finally, several issues remain. The estimation period needs to be expanded in order to analyze more recent events. Climate conditions should be considered as a causative factor of TFP change. The estimation of the influence function needs to be improved in order to reduce multi-collinearity by using a more effective estimation method. Regional differences in TFP and its causative factors are also interesting for rural revitalization policy.

References

- 1 Denison, E. F. (1979) *Accounting for Slower Economic Growth*, Washington D.C., The Brookings Institution.
- 2 Fukao, K. and Miyagawa, T. (2008) *Productivity and the Japanese economic growth*, Univ. of Tokyo Press.
- 3 Policy Research Institute for Science and Technology, (1999) *Investigation Report on quantitative method for evaluation of economic benefit caused by the research and development policy, interim report*, NISTEP REPORT No.64 pp.103-115
- 4 Kuroda, M. (1985) "Economic growth and the change of the total factor productivity: Comparison of growth factors between Japan and the USA," *Mita business research*, 28(2), pp.25-52.
- 5 Kuroda, Y. (1989) "Impacts of Economies of Scale and Technological Change on Agricultural Productivity in Japan," *J. of Japanese and International Economies*, 3(2), pp.145-173.
- 6 Kuroda, Y. (1995) "Labor Productivity-Measurement in Japanese Agriculture, 1956-90," *Agricultural Economics*, 12(1), pp.55-68.
- 7 Takayama, K. and Takahashi, D. (2010) "The estimation and analysis on the long-term economic statistics of Japanese agriculture: From 1963 to 1993," Working paper submitted in the open seminar of the university of Tokyo, mimeo.

□8□Torii, A. (2001) *The business efficiency of the Japanese industry*, NTT Press.

□9□Yamada,S. (1991) "Quantitative Aspects of Agricultural Development," in Hayami and Yamada eds., *The Agricultural Development of Japan: A Century's Perspective*, Tokyo, University of Tokyo Press.

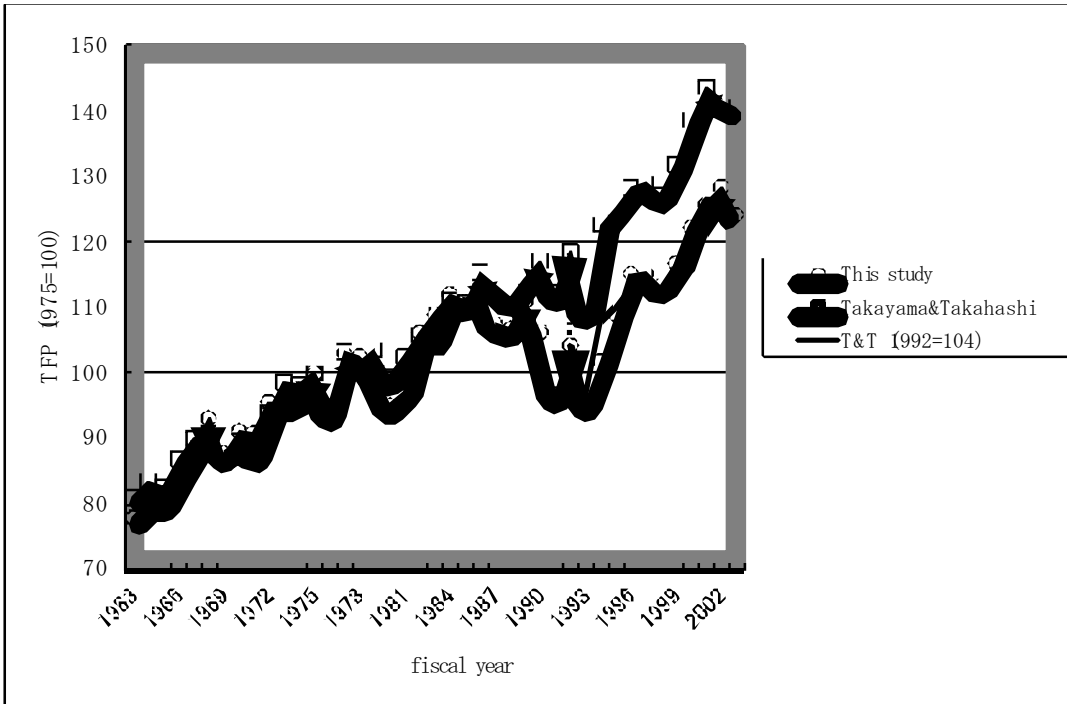


Figure 1: Chronological change in the TFP of agricultural production

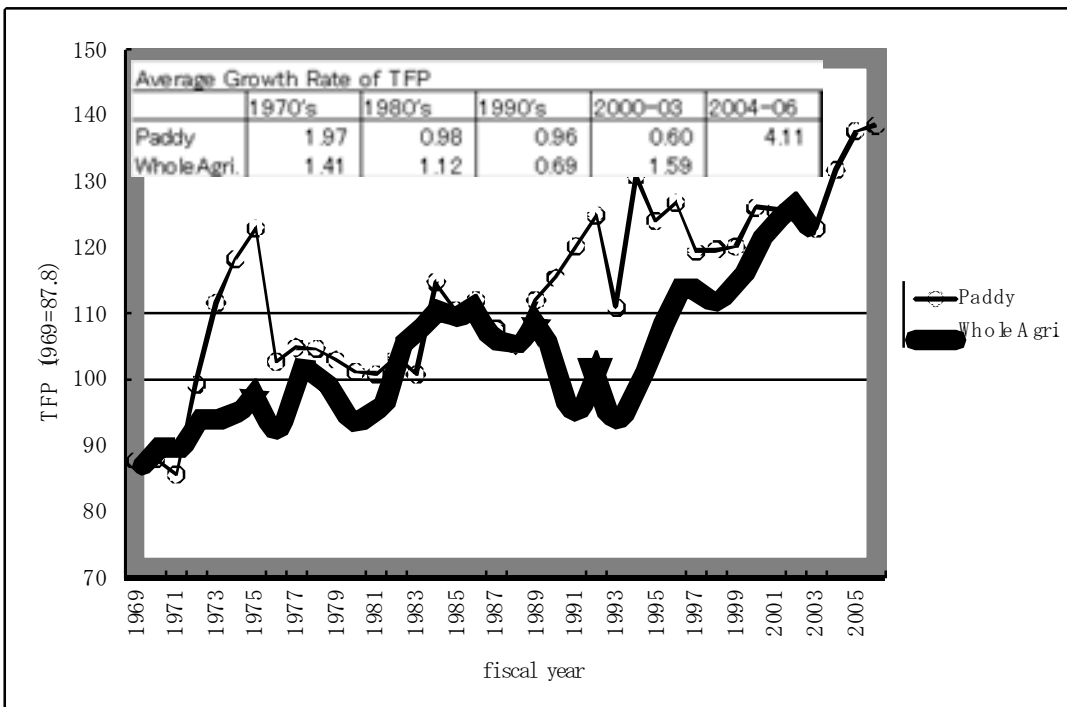


Figure 2: Chronological change in the TFP of rice production

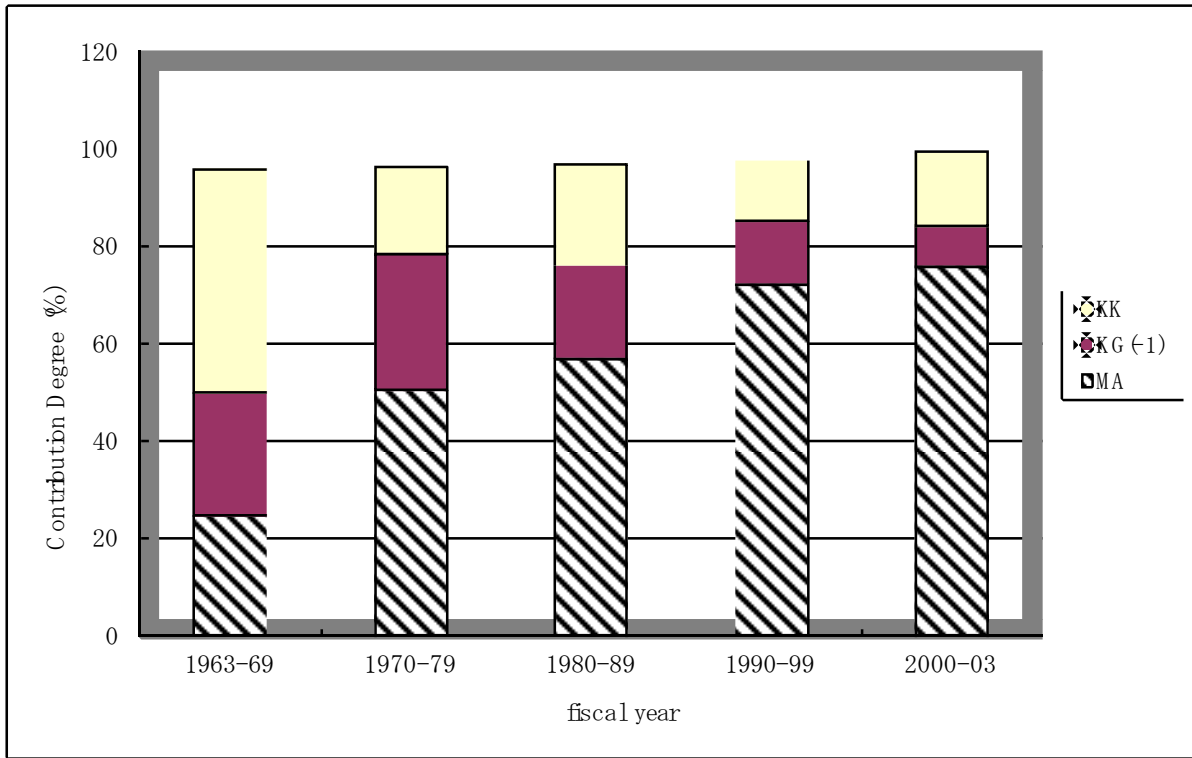


Figure 3: Contribution degree of each factor to the TFP growth of general agriculture

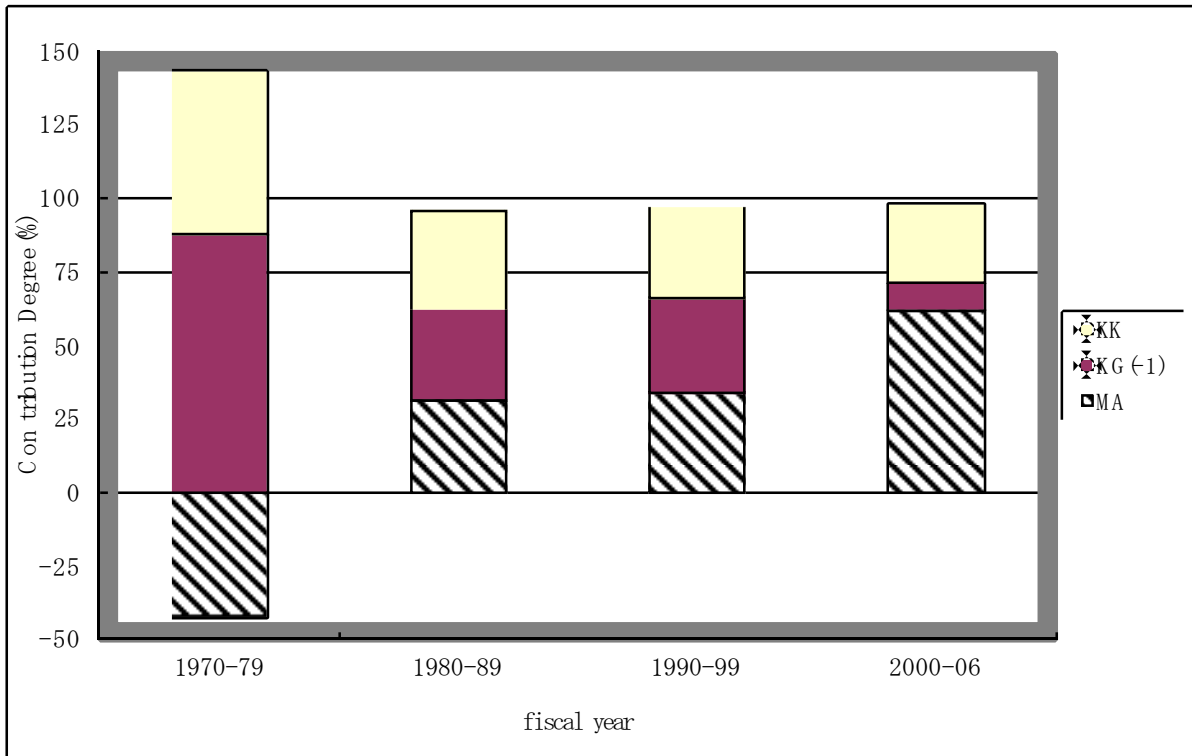


Figure 4: Contribution degree of each factor to the TFP growth of rice production

Table 1: Estimations of Eq. (2)

Variables	Whole Agriculture			Paddy	
	A-1	A-2	T&T	R-1	(1)式 2
Const.	-4.814 (-3.46**)	-5.080 (-6.4**)	-1.087 (-2.06**)	-2.788 (-10.4**)	-3.239 (13.0**)
ln(MA)	0.870 (4.24**)	0.903 (4.2**)	0.979 (6.86**)	0.322 (3.98**)	0.368 (5.0**)
ln(K)	0.037 (4.42**)	0.067 (4.1**)	0.063 (5.70**)	0.067 (9.60**)	0.125 (10.2**)
D90-03	-0.162 (-4.36**)	-0.164 (-4.2**)	-0.067 (-2.57**)	-	-
D91+D93	-0.099 (-3.46**)	-0.098 (-3.3**)	-0.075 (-3.78**)	-	-
D73-75		-	-	0.183 (7.07**)	0.179 (7.3**)
AdjR2	0.922	0.918	0.978	0.897	0.906
DW	1.236	1.163	1.679	1.515	1.558
AC	-153.2	-150.9	-184.0	-134.4	-137.9
N	41	41	41	38	38

Note: 1. MA is the average farm management area of an individual farmer; K is the sum of public capital (KG_{-1}) and knowledge capital (KK).

2. In A-1 and R-1 models, $\ln[K]=\ln[KG_{-1}*KK]$ and in A-2, T&T and R-2, $\ln[K]=\ln[KG_{-1}+KK]$.

3. The T&T model used the data of Takayama and Takahashi for the TFP.

4. The values in parentheses are the t-statistic values, and ** indicates the significance level of 1%.