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Technological investment brings positive impact to agricultural productivity

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Abstract
This paper is an attempt to come up with a tentative theory on agricultural productivity through time. Using quantitative exploratory data analysis technique, agriculture related data of the Philippines from 1980 to 2000 was acquired and analyzed using the cluster analysis. Result reveals that the years having the highest agricultural productivity are the most recent years in the dataset which is characterized as having relatively higher cereal yield per hectare, higher population, higher staple food consumption per capita, lesser arable area, lesser employment in agriculture relative to the total employment, relatively higher fertilizer consumption, and the use of more machines in the farm. The need to cope up with the increasing demand for food coupled with the dwindling agricultural resources through time triggers agricultural mechanization and optimum utilization of farm inputs. Agricultural productivity is, thus, demand-driven and is achieved through investment in technology to compensate losses in agricultural resources.

Keywords: farm mechanization, food security, food production, agricultural technology

Introduction

The Rapid population growth and industrialization have gradually displaced the natural resources intended for agricultural production. The growing competition for land, water, and energy, in addition to the overexploitation of fisheries, will eventually affect our ability to produce food [1]. This scenario brought a huge challenge to enhance agricultural production in order to provide the growing population with sustainable supply of food. Despite this, data revealed that agricultural production has somehow increased over the years. Over the past 50 years, growth in crop production has been driven largely by higher yields per unit of land, and crop intensification [2]. This paper is an attempt to come up with a tentative theory that would explain the dynamics of agricultural productivity over time.

Several studies pointed out the factors influencing agricultural production growth. Fan [3] studied the recent rapid agricultural production growth in Chinese agriculture and identified technological change as crucial to furthering production growth because of the limited increase in the use of conventional inputs particularly land. Using a modified non-parametric approach, Nin [4] found that most developing countries in the sample study are experiencing positive productivity growth with technical change being the main source of this growth. Ewert *et al.* [5] estimated changes in crop productivity and identified technology development as the most important driver but relationships that determine technology development remain unclear and deserve further attention. Fulginiti and Perrin [6] in their study on developing countries pointed out that price policies may be one of the important contributing factor in agricultural productivity.

Despite the numerous studies describing the changes in agricultural productivity, the characteristics of different period of time as to the different factors related to agricultural production and potential demand for food has not been studied at length. In this study, exploratory data analysis was employed using the data mining technique. Datasets were acquired from reliable online databases.

Methodology

The information and datasets utilized in this study were the annual agriculture and agriculture-related data of the Philippines covering the period from 1980 to 2000. The data were taken from the online database of the Food and Agriculture Organization, World Bank, and from the International Rice Research Institute [2] [7] [8]. Philippines had been chosen to represent the developing countries where agriculture is a major economic activity. The country is among the top 20 rice producing countries [2], and utilizes this commodity as the most important food source for human consumption. The 1980-2000 periods were chosen for analysis because of the availability of the data sets of all the variables considered in the study. Table 1 presents the 21 years data of the different variables included in the analysis.

Cluster analysis was carried out to group the observations (in this case, the years) according to their similarities on the variables considered in this study. Three clusters were specified in the analysis using the Minitab software.

Table 1: Datasets included in the analysis

Obser-vation	Year	Net Production Index Number (2004-2006 = 100)	Cereal yield (kg/ha)	Total Population (1000)	Rice consump-tion per capita (kg/yr)	Arable land area (1000 ha)	Employment in agriculture (% of total employment)	Total Fertilizer Consumptions (tons)	Agricultural machinery, tractors per 100 sq. km of arable land
1	1980	56.45	1606.4	47398	96.77	5228	51.80	334000	20.15
2	1981	57.72	1646.6	48716	96.97	5220	51.50	319609	19.56
3	1982	59.68	1822.6	50068	97.99	5240	52.10	345600	18.76
4	1983	55.53	1659.9	51453	85.69	5260	52.00	363477	17.82
5	1984	56.79	1747.3	52873	97.41	5280	50.10	264479	16.42
6	1985	56.89	1841	54325	97.67	5350	49.60	283677	24.67
7	1986	61.09	1914.7	55812	96.75	5400	49.80	389800	32.78
8	1987	59.74	1847.3	57329	93.58	5420	47.80	485725	40.96
9	1988	60.03	1877.2	58867	92.88	5440	46.10	504482	49.08
10	1989	62.86	1945.4	60410	96.18	5460	45.10	533777	57.14
11	1990	69.26	2064.8	61949	93.75	5480	45.20	587092	65.24
12	1991	69.98	2042.7	63476	84.64	5487	45.30	447818	73.36
13	1992	71.85	2103.3	64997	87.93	5435	45.40	505400	77.83
14	1993	72.81	2212.8	66517	88.88	5385	45.80	565490	82.45
15	1994	74.57	2261.7	68051	89.03	5335	44.70	600198	86.97
16	1995	75.12	2273.9	69607	92.77	5285	44.10	598407	91.77
17	1996	80.34	2308.2	71185	99.05	5235	41.70	736800	96.47
18	1997	81.07	2375.3	72781	97.40	5185	40.40	809195	101.45
19	1998	75.31	2240.7	74393	92.26	5135	38.60	628434	106.52
20	1999	81.24	2464.8	76018	100.07	5085	38.80	743764	111.70
21	2000	84.27	2580.8	77652	103.74	5034	37.10	734550	116.81

Results & Discussion

Results on the partition of the observations in the three clusters is presented in Table 2 while Figure 1 shows the observations in each of the three clusters specified in the analysis. Cluster 1 contains 17 observations which represents years 1980-1995 and 1998, while Cluster 2 contains 3 observations representing years 1996 and 1999-2000, and cluster 3 representing year 1997. The years belonging to the same cluster suggest that they have similarities on the factors included in the analysis.

Table 2: Distribution of Clusters by number of observations

	No. of observations	Within cluster sum of squares	Average distance from centroid	Maximum distance from centroid
Cluster 1	17	2.377658783E+11	106422.45	191946.585
Cluster 2	3	68828694.86	4754.794	5497.200
Cluster 3	1	0.000	0.000	0.000

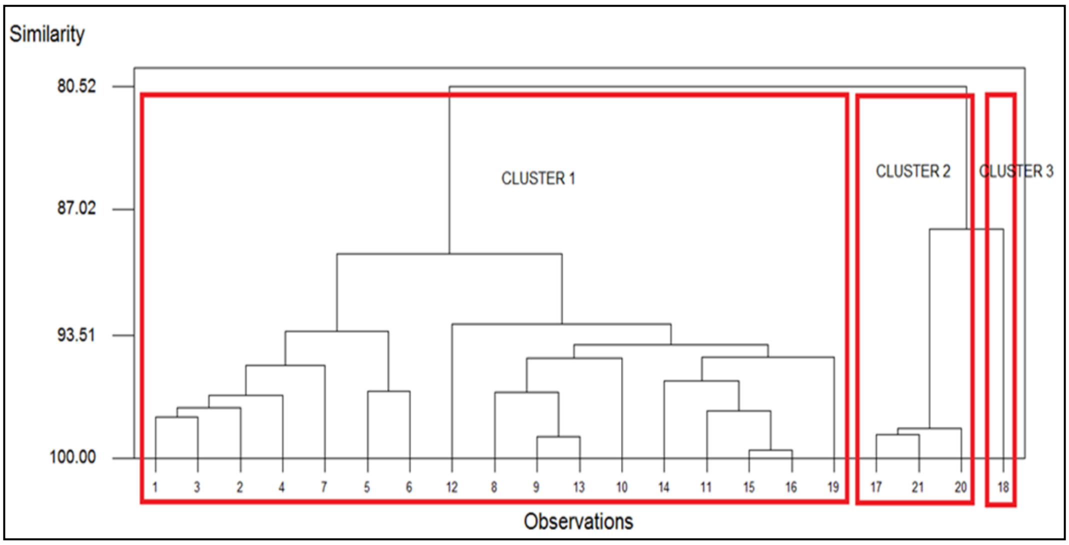

Fig 1: Dendogram of the observations in different clusters

Table 3 describes the centroidal values of the different variables included in the analysis under the different cluster of years. The clustering of years is mainly determined by the Net Production Index Number, which is a measure of agricultural production relative to some base period [9]. Cluster 2 which represent the years 1996 and 1999-2000 has the highest Net Crop Production Index Number while Cluster 1 (years 1980-1995 and 1998) has the least Net Crop Production Index Number. Further, the years having the highest agricultural production are the most recent years in the dataset which is characterized as having relatively higher cereal yield per hectare, higher population, higher staple food consumption per capita, lesser arable area, lesser employment in agriculture relative to the total employment, relatively higher fertilizer consumption, and the use of more machines in the farm.

The above observation suggest that agricultural production varies directly as the population, staple food consumption per capita, the use of agricultural inputs and machinery, while inversely to the land and labor resources.

Table 3: Cluster centroids of the different variables included in the analysis

Variable	Cluster 1	Cluster 2	Cluster 3	Grand centered
Net Production Index Number (2004-2006 = 100)	64.4518	81.95	81.07	67.7429
Cereal yield (kg per hectare)	1947.5471	2451.2667	2375.3	2039.8762
Total Population (1000)	59190.6471	74951.6667	72781	62089.381
Rice consumption per capita (kg/yr)	93.0088	100.9533	97.4	94.3529
Arable Area (1000 ha)	5343.5294	5118	5185	5303.7619
Employment in agriculture (% of total employment)	47.3529	39.2	40.4	45.8571
Total Fertilizers Consumptions (tons)	456321.4706	738371.333	809195	513417.8095
Agricultural machinery (tractors per 100 sq. km of arable land)	51.8518	108.3243	101.4465	62.2809

Conclusions

A tentative theory has been arrived based on the analysis as follow:

The need to cope up with the increasing demand for food coupled with the dwindling agricultural resources through time triggers agricultural mechanization and optimum utilization of farm inputs. Agricultural productivity is, thus, demand-driven and is achieved through investment in technology to compensate losses in agricultural resources.

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