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Investigating Productivity Indices in the Agronomy and Horticultural Sub-Sector During 1992-2001

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Abstract
Productivity as one of the most important concepts in recent decade applied to improving production. The most common definition of productivity is the ratio of outputs to inputs. Although more precise definitions of productivity have been provided by different authors and organizations in different countries. Agricultural productivity is also measured as the ratio of agricultural outputs to agricultural inputs. Generally, the market value of the final output is a tool for measuring output. Different indices are measured in agricultural productivity including total factor productivity, land index, labor index, machinery index, production index, capital index, etc. In this study 9 productivity indices were measured and analyzed in the agronomy and horticultural sub-sector which is the biggest and the most important sub-sector in the agricultural sector. Data were collected from different Iranian official sources for 11 years from 1992-2001. Also, the data collected were used to explore the trend of different productivity indices in the sub-sector during the studied years. Furthermore, the indices were analyzed and interpreted using advanced statistical methods (principal component analysis).

Keywords: Productivity index, Labor index, TFP, Production index, Principal component analysis.

بررسی شاخص‌های بهره‌وری در زیربخش زراعت و باغداری طی سال‌های ۱۳۸۱-۱۳۷۱ (۲۰۰۲-۱۹۹۲)

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چکیده
بهره‌وری یکی از مهم‌ترین مفاهیم در طی دهه اخیر جهت افزایش تولید بوده است. رایج ترین تعریف از بهره‌وری عبارت است از نسبت ستانده‌ها به داده‌ها. اگر چه تعاریف دقیق‌تری توسط افراد و سازمان‌های گوناگونی در کشورهای مختلف ارایه شده است. بهره‌وری کشاورزی نیز بوسیله نسبت ستانده‌های کشاورزی به داده‌های کشاورزی اندازه‌گیری می‌شود. عموماً ارزش تجاری محصول نهایی بعنوان یک ابزار اندازه‌گیری داده بکار می‌رود. شاخص‌های متعددی در بهره‌وری کشاورزی اندازه‌گیری می‌شوند. از جمله این شاخص‌ها می‌توان به بهره‌وری کل عوامل، بهره‌وری زمین، بهره‌وری نیروی کار، بهره‌وری ماشین آلات، بهره‌وری تولید، بهره‌وری سرمایه و غیره اشاره کرد. در این تحقیق ۹ شاخص بهره‌وری در زیر بخش زراعت و باغداری بعنوان بزرگترین و مهم‌ترین زیر بخش در بخش کشاورزی مورد اندازه‌گیری و تجزیه و تحلیل قرار گرفت. اطلاعات مورد نیاز از متابع مختلف رسمی طی دوره ۱۱ ساله از ۱۳۷۱ تا ۱۳۸۱ جمع آوری گردید. از داده‌های جمع آوری شده به منظور استخراج روند شاخص‌های بهره‌وری در زیر بخش زراعت و باغداری در طی سال‌های مورد مطالعه، استفاده گردید. بعلاوه شاخص‌های بهره‌وری اندازه‌گیری شده در معرض تجزیه و تحلیل‌های پیشرفته آماری (تجزیه به مؤلفه‌های اصلی) قرار گرفتند.

کلمات کلیدی: شاخص تولید، شاخص نیروی کار، بهره وری کل عوامل، شاخص تولید، تجزیه به مؤلفه های اصلی.

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Introduction

With accelerating globalization, competitiveness has taken new dimensions and, in order to obtain a greater share of world trade and to survive in the domestic market, economic institutions try to increase their competitiveness strongly. Recent studies have shown that competitiveness and productivity are closely associated. In simple terms, improving productivity can increase competitiveness. Today, productivity is called an intellectual perspective of the concept of smart working. Basic concepts of productivity are simple, but the problem is the lack of a clear and specific method for productivity assessment. Hence, to provide definitions of productivity and assessment indices are crucial to intellectual productivity.

Although in the last century the concept of 'productivity' was introduced into the global literature, it can be regarded as synonymous with work, production and exchange. Any efforts to achieve better opportunities for business conditions, production and achieving top human goals have led the concept of productivity. This concept has been exposed to changes regularly from the beginning of its appearance in the scientific literature. The term "productivity" has been defined variously in the literature, some of which are as follows:

In 1950, OEEC[1] provided the following definition of "productivity" as: "the quotient obtained by dividing output by one of the factors of production. In this way it is possible to speak of the productivity of the capital, investment, or raw materials according to whether output is being considered in relation to capital, investment, or raw materials, etc." Bernolak (1980), defined productivity as a relationship between the quantity of goods and services produced and the quantity of resources in turning out those goods and services. Monhney (1998) defines productivity as: "an efficiency concept generally cast as ratio of output to input into some productive process". Campbell and Campbell (1998b) also believe that the two terms efficiency and productivity can be used synonymously. According to them, for both terms, the indicator is a ratio of outcomes to inputs.

A more precise definition of productivity has been provided by Wilson (1994) as follows: "productivity is the ratio of outputs produced to the input resources utilized in their production. Typically, productivity is also measured against a "base period" so as to facilitate trend analysis of the productivity measure."

Australian Industry Commission (1997) has also defined productivity more precisely in the following words: "productivity is a measure of the capacity of individuals, firms, industries or entire economies to transform input into output. More specifically productivity is a measure of the rate at which output (of goods and service) are produced from given amount of input. The term "productivity" has been defined by Sink (1985) as: "relationship between outputs generated from a system and the input provided to create those outputs."

NIPO[2] had defined productivity as: "the ability of producing value in a system."

Legislation was approved in the Iranian Forth Development Plan Act which requires the government to achieve a 2.5% out of an 8.5% increase of GDP through productivity. The agriculture sector has an important role in economic growth rate, thereby, GDP. A study was conducted to investigate the productivity indices in the most important sub-sector within the agricultural sector. The agronomy and horticulture sub-sector is the biggest and most important sub-sector which was chosen for this study.

The aim of this study was to study:

1. The trend of different indices during studied period.
2. The most important index/indices which affected crop production in the sub-sector.
3. the most efficient years which affected the productivity indices, thereby production.

Material and Methods

In general time series analysis is used to show the trend of productivity indices over the time. Therefore it is necessary to eliminate the effect of current inflation from information items with a monetary nature by the use of suitable indices. In order to identify deflation or price adjustment, different indices are used based on given cases. Each of those methods has its own technical justifications.

The most appropriate indices used for price adjustment are as follows:

1. Implicit index of the agricultural sector and sub-sectors for adjusting of value added of agricultural sectors and sub-sectors.
2. Implicit index of the capital formation of agricultural sectors for adjusting capital stock of agricultural sectors and sub-sectors.
3. Wholesale price index for adjusting production costs (sowing, care and harvest).
4. Cost of living index for adjusting compensation of employees in agricultural sectors and sub-sectors.

The data for these indices have been collected for a period of 11 years (1991-2001) from the statistical sources of the Central Bank of Iran and the Statistical Centre of Iran (Table 2 and Table 3). These indices are calculated according to 1997 as the base year.

Table 1- The calculated agronomy and horticultural sub-sector indices in Iran during 1992-2001.

	Index	Formula
1	Labor productivity index	The amount of crop production / Number of employees
2	Capital productivity index	Surplus value / Current constant capital
3	TFP[3]	Surplus value / Employees compensation + Current constant capital
4	Land productivity index	The amount of crop production / Total land used for planting
5	Machinery productivity index	The amount of crop production / Efficient machinery power
6	Planting productivity index	The amount of crop production / Planting costs
7	Care productivity index	The amount of crop production / Care costs
8	Harvest productivity index	The amount of crop production / Harvest costs
9	Production productivity index	The amount of crop production / Total production costs

Table 2- Indices of monetary item adjustment according to fixed prices of year 1997.

Year	Cost of Living Index	Implicit Index of Agricultural Sector	wholesale price index
1991	22.4	19.2	191.1
1992	27.9	24.6	25.2
1993	34.3	35.8	31.9
1994	46.3	47.2	45.9
1995	69.2	65.3	72.7
1996	85.2	85.2	91.0
1997	100.0	100.0	100.0
1998	118.1	111.4	116.7
1999	141.8	131.3	144.9
2000	159.7	150.5	166.3
2001	177.9	162.8	174.7

Table 3 - Data collected from NIPO[2], Statistical center of Iran and the Central Bank.

Year	Labor Productivity	Capital Productivity	TFP
1990	9.06	8.51	8.78
1991	3.75	0.01	1.81
1992	9.08	7.17	8.08
1993	-0.22	-1.77	-1.03
1994	0.28	0.59	0.44
1995	-1.14	2.93	0.98
1996	1.84	0.41	1.10
1997	0.14	-1.22	-0.57
1998	8.24	9.28	8.78
1999	-8.50	-12.27	-10.46
2000	5.37	-0.32	2.41
2001	-3.54	-6.81	-5.24
2002	6.81	4.96	5.85
2003	3.21	1.88	2.52
2004	0.36	3.46	1.98
2005	5.19	1.86	3.46

Results

In order to investigate the trend of different productivity indices in the agricultural sector and sub-sectors (agronomy and horticulture) over the years studied, the time period has been divided to two sections: before 1997 and after 1997. This division was done due to different government and, hence, different official policies which have had unavoidable effects on the agricultural sector.

General indices for the agricultural sector

Labor productivity index

The labor productivity index is defined as the ratio of value-added in the agricultural sub-sector divided by the number of employees in each sub-sector. In fact, it measures the ratio of (the real value) output of labor. In this measurement, hours worked by labor is preferred over the number of employees. Fig.1 shows the trend of labor productivity index during 1992-2001. This index showed an almost steady trend during 1992-2000 with a slight increase in 1998, but a significant increase occurred in 2001. This increase was about 60% which is remarkable for labor productivity index.

Capital productivity index

The capital productivity index is the ratio of crop production (agronomy and horticulture) divided by current constant capital of sub-sector. Fig.2 shows the trend of capital productivity index over the studied years. The trend is almost steady except in 1998 with a slight increase (about 20%).

TFP

TFP is the ratio of surplus value of the sub-sector divided by the sum of compensation of employees and current constant capital of the sub-sector. In other words, TFP is the ratio of output to the input of labor and capital.

As can be seen in Fig. 3, TFP showed a mild increase from 1992 to 1998, but again decreased up until 2001. TFP is an indicator of efficiency. This result indicated that during 1992-1998, labor and capital combined to generate output efficiently and effectively. However it showed a decline after 1998.

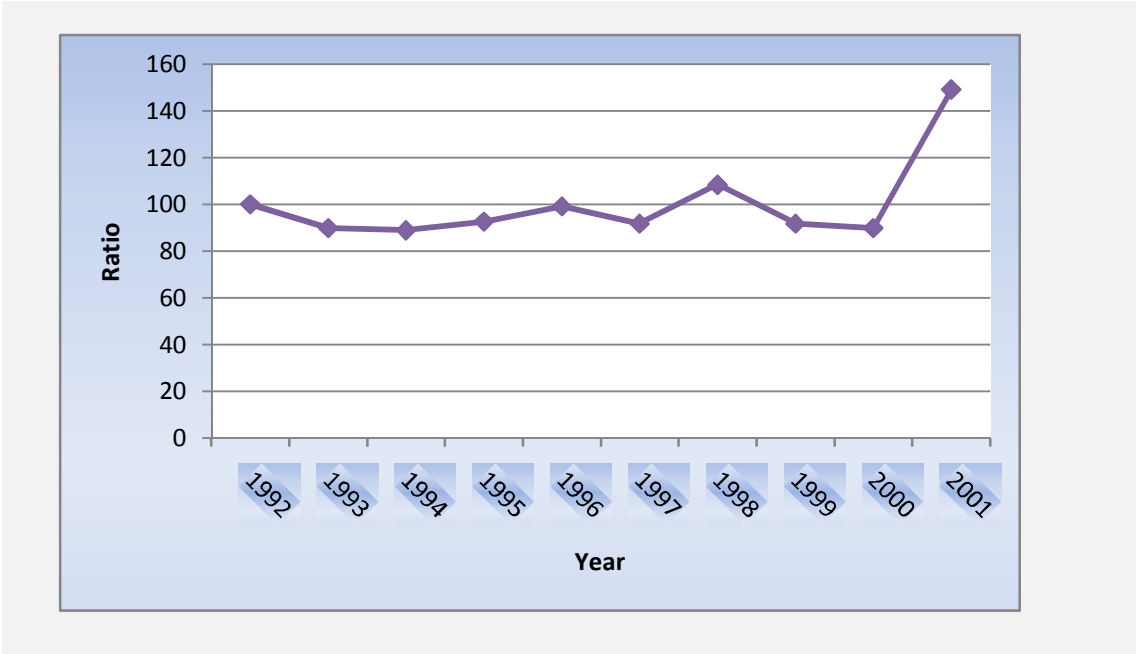

Fig. 1- Labor productivity index (percent) according to the base year 1997.

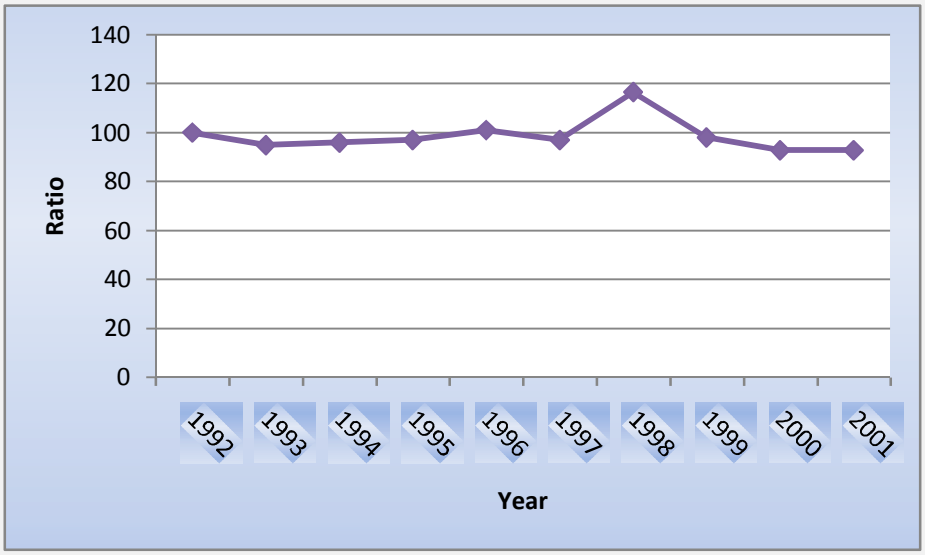

Fig. 2- Capital productivity index (percent) according to the base year 1997.

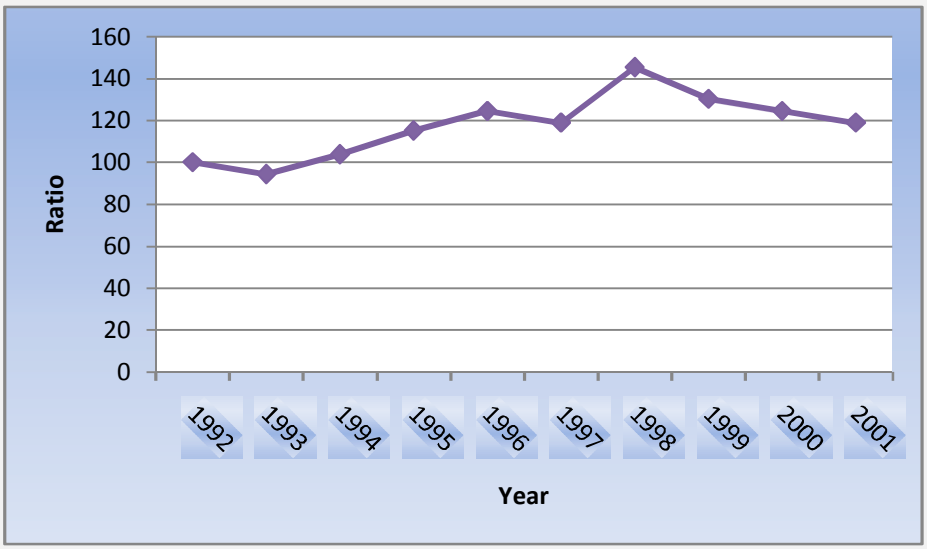

Fig. 3- Total factor productivity (percent) according to the base year 1997.

Land Productivity Index

The land productivity index is the ratio of the amount of crop production (output) to total land under planting. Fig. 4 shows the trend of the land productivity index during 1992-2001. The overall trend shows a mild increase in the index during the years studied. This result indicates relatively positive efforts towards using land efficiently for higher crop production.

Machinery productivity Index

The machinery productivity index is the ratio of the amount of crop production to the efficient power of machinery used in the sub-sector. The trend of this index is shown in Fig. 5. This index shows a decline for 1993, but experiences a slight increase during 1993 to 2001 which indicates the efficient use of machinery power to increase the crop production in sub-sector.

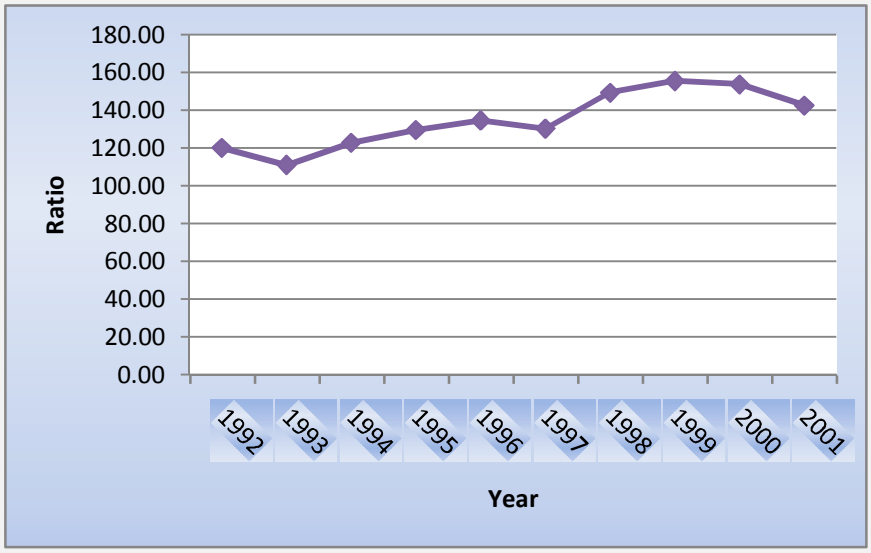

Fig. 4 - Land productivity index (percent) according to the base year 1997.

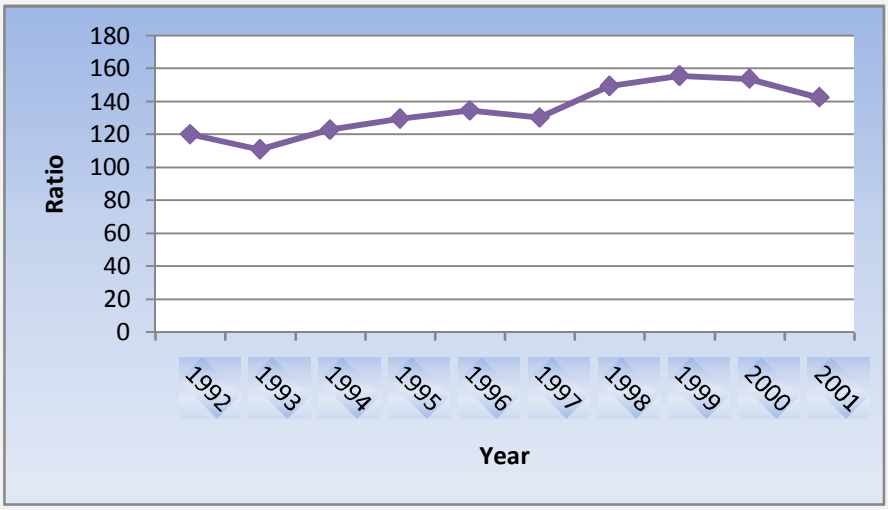

Fig. 5- Machinery productivity index (percent) according to the base year 1997.

Planting Productivity Index

The planting productivity index measures the ratio of output (crop production) to the planting costs. According to Fig. 6, this index is low during 1993, 1995, 2000 and 2001, but shows high values in 1994, 1996, 1997, 1998 and 1999. This result indicates that there is no particular efficient program for managing the planting costs in the sub-sector. For example, it is fairly obvious that most farmers use heavy fertilizer applications during planting to increase the yield. This manner is common among farmers without giving consideration to the economic implications.

Care Productivity Index

The care productivity index is the ratio of the amount crop production (output) to crop care costs during the growing season in the sub-sector. Crop care includes irrigation, pest and weed control, fertilizer applications etc. Fig. 7 shows the trend of the care productivity index in the sub-sector during 1992-2001. Except for 1997 (with a change in the government), the trend of this index has experienced a considerable increase during the years studied. This result indicates that, despite the higher planting costs in Fig.6, the overall costs of care operations during the growing season have decreased which resulted in higher care productivity index.

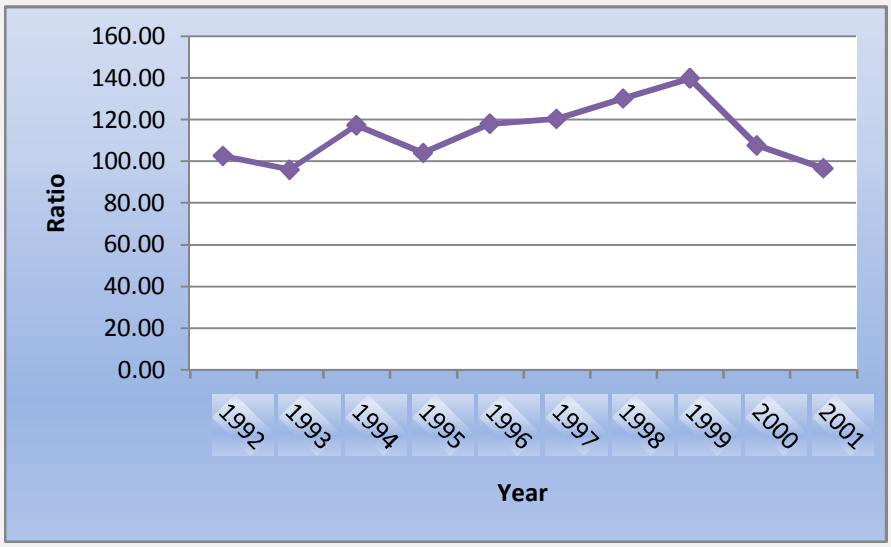

Fig. 6 - Planting productivity index (percent) according to basic year 1997.

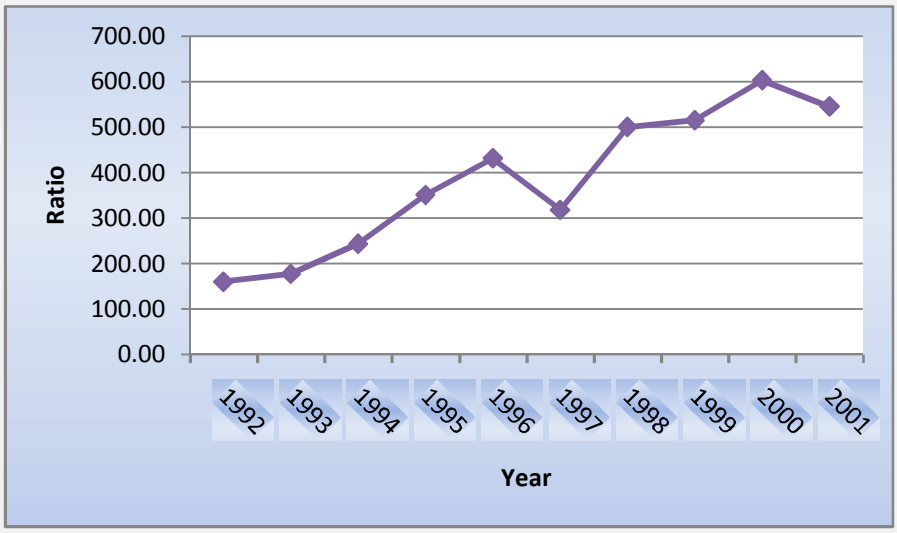

Fig. 7- Care productivity index (percent) according to the base year 1997.

Harvest Productivity Index

The harvest productivity index represents the ratio of the amount of crop production (output) to harvest and post-harvest costs. Post-harvest includes any operations from harvesting the products until storage; however, transportation of products to markets is not included in this. Fig. 8 illustrates the trend of harvest productivity index. The trend is very similar to the care productivity index (Fig. 7) which indicated efficient harvest and post-harvest operations during 1992-2001 (except 1997).

Production Productivity Index

The production productivity index is the ratio of the amount of crop production (output) to the total production costs. Fig. 9 shows the trend of the production productivity index. The index trend is highly similar to that of the care productivity index (Fig. 7) and the harvest productivity index (Fig. 8). This result indicates that most of the items involved in the production process have been efficiently used. The higher production productivity index is a promising issue for the agronomy and horticultural sub-sector.

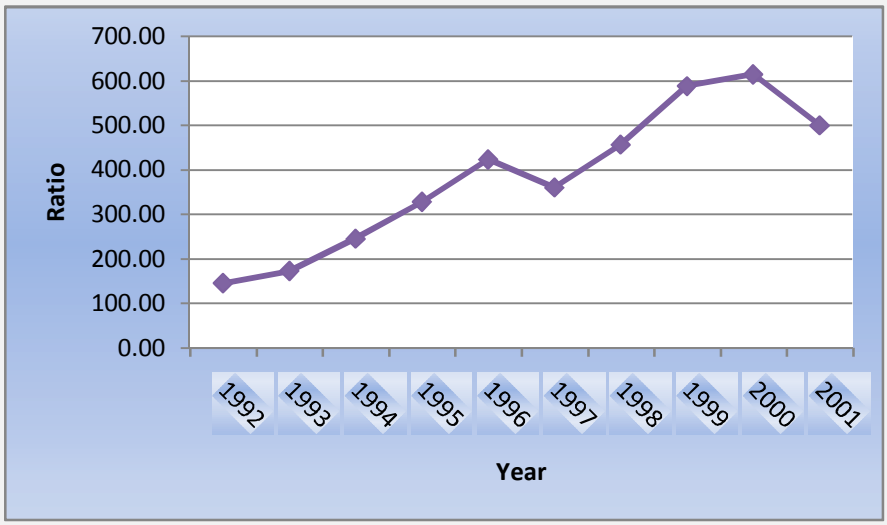

Fig. 8- Harvest productivity index (percent) according to basic year 1997.

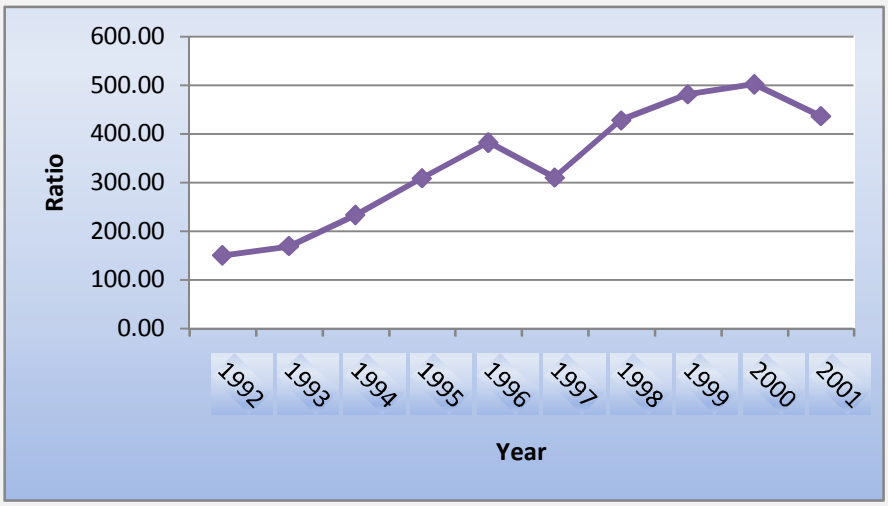

Fig. 9- Production productivity index (percent) according to the base year 1997.

Principal Component Analysis (PCA)

Principal component analysis was performed for the agronomy and horticultural sub-sector indices. The results are given in Table 4 and they include eigenvalues, proportion variance, cumulative variance, and PC scores. According to Table 4, PCs with eigenvalues with equal and higher than 1 were considered significant. The first two PCs (PC1 and PC2) were significant with eigenvalues of 6.08 and 1.61, respectively. This situation is also shown in Fig. 10 which provides the scree plot of eigenvalues for PCs. Furthermore, the variance proportions of PC1 and PC2 were 67.6% and 17.9%, respectively, which made 85.5% of total variance. This 85.5% of total variance means that these two PCs explain 85.5% of variance (information) in original data.

Within PC1 and PC2, the variables with score value of 0.30 and higher are considered significant. In PC1, with a 67.6% variation, TFP, machinery, land, care, harvest and production indices are significant. The positive sign of these variables indicates the positive correlation between them. In PC2 with a 17.9% variation, labor, capital and planting indices are significant. The signs for the capital and planting indices are negative while the sign of labor is positive. The different signs in PC2 indicate that labor has a negative relationship with both capital and planting. It is important to consider the amount of variance in PC2, i.e. this kind of relationship between labor, capital and planting is observers only in 17.9% of total variation among original data.

Table 4- The PCA output which includes eigenvalues, proportion variance, cumulative variance, and PC scores. Bold values indicate significant parameters.

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9
Eigenvalue	**6.0828**	**1.6106**	0.9781	0.2382	0.0725	0.0148	0.0028	0.0002	-0.0000
Proportion	0.676	0.179	0.109	0.026	0.008	0.002	0.000	0.000	-0.000
Cumulative	0.676	0.855	0.963	0.990	0.998	1.000	1.000	1.000	1.000
PCA Scores									
Indices	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**	**PC8**	**PC9**
Labor	0.109	**0.472**	-0.723	0.491	-0.005	0.003	-0.040	-0.005	-0.000
Capital	0.122	**-0.577**	-0.591	-0.351	0.142	-0.365	-0.160	-0.035	-0.000
TFP	**0.376**	-0.215	-0.195	-0.167	-0.440	0.736	0.060	0.084	-0.000
Machinery	**0.399**	0.035	0.075	-0.003	0.553	0.156	0.051	-0.035	-0.707
Land	**0.399**	0.035	0.075	-0.003	0.553	0.156	0.051	-0.035	0.707
Planting	0.240	**-0.549**	0.176	0.743	-0.121	-0.157	0.115	0.070	-0.000
Care	**0.386**	0.217	0.016	-0.219	-0.203	-0.402	0.558	0.491	-0.000
Harvest	**0.388**	0.165	0.196	-0.020	-0.176	-0.176	-0.797	0.295	-0.000
Production	**0.395**	0.141	0.100	-0.080	-0.297	-0.243	0.068	-0.810	0.000

Fig. 11 shows the combination of scatter plot of variable scores of PC 1 and PC2 and also year scores. This scatter plot is useful to the variable weights along with years for better interpretation. However this combined scatter plot has been split into two other scatter plots (Fig. 12 and Fig. 13) which will be explained later.

In Fig. 12 the loading plot of PC1 and PC2 is shown which indicates the correlation between old variables and new PCs. In fact, the loading plot shows the amount of influence of each variable on the new PC formation. According to Fig. 12, along with PC1 axis the indices of care, harvest, production, machinery and TFP are located at the positive end.

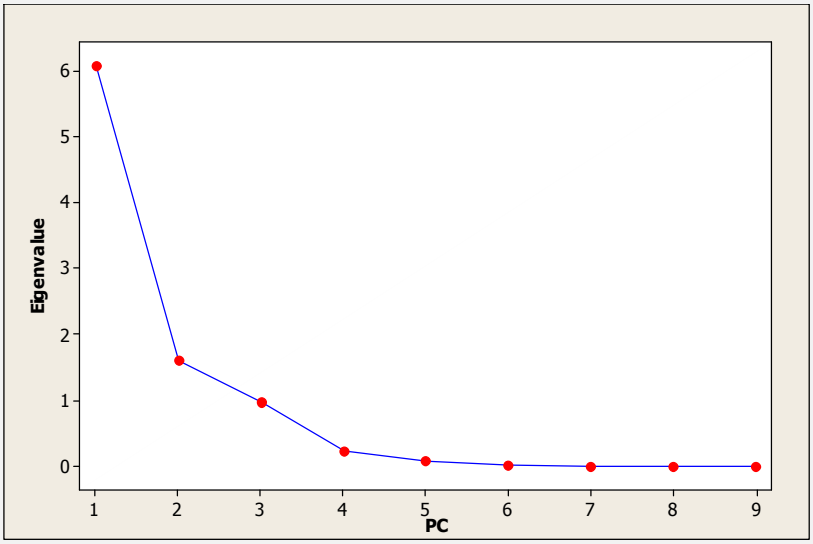

Fig. 10 - Scree plot of PCs with their related eigenvalues.

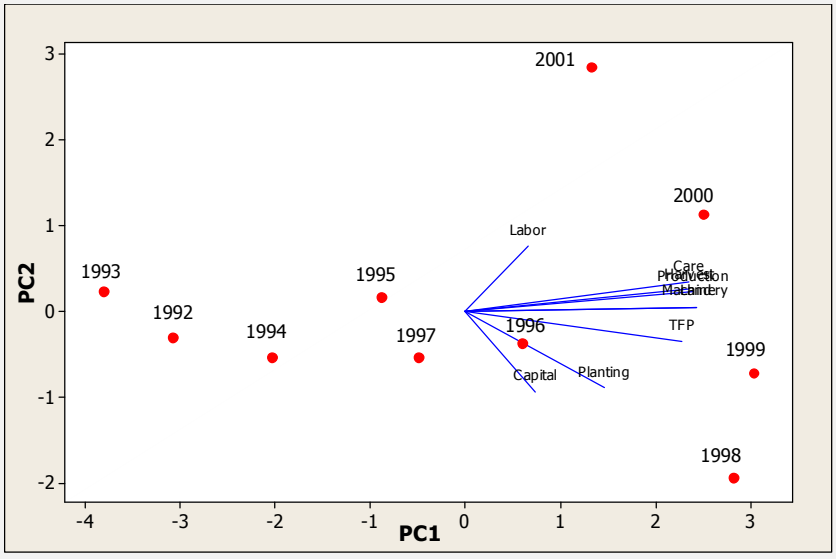

Fig. 11- Scatter plot of PC2 scores on PC1 scores, based on variable weights and annual scores.

This result shows that the aforementioned indices at the right end of PC1 had a greater contribution to the formation of PC1 and all have a positive correlation with each other. In contrast, labor, capital and planting indices had no significant impact on PC1.

Along the PC2 axis, the labor index is located at the positive end of this axis and the other two indices (capital and planting) are at the negative end. This result indicates that 17.9% of original data increase in the labor index comes with the decrease in capital and planting indices and vice versa.

Fig. 13 is a useful typical scatter plot of PCs which shows the influence of variables on a given PC according to any grouping variable. In this investigation, the grouping value is the number of years of study. The years 1998, 1999, 2000 and 2001

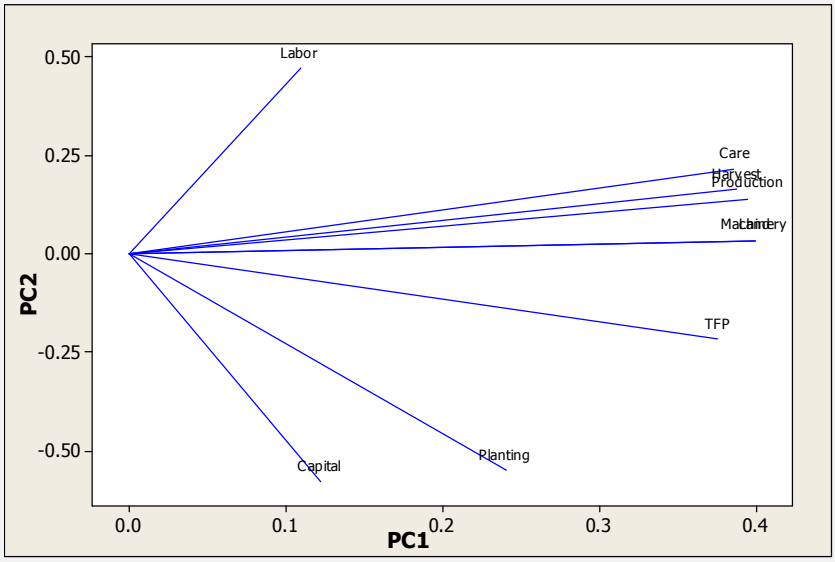

Fig. 12- Loading plot of PC1 and PC2 scores based on variable weights.

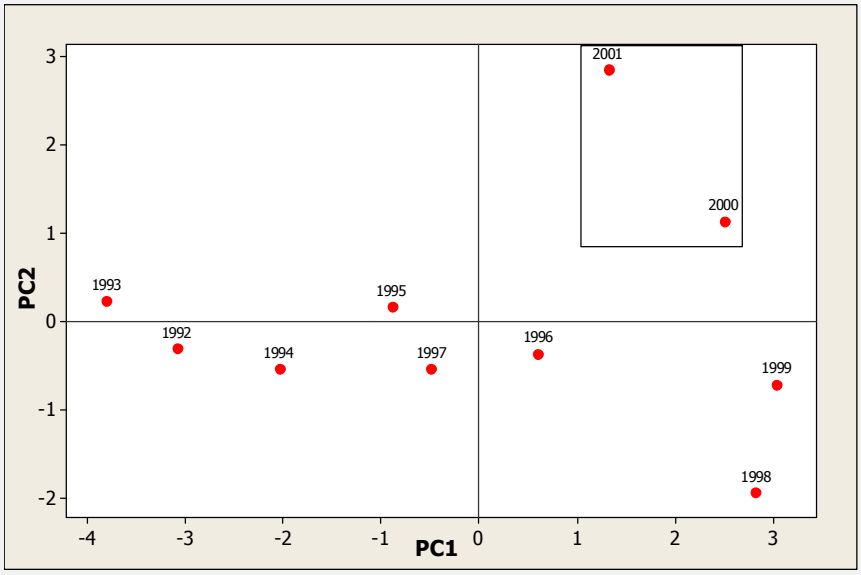

Fig. 13- Scatter plot of PC 1 and PC2 scores based on annual scores.

are located at the positive end of PC1. Again, with a combination of Fig. 12 and Fig. 13, the positive end of PC1 indicates that in years 1998-2001 the indices for care, harvest, production machinery and TFP had higher values in contrast with 1992-1994 (at the negative end of PC1). This result indicates that for most indices the second period (after 1997) has a higher value in most of the productivity indices.

In PC2, the year 2001 is located at the positive end with 1998 at the negative end. With help from Fig. 12, it is discovered that 2001 has higher labor value but lower capital and planting values, while year 1998 has lower labor value and higher capital and planting values. With this result we can understand the negative relationship between labor and other two indices (capital and planting) in PC2 with a 16.7% variation.

By combining PC1 and PC2, it can be shown that the years 2000 and 2001 are almost the best years based on productivity indices. This result is due to the years and indices located at the positive end of both PC1 and PC2.

Discussion

The calculated productivity indices showed different trends for different indices. The labor productivity index was consistent during 1992 to 2000, but increased rapidly up to 2000. This increase was about 60%. Almost the same trend was observed for the capital productivity index, except that in 1998 it showed a 20% increase. The labor productivity index shows the ratio of output to labor input, and it may also affected by many factors other than the influence of the workforce, such as: the amount of available capital equipment and its nature, management practices and the introduction of new technologies. However, the results indicate that perhaps the number of employees is high in contrast with the surplus value of the sub-sector. In other words, the high number of lower educated employees leads to a lower surplus value and hence to a lower labor productivity index. It is probably useful to reduce the number of employees but increase the level of academic education in the employees of this sub-sector. The trend of the capital productivity index indicates that the current constant capital had no significant effect on surplus value in the sub-sector. This result may be due to the lack of efficient use of technology or to somewhat weak management programs in the sub-sector.

There was a similar trend for three indices, namely the TFP, land productivity index and machinery productivity index. All these three indices showed a slight increase during the studied years. This increase varied from 20% to 50%. For TFP which is used as an indicator of efficiency, a combination of labor and capital generated output efficiently. A similar explanation can be shown for the land and machinery indices.

Except for the planting productivity index which showed high variation during these years, the care productivity index, harvest productivity index and production productivity index all showed a high linear increase during 1992-2000. This increase was about 500% in 2000. These results indicate promising improvement in production productivity including planting, care, harvest and post-harvest processes which affect agricultural productivity.

Also, principal component analysis (PCA) was performed as a final and effective analysis to interpret the results. PCA is one the most common methods of multivariate analysis. In General, it is used to identify a small set of variables which account for a large variation among original data. In other words, when there is large number of variables, it is hard to interpret the relationship between original variables and identify the most important variable or variables which have the highest influence on variation (information) in the original data. In experimental designs, each dependent variable is generally exposed to analysis of variance (ANOVA) and then the results are interpreted individually for each variable. When

the number of variables increases, the interpretation becomes more complex. PCA as one of the most useful multivariate analyses combines all the variables in one analysis. This technique provides new variables called principal components (PC) which are independent (orthogonal) from each other, while the original variables are correlated. Another important feature of these new variables (PCs) is that these PCs have a linear correlation with the old variables. PCA is therefore a useful technique when there is strong correlation among the original variables. In other words, if the original variables have not correlated with each other, PCA does nothing. The first PC has the highest variance and the second PC the next highest variance and so on. In PCA we are hoping to reduce the number of variables to the minimum number of PC. It means if PCA produces only one PC with 100% variance, it will be the best result, but in reality this result is rare or impossible (Kamboozia, 1994; Manley, 1994; Sharma, 1996).

The PCA results indicate that in almost all of the second period (post-1997), most of the productivity indices have improved. These indices were TFP, machinery, land, care, harvest, and production. However there was another relationship found between some indices which were shown in years 1998 and 2001. In these two years, the labor index had a negative correlation with two other indices which were capital and planting. The year 2001 had a higher labor index but lower capital and planting indices in contrast with 1998. The results also showed that almost two years 2000 and 2001 have the best situations from productivity indices point of view.

Notes

1. Organization for European Economic Cooperation
2. National Iranian Productivity Organization
3. Total Factor Productivity

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