Analysis of Indonesian Agroindustry Competitiveness in Nanotechnology Development Perspective Using SWOT-AHP Method

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Abstract

Application of nanotechnology opens vast opportunities for increasing the competitiveness of the national agroindustries. In this study, five agroindustries that potentially applied nanotechnology were reviewed and analyzed by using a SWOT-AHP (strength, weakness, opportunity, threat, and analysis hierarchy process) to determine the position of the competitiveness of each industry. Criteria were analyzed based on internal factors that have the potential to be the strengths and weaknesses, and external factors into opportunities and threats. The survey was conducted involving 10 experts engaged in the field of nanotechnology, food, agriculture and policy. Further data were processed using Superdecisions Software Version 2.0.8. Results showed that internal criteria were dominated by the factors of technology and availability of raw materials and energy and provided a significant competitive value (0.67) compared with external criteria (0.33), which were dominated by the factors that create significant economic impact (such as increase in value-added products and a broaden market scope). Development of nanotechnology, which is directed to industrial food, herbal medicine, and fertilizer, is highly prospective for supporting the national program of food security and health as detailed in the National Research Agenda. Competitiveness position value for each industry shifted when independent variables used in the analysis of quantitative SWOT was replaced with dependent variables used in the SWOT-AHP. The result of this study can be used as a reference for the stakeholders for strategic decision making in relation to improving the competitiveness of national agroindustry through the development of nanotechnology.

Keywords: Nanotechnology, Agroindustry, Competitiveness, SWOT-AHP

1. Introduction

Application of nanotechnology opens vast opportunities in improving competitiveness of national agroindustry (Tiju & Mark, 2006; Norman & Hongda, 2002). However, nanotechnology development strategy by considering strategic factors to enhance global competitiveness of the national agroindustry has not been formulated yet. SWOT Analysis (acronym of strength, weakness, opportunity and threat) is widely used in formulation of strategy by evaluating internal strengths and weaknesses and external opportunities and threats of an organization that can serve as a foundation for formulation and development of a policy. However, the conventional SWOT, used to analyze strategic environmental factors qualitatively only so that the result was less objective and did not give priority to existing various factors and strategies (Hill & Westbrook, 1997). David (1998, 2002) has reviewed various methods of quantitative SWOT matrix involving EFE (external factor evaluation) and IFE (internal factor evaluation) that could be used to formulate more accurate strategy.

In a previous study, Rochman et al. (2011) had examined nanotechnology development strategy to increase competitiveness of national agroindustries by using quantitative SWOT analysis. Competitive position of ten agroindustries, that potentially applied nanotechnology, was analyzed using SWOT matrix. However, the quantitative SWOT analysis generally used independent variables, so that the competitive position of each industry could not completely be compared objectively.

On the other hand, AHP (analytic hierarchy process) is an analytical tool with multi-criteria decision that uses mathematical methods both quantitatively and qualitatively to analyze complex decision problems (Saaty, 1980). Application of AHP in SWOT analysis method can help decision maker to select alternatives and strategies that have been provided from the results of SWOT analysis (Saaty, 1987). In order to improve performance of the use of SWOT analysis, AHP method can be combined with SWOT analysis (Kurttila et al. 2000; Stewart et al. 2002) so that a new hybrid method that provides objective weighting can be obtained.

Therefore, this study aims to 1) assess and analyze five agroindustries, that potentially apply nanotechnology, by using SWOT-AHP (strength, weakness, opportunity, threat - analysis hierarchy process) and then 2) to determine competitive position of each industry objectively by comparing with quantitative results of SWOT analysis that was obtained in previous studies (Rochman et al., 2011).

2. Research Method

Figure 1 shows research procedure to determine competitive position of agroindustries that potentially apply nanotechnology by using SWOT-AHP method. First, selection was conducted by choosing the highest competitiveness score of five agroindustries that potentially applied nanotechnology in quadrant SO that obtained from the result of previous study (Rochman et al., 2011). The five industries were 1) fertilizer industry, 2) pesticide industry, 3) food industry, 4) herbal medicine industry and 5) packaging industry as shown in Table 1. Competitive criteria were determined by identifying internal factors that had potential to be the strengths and weaknesses, and external factors which could result in industry opportunities and threats. Table 2 shows a list of criteria that consist of potential internal strengths and weaknesses, and external opportunities and threats in the future.

The next stage is to construct a hierarchical structure of the selected five agroindustries that potentially applied nanotechnology, which consists of three hierarchical levels which were goal, criteria and alternatives. Table 3 shows composition of institutions and areas of experts that were the sample in this study. The selected institutions consisted of institutions that deal with industry and R & D in the field of nanotechnology and agriculture. The chosen ten experts have at least expertise in two areas, such as an expert in the field of policy and on the other hand they also have good understanding on nanotechnology. Or those who mastered in the field of food, on the other side also have good knowledge in agriculture or nanotechnology. Investigations were carried out by direct interviews or sending questionnaires via email. The questionnaires were made as pair wise comparisons to determine the competitiveness of each criteria and to rank the competitiveness of each industry. The data obtained were processed using Superdicisions Software Version 2.0.8.

The results of values weight of criteria and competitive position of each industry were mapped within SWOT coordinates. The competitiveness values obtained from quantitative SWOT method (Rochman et al., 2011) were then compared with the results obtained in this study using SWOT-AHP method to see how far the correction caused by the differences of variables (independent variables for the quantitative SWOT method and the dependent variable for the SWOT-AHP).

3. Results and Discussion

Results of pair wise comparison between criteria in both internal and external groups give value weight on competitiveness of each criteria in nanotechnology development perspective in agroindustry as shown in Figure 2. Internal criteria are clearly more influential with value weight of 0.67 compared to external criteria (0.33). For internal criteria, the highest weight value is occupied by the availability of human resources/ experts of nanotechnology (0.20) and the easiness level for mastering nanotechnology (0.17) followed by the availability of raw materials and energy sources (0.11) and infrastructure facilities (0.08). Total of these four internal criteria reach 45% of the total weight of competitiveness or dominate around 67% of the total value of the weight of internal criteria. This indicates that development of nanotechnology-based agroindustry depends on the strength factors of R & D which consists primarily of the level of mastery of technology, human resource capability and its supporting facilities in addition to the availability of raw materials and energy sources. This illustrates that, in addition to the factors of technology as a source of innovation, it is necessary also to posses raw material that must be economical and easy to be obtained.

These results suggest that the barrier of entry of nanotechnology-based business is not dominated by purely financial factors but rather factors of innovation and the supply of raw materials. Therefore, many countries in the world, especially developed countries, have interrupted the existing system, by allocating huge funds and mobilize resources to improve the global competitiveness of their national industries (Kawai, 2002). This condition is also consistent with the results of the survey of the Ministry of Industry (Herman et al., 2009) regarding the current state of national industry that potentially apply nanotechnology as shown in Figure 3. As shown, the biggest problem faced by industry for applying nanotechnology is the mastery of technology and human resource factors in addition to limited information.

Meanwhile, competitiveness of external criteria possesses only 33%, where the highest weight is dominated by the attraction of consumers to use nanotechnology products (0.12) and economic value-added nanotechnology product (0.08). Other factors, such as: governance and organizational policies, supporting environment during implementation, global dynamics and risk, do not affect significantly the competitiveness of industry.

Figure 4 shows results of SWOT-AHP for determining competitive position of agroindustries that apply nanotechnology at each hierarchical structure. Food industry (0.3) and herbal medicine industry (0.3) have the highest competitive position followed by fertilizer industry (0.23), packaging industry (0:09) and pesticide industry (0.08) respectively. Table 4 and Figure 5 show the level of competitiveness of each criterion for agroindustries that potentially apply nanotechnology. In herbal medicine industry, the level of competitiveness in almost all criteria, is relatively high. This indicates that herbal medicine industry takes the greatest potential for applying nanotechnology by utilizing local raw materials of natural resources and human resources. China and Korea have formulated strategy for development and application of nanotechnology as a national focus program for improving the global competitiveness of their herbal medicine industry (Kawai, 2002).

In herbal medicine industry in Indonesia, the lowest level of competitiveness criteria is the level of the ease of mastery of nanotechnology (0.08) and the cost of implementation (0.11) for the internal criteria and the magnitude of risk from the application of (0.12) nanotechnology to external criteria. Processing technologies (extraction, separation and purification) for raw materials from natural resources is still a significant constraint so that herbal medicine industries tend to utilize the imported active agents with expensive price. Meanwhile, the cost of testing and certification of drugs in Indonesia is still relatively expensive and takes time, thus inhibiting the process of implementation of nanotechnology in industry. It is also because in general there is still resistance to new drug application because of the high level of risk potency.

Food industry in general has the potential application of nanotechnology as well as herbal medicine industry, both in terms of availability of raw materials, human resources, added value and economic impact of application of nanotechnology. However, the readiness of food industry will be an internal constraint, because the application of nanotechnology will slightly affect many existing products which had long been accepted by consumers. The appearance of new products requires a specific strategy that is not necessarily easy. Although the market in the food industry is very large, but in relation to the application of nanotechnology until now not all food products can apply nanotechnology because food is generally served after passing through the cooking process, thus affecting or even damage the quality of the function of nano itself.

On the other hand, although fertilizer industry has potential natural resources and the level of easiness in implementation, but the readiness of fertilizer industry and market scale and scope, availability of research facilities and human resources still remain inadequate. This is also exacerbated by the dependence on the global dynamics, where the price of raw materials and import of energy is still volatile. Government support to the fertilizer industry (in the presence of fertilizer subsidies) can raise the potential for competitiveness, although until now the impact of the application of nanotechnology in the fertilizer industry is still not widely reported. Packaging and pesticides industries have the lowest level of competitiveness because almost all criteria (aspects of technology, raw materials, the readiness of human resources, infrastructure and economic impact and influence of global dynamics, etc.) have relatively no significant value.

The selection of herbal medicine and food industry as key priorities in agroindustry in Indonesia will be in line with the priority program of the Ministry of Research and Technology, which puts the health and food security as one of seven focuses on national priority programs (ARN, 2010). Meanwhile, fertilizer, pesticide and packaging industries are as supporting industries to obtain a maximum agricultural productivity.

Table 5 and Figure 6 show comparison of competitive position of each agroindustry that might apply nanotechnology derived from quantitative SWOT analysis (Rochman et al, 2011) and SWOT-AHP. In order to obtain a relevant comparison, the quantitative SWOT analysis results were normalized by dividing each competitive value of industry with a total value of the whole. Sign II shows the results of SWOT-AHP while the value of quantitative SWOT analysis results are given no sign.

Competitive position of herbal industry from the results of the SWOT analysis that has been normalized quantitative shifts to the lower-left or decline drastically, which means that a decline in the level of internal and external opportunities while using a SWOT-AHP. Contrary to this, the food industry's competitiveness position shifts to the right-up or increase drastically, which means that an increase in internal strengths accompanied by the increase in external opportunities after using a SWOT-AHP. On the other hand, the fertilizer industry's competitiveness position shifted to the right-down significantly indicating that a significant increase in external opportunities but accompanied by a decrease in the level of internal strength. While there are no significant change for competitive position of pesticides and packaging industry by using both quantitative SWOT and SWOT-AHP.

Differences in approach between quantitative SWOT analysis and SWOT-AHP may also cause differences in competitive position of each industry. In quantitative SWOT analysis, where the variables of competitiveness of each industry are independent to each other, competitive position of herbal medicine industry has a relatively higher than that of other industries. This shows that when we do not consider other factors outside of herbal medicine industrial system (for example we do not consider competitiveness of other industries) the development opportunities of herbal medicine industry will be very prospective. But when the competitiveness variables (criteria and competitiveness among industries) is considered by calculating using a SWOT-AHP method, then the competitive position of herbal medicine industry would be corrected by a decrease to the left-down significantly, although the position still has a relatively high value compared with other industries.

Meanwhile, competitive position of food industry shifts to increase significantly when we consider criteria and factors of competitiveness among industries. This illustrates that food industry has a competitive position relatively higher than that of other industries. On the other hand, fertilizer industry experiences a correction to right-below position, which indicates that despite the competitiveness of the external opportunities is better than others, but the internal strengths are still much weaker than the average. In the packaging and pesticide industries, both competitive positions of internal strengths and external opportunities do not change significantly with different methods and their values are far below average.

4. Conclusions

Five agroindustries that potentially apply nanotechnology, assessed and analyzed using quantitative SWOT and SWOT-AHP to determine their competitive positions. Internal criteria which are dominated by mastery of technology and availability of raw materials and energy, give a significant competitive value (0.67) in comparison to external criteria (0.33), which are dominated by the factors that create significant economic impact (such as increase in value added nano-enabled product and large market scale and scope). Nanotechnology development focusing on food, herbal medicine and fertilizer industries is very prospective especially for supporting the national program of health and food security as reported in National Research Agenda. Competitive position value of each industry shifts when independent variables that utilized in quantitative SWOT analysis are replaced with dependent variables that utilized by SWOT-AHP method. The results of this study can be used as a reference for stake holders in formulating a strategy of decision making for improving the national agroindustry through nanotechnology development.

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Table 1. List of five agroindustries that potentially apply nanotechnology

No	Industry types	Explanation
1	Fertilizer	Nutrients Nanoparticles for fertilizer formula with high efficiency – Fertilizer made from carbon nano-tube to accelerate germination and seedling growth of tomato plants (Maria *et al*, 2010).
2	Pesticide	Nanoparticles for enhancing the effectiveness, solubility and stability of pesticides. – Pesticides have been developed in the form of nanoemulsion and encapsulation that contains particles between 100-250 nm. (Tiju & Mark, 2006).
3	Food	Nanoparticles for enhancing the solubility, absorption efficiency and nanocoating (encapsulation) for protective vitamins and other nutrients - The use of nanoparticles to enhance dispersion choronoid in margarine products (Bugusu, 2008). - Bread that contains beta carotene and nanoparticles of Fe and Ca compounds for improving nutrition and health (Bhupinder, 2010)
4	Herbal medicine	Nanoparticles to enhance the solubility of active agents and improve efficiency of absorption by the body - Nano-ginseng (Lee *et al,* 2006).
5	Packaging	Nanoparticles as reinforcing filler, anti-bacteria, oxygen gas filtration, thermal stability etc. (Miller & Kinner, 2006; Sorrentino et al., 2007)

Table 2. Symbols used for criteria of agroindustry competitiveness

Factors	Criteria of agroindustry competitiveness	Label
Internal Environments	Sustainability or a potency to survive in the future	KI 1
	Availability of research facilities, equipment and infrastructure	KI 2
	Production costs for nanotechnology application	KI 3
	Level of easeness for mastering technology	KI 4
	Availability of raw materials (natural resources) and sources of energy	KI 5
	Availability of human resources who are expert in nanotechnology	KI 6
	Readiness of application of nanotechnology in industry	KI 7
	Total internal criteria	KI
External Environments	Governmental support to provide better policy	KE 1
	Attraction of consumers to use nanotechnology products	KE 2
	Added value and economic impact when applying nanotechnology	KE 3
	Market scale and scope for nanotechnology implementation	KE 4
	Readiness of environment during nanotechnology implementation	KE 5
	Global dynamics that affect the supply-demand of raw materials, energy, prices, and macroeconomic	KE6
	The risk of application of nanotechnology in agroindustry	KE7
	Total external criteria	KE

Table 3. Type of institutions and filed of expertises involved in the survey

Institutions	Number (person)	Field of expertise	Number (person)
Ministry of Agriculture	2	Policy	3
Bogor Agricultural University	2	Foods	5
Research Center (LIPI, BPPT)	4	Nanomaterial	5
Ministry of Industry	2	Agriculture	6

Table 4. The level of competitiveness of each criterion for agroindustries that apply nanotechnology.

Criteria		Industry				
		I1	I2	I3	I4	I5
Internal	KI 1	0.380	0.058	0.369	0.160	0.033
	KI 2	0.053	0.030	0.392	0.392	0.132
	KI 3	0.491	0.134	0.234	0.110	0.032
	KI 4	0.415	0.111	0.358	0.078	0.038
	KI 5	0.283	0.094	0.302	0.283	0.039
	KI 6	0.083	0.050	0.329	0.363	0.175
	KI 7	0.265	0.043	0.118	0.439	0.135
Internal coordinate		0.281	0.074	0.300	0.261	0.083
External	KE 1	0.130	0.047	0.264	0.497	0.063
	KE 2	0.118	0.067	0.226	0.500	0.093
	KE 3	0.376	0.199	0.131	0.267	0.027
	KE 4	0.140	0.051	0.379	0.379	0.051
	KE 5	0.130	0.074	0.298	0.387	0.111
	KE 6	0.071	0.071	0.598	0.187	0.071
	KE 7	0.251	0.055	0.124	0.124	0.447
External coordinate		0.174	0.081	0.289	0.334	0.123

Note: Fertilizer industry (I1); Pesticide industry (I2); Food industry (I3); Herbal medicine industry (I4); Packaging industry (I5)

Table 5. Comparison of the competitiveness position of each of the agroindustry that applies nanotechnology derived from quantitative SWOT analysis and SWOT-AHP

Type of industry	**SWOT Result**		**SWOT result after normalization**		**SWOT-AHP**	
	Coor. X	**Coor. Y**	**Coor. X**	**Coor. Y**	**Coor. X**	**Coor. Y**
Fertilizer	0.75	1.03	0.19	0.25	0.28	0.17
Pesticide	0.38	0.3	0.10	0.08	0.07	0.08
Food	0.96	0.7	0.24	0.17	0.30	0.29
Herbal medicine	1.45	1.65	0.37	0.40	0.26	0.33
Packaing	0.41	0.40	0.10	0.10	0.08	0.12
Average	0.13	0.38	0.20	0.20	0.20	0.20

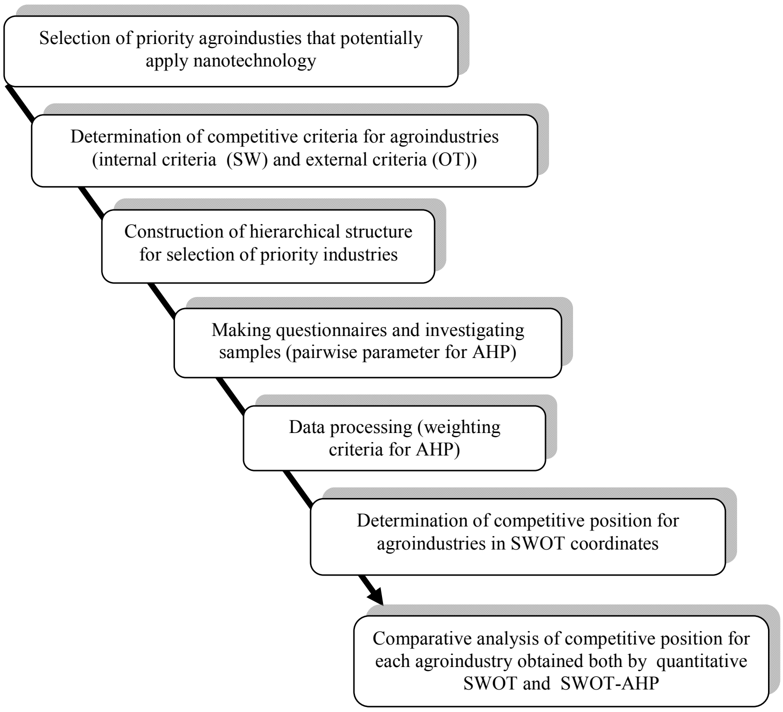

Figure 1. Procedure for determining competitive position of agroindustries that potentially apply nanotechnology using SWOT-AHP method

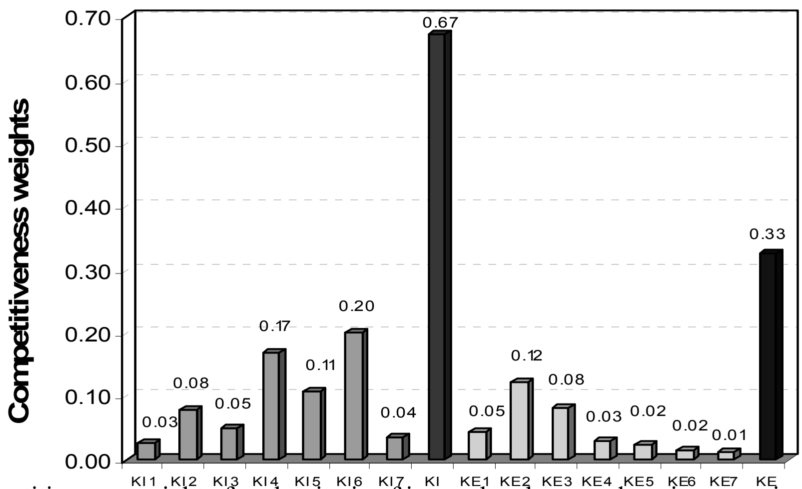

Figure 2. Competitiveness weight of each criteria of internal and external environment in nanotechnology development perspective in agroindustry

(Note: Please refer to Table 2 for the notification of the symbols mentioned in the figure)

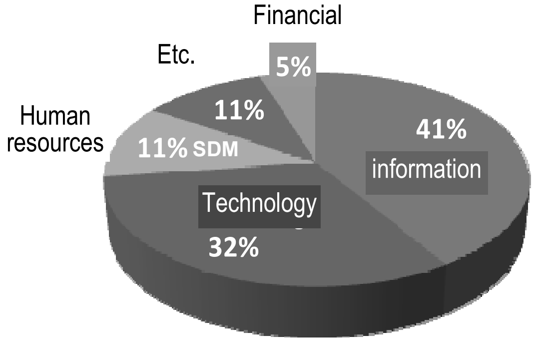

Figure 3. Problems faced by the national industry when applying nanotechnology (Herman et al., 2009)

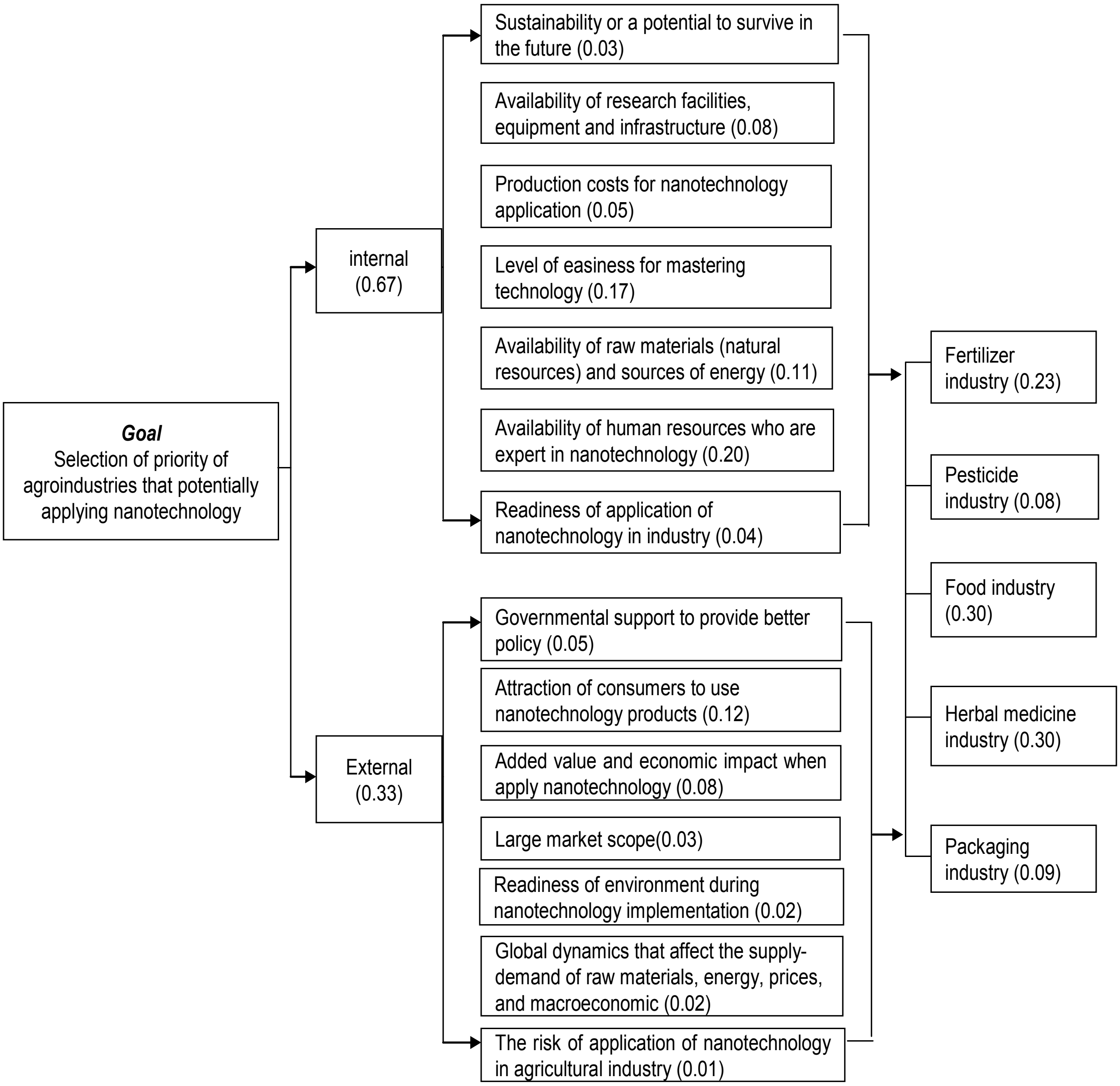

Figure 4. Hierarchical structure of determination of competitive position for agroindustries that applying nanotechnology by using SWOT-AHP

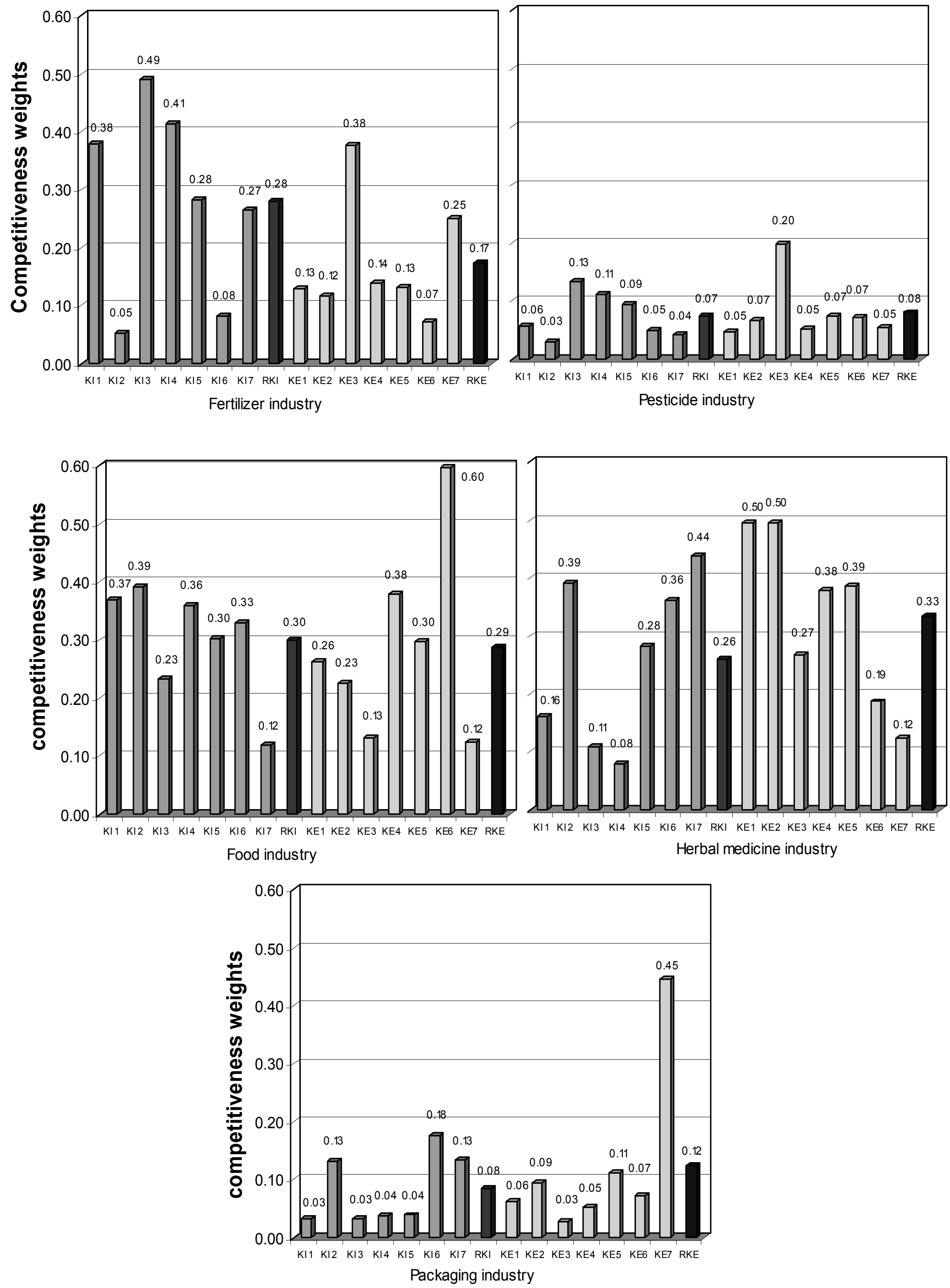

Figure 5. Competitiveness levels of each criteria of agroindustry when applies nanotechnology.

(Note: Please refer to Table 2 for the notification of the symbols mentioned in the figure)

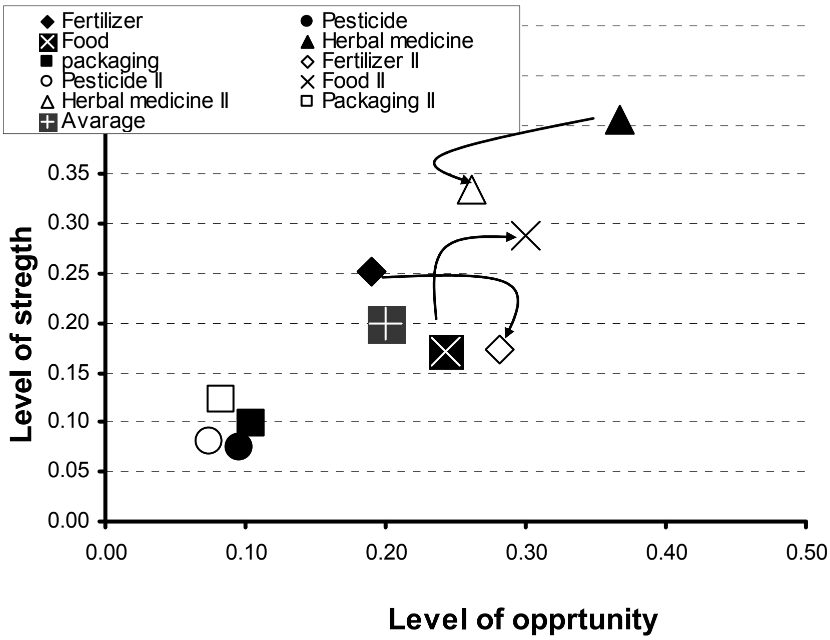

Figure 6. Comparison of the competitive position of each agroindustry which is obtained by quantitative SWOT analysis that has been normalized and SWOT-AHP in quadrant SO