EXPLORING THE MODEL OF NANOTECHNOLOGY DEVELOPMENT IN AGRICULTURE SECTOR OF IRAN

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ABSTRACT

The main goal of this study is to identify factors affecting development of nanotechnology and explore the model of nanotechnology development in agriculture sector. A descriptive type of research was conducted for this study. The total population was all agricultural researchers in Iran. Proportionate stratified random sampling method was used to select 210 researchers. A questionnaire was developed by the researcher and used to collect data. Respondents were asked to indicate their responses on a five-point likert type scale. The statements were validated and the reliability estimate calculated and found to be 0.84 averagely. Descriptive statistics were used to describe data and CFA was used to test the fit of the proposed model, using the LISREL software. Research findings showed that professional skills and organizational culture had a significantly positive effect on psychological empowerment of faculty members, but organizational factors had hardly any effect on psychological empowerment of faculty members.

Keyword: nanotechnology, model, agriculture researcher, confirmatory factor analysis, LISREL.

INTRODUCTION

For a few years now, nanotechnology has been recognized as a promising new growth innovator. This leads to a shift from the exploration of nanotechnology knowledge towards a phase of exploitation. The coming years this commercialization of nanotechnology will be extended. Nanotechnology is a disruptive technology phenomenon, which leads to more difficulties in overseeing business opportunities (Knol, 2004). Nanotechnology today is regarded as a revolutionary technology that can help address key needs relating to energy, environment, health and agriculture in developing countries (TERI, 2010).

The nature of nanotechnology is strongly multidisciplinary and Hullmann and Meyer (2003) show this via the range of scientific disciplines nanotechnology publications and nanotechnology patents covers. Some discipline examples for instance are material science, polymer science, electrical and electronic engineering, optics, biophysics, organic chemistry, or cell biology. They conclude that patent data suggests that the core activities of nanotechnology focus on electronics, instrumentation, and chemicals/pharmaceuticals.

Nanotechnology embeds nanoscience insight in order to fabricate new materials, structures or devices which exploit nanoscale properties (Knol, 2004). The Table below gives more insight into which nanotechnology properties have a specific role in new or enhanced applications.

Table-1. Properties and effects on nanoscale and related (possible) applications.

Properties and effects perceived on nanoscale	Example of (possible) applications
Higher surface to volume ratio - enhanced reactivity	Catalysis, solar cells and batteries
Lower percolation threshold	Conductivity of materials
Increased hardness with decreasing grain size	Hard coatings and thin protection layers
Narrower band-gap with decreasing grain size	Opto-electronics
Higher resistivity with decreasing grain size	Electronics
Increased wear resistance	Hard coatings and tools
Lower melting and sintering temperature	Processing of materials and low sintering materials
Improved transport kinetics	Batteries and hydrogen storage

(Kohler *et al.*, 2003)

Given the enabling nature of nanotechnology and ability to develop along with existing technologies, it has the potential to be utilized as a tool to address key development related challenges in diverse sectors like energy, water, agriculture, health, environment and the like. Enabling energy storage, production and conversion within renewable energy frameworks has been cited as the primary area where nanotechnology applications might aid developing countries (TERI, 2010).

Although industries and applications are or will be (further) influenced by nanotechnology, Bhat (2005) argues that the multidisciplinary nature of nanotechnology makes it very difficult to pin down and prophesy the future impact in any specific sector appropriately. However, one of the other industries that nanotechnology has entered is agriculture. Several studies suggest that nanotechnology will have major, long-term effects on agriculture and the production of food, but it remains unclear whether effects on developing country agriculture and nutrition will be positive or negative. Nanotechnology may help make food products cheaper and production more efficient and more sustainable through using less water and chemicals, which would be a great help to developing world agriculture (Barker *et al.*, 2005).

So, nanotechnology has the potential to revolutionize agriculture and food systems. Agricultural and food systems security, disease treatment delivery system, new tools for molecular and cellular biology, new material for pathogen detection, protection of environment and education of public and future workforce are examples of important inks of nanotechnology to science and engineering of agriculture and food systems (Scott and Chen, 2003).

Modern agriculture is highly knowledge-intensive and increasingly information-driven. With declining terms of trade affecting agriculture vis-à-vis other industries, technological innovations are necessary to reduce transaction costs and facilitate the production and consistent supply of top quality, safe and traceable products to meet consumer demands (Opara, 2003).

In the case of nanotechnology it is advisable to construct scenarios that are influenced by a broad range of elements that originate from science, technology, market, political, legal, and ethical domains. Key factors need to be identified in a variety of segments: developments in nanoscience and nanotechnology, general developments in nanotechnology-influenced industries and markets, specific developments in industries related to alliances, mergers, intellectual property (patent) aspects, (supra)national government (innovation and subsidy) policies on nanotechnology, legal aspects related to nanotechnology and nanotechnology-based applications, societal discussions on implications of nanotechnology, etc (Knol, 2004).

Nanotechnology development in the forerunner countries is characterized by, inter alia, increased investment in research and development (R and D), development of competitive R and D infrastructure, interdisciplinary education and training system together with development of entrepreneurship, technology transfer and innovation and, contribution to economic growth (TERI, 2010).

According to another study, six key indicators including people primary workforce, SCI papers, patent applications, final products market, R and D funding, and venture capital could portray the value of investments in nanotechnology development and associated science breakthroughs and technological applications (Roco, 2011).

Nanotechnology development requires skilled people and specialized equipment, so the capital requirements are higher than for businesses in other sectors. This would seem to indicate that if this sector were truly ‘vibrant’, a high level of venture capital investment would also be seen (Crawley, 2007). Roco (2011) believe that there are two foundational steps in nanotechnology development. Nanotechnology would grow in two foundational phases from passive nanostructures to complex nanosystems. The first foundational phase focuses on inter-disciplinary research at the nanoscale and the second foundational phase will focuse on nanoscale science and engineering integration. The transition from the Nano 1 phase to the Nano 2 phase is focused on achieving direct measurements at the nanoscale, science-based design of nanomaterials and nanosystems, and general-purpose technology integration.

Developing clear national strategies to engage with this emerging technology is necessary. It is imperative to link technology developments with social priorities and goals. The role of the state would be imperative in charting the trajectory of nanotechnology developments in developing countries. Although the growing importance of private sector cannot be underestimated, but in developing countries, the share of public investment in total nanotechnology R and D basket is relatively greater in comparison to private sector (TERI, 2010). In the other hand, industrial adoption of nanotechnology will not succeed without customer acceptance of nanotechnology. The debate about nanotechnology safety is covered heavily in other sources, but it is important to note that responsible development of nanotechnology was critical to be success (Crawley, 2007).

Anyway many factors are involved in nanotechnology development. Although the arrival of nanotechnology in Iran's agricultural sector is in its early stages; But according to the above studies and the importance and future role of nanotechnology in agriculture, the main goal of this study is to identify factors affecting development of nanotechnology and explore the model of nanotechnology development in agriculture sector.

According to the different studies, Figure-1 depicts the hypothetical causal model. Each factor of the model was selected on the basis of the literature review. Previous studies reveal that nanotechnology development in any sectors is influenced by human resources (Ndozuau *et al*., 2001; McNeil *et al*., 2007), and human resources is affected by awareness and education (Roco and Bainbridge, 2005; Lojkowski and Werner, 2007). According to some other studies, commercial (Lojkowski

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and Werner, 2007; Malch and Tuquer, 2004), economic (McNeil *et al*., 2007; Harper, 2009), and policymaking (Malch and Tuquer, 2004) factors also influence the nanotechnology development in agriculture. The hypothesized causal relationships also show that infrastructural factor (Ndozuau *et al*., 2001; McNeil *et al*., 2007) could affect all other factors.

The proposed research model, based on the literature review, is shown in Figure-1. This model gives rise to a series on hypotheses:

H_1: Infrastructural factor has a positive effect on the all other factors.
H_2: Educational factor has a positive effect on the human resource factor.
H_3: All factors have a positive effect on the nanotechnology development in agriculture.

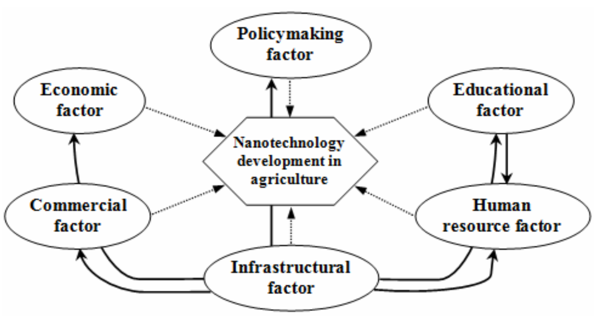

Figure-1. Proposed posed hypothetical model.

MATERIALS AND METHODS

Methodology used in this study involved a combination of descriptive and quantitative research. The statistical population included was 1226 researchers in 25 research institutes of the Ministry of Agriculture that 210 researchers were selected through stratified random sampling method. The data collection method involved the use of personal interviews with a self-administered questionnaire. The questionnaire was designed to gather data on the factors influencing nanotechnology development in agriculture sector. Researchers were asked to indicate their agreement on a five-point Likert type scale (ranging from 1 being "strongly disagree" to 5 being "strongly agree") with statements regarding the six factors affecting nanotechnology development in agriculture sector: (1) Infrastructural factor, (2) Commercial factor, (3) Economic factor, (4) Policymaking factor, (5) Educational factor, and (6) Human resource factor.

The content validity of questionnaire was measured by a group of nanotechnology specialists. In order to investigate the reliability of research questionnaire, 30 researchers were randomly selected and they completed the questionnaire. Cronbach's alpha for the questionnaires were 0.84 respectively. Data collected was analyzed using descriptive statistical methods through Statistical Package for the Social Sciences (SPSS) and confirmatory factor analysis technique through Linear Structural Relationships (LESREL).

LISREL is a versatile and powerful program for fitting structural equation models and multilevel models to observed data. Since confirmatory factor analysis (CFA) is a special case of structural equation modeling, LISREL can be used easily for such analyses. CFA is commonly used in social research. CFA is frequently used when developing a test, such as a personality test, intelligence test, or survey (Kline, 2010) as this study. CFA were conducted to test the fit of the proposed model for the entire sample, using the LISREL program (Jöreskog and Sörbom, 2002). Because the data were approximately normally distributed, maximum likelihood (ML) estimation was used for confirmatory analysis. Briefly, we used goodness of fitness which its null hypothesis indicates that the model is valid (we prefer to accept the null hypothesis, i.e., p-value> 0.05); RMSEA (Root Mean Square Error of Approximation) which takes into account the error of approximation in the population and asks "How well would the model fit the population covariance matrix if it were available?" (P-value less than 0.05 indicate good fit, and higher than 0.08 represents reasonable errors of approximation in the population).

RESULTS

The results of descriptive statistics indicated that agriculture researchers who participated in the study ranged in age from 28 to 59 years. The mean age of respondents was 39.8 years. 87.6% of experts were male and the rest (12.8) were female. Researchers were asked to report their scientific and educational degree: 46.2% of respondents were post graduate; 31.9% were assistant professor; 14.3% had associate professor degree; and 7.6% were professor. 45.7% of respondents had a master's degree and 54.3% had completed PhD degree. Also researchers were asked to indicate the number of years of job experience that they possessed. Years of job experience ranged from 2 to 30 years with the mean of 12.4 years.

The hypothesized structural causal model was tested by LISREL, which included a test of the overall model as well as individual tests of the relationships among the latent constructs. As presented in Figure-2, the results offered support for the relationship between factors at a significant level of 0.05.

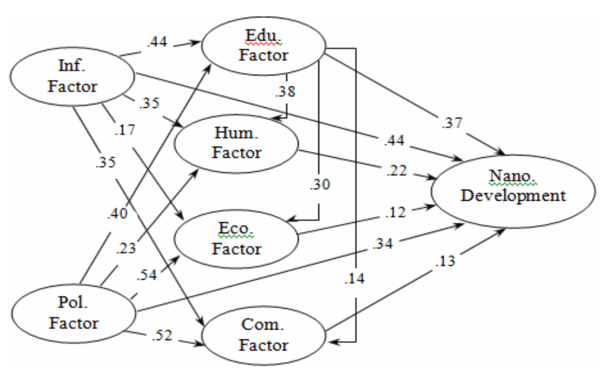

Figure-2. The results of testing hypothetical model.

Consequently, the measures of fit were examined including the Goodness of Fit Index (GFI = 0.91), the Comparative Fit Index (CFI = 0.97) and Root Mean Square Error of Approximation (RMSEA = 0.041). This model appeared to fit well enough, with the GFI and CFI both greater than 0.90 and RMSEA less than 0.05. Based on the above fit indices, it can be concluded that the final model fits the proposed model (Table-2).

Table-2. Goodness-of-fit measures for the structural equation model (N=210).

X^2	GFI	AGFI	RMR	RMSEA	NFI	NNFI	CFI
2.13	0.91	0.79	0.044	0.041	0.98	0.91	0.97

As can be seen, Figure-2 presents the results of the model map. They suggest that the structure in the model is suitable approximately. These findings thus lend further support to the five-factor model of nanotechnology development in agriculture sector.

Based on the obtained model, H_1 was supported. This implied that improvement of infrastructural factor would lead to improvement of human resource, educational, commercial, and economic factor. But in spite of the hypothetical model, there was no association between infrastructural factor and policymaking factor. H_2 was also supported. The educational factor had a significantly positive effect on human resource factor. While it was discovered that educational factor was a determinant of status of economic and commercial factors. In examining the third hypothesis, H_3 was also accepted. All six factors had significantly positive effect on nanotechnology development in agriculture sector with different effect coefficients.

CONCLUSIONS

The findings of this study could explore a model on the nanotechnology development in agriculture sector. First of all, as the confirmatory factor analysis showed, factors were categorized into six factors namely, human resource, educational, commercial, economic, policymaking and infrastructural factors. The factors were shown by the magnitude of their impact (Figure-2).

The findings of testing of the proposed model have implications for the effect of policymaking factor on educational, human resource, economic and commercial factors. Although this relationship is not seen in the hypothetical model, to improve economic situation and trade development for nanotechnology policies should be improved. The role of government and its policies on commercial and economic factors in various studies such as TERI (2010) and Crawley (2007) was confirmed.

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