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Scenarios of nanotechnology development and usage in Turkey ☆

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ABSTRACT

The analysis of future development of an emerging technology, e.g. nanotechnology, by experts has been criticized in the literature for the over-optimism they possess. A more balanced approach would be to take choices of the ordinary people and the effects of the environmental factors into consideration during this process. Prior work on willingness-to-buy for nanotechnology products has indicated that attitudes and beliefs of individuals may have a significant influence on the social acceptance process.

This study surveys the expectations of Turkish individuals and uses that information as an input to understand the possible developments in the use of products based on nanotechnology. Five different patterns emerging from the responses have been converted to 5 distinct scenarios suggesting various possible development paths for nanotechnology in Turkey.

A final scenario has also been formulated using the information on expected context of 2029. It foresees a future where nanotechnology and its applications will be significantly appreciated by the society and is expected to be used in almost all areas of the economy and industry. The survey participants, although reserving their doubts on the potential threats of nanotechnology on human health, will not be hesitant to use it. They also believe that, with increased public investment in the coming years, the utilization of this emerging technology will further be enhanced by 2029.

This study indicates that values of context and focus variables in 2009 and 2029 and foreseen changes from 2009 to 2029 may help companies in the resolution of three types of uncertainty concerning drivers of change, uncertainty about their evolution ("state" uncertainty), uncertainty about their impact on the competitive position of the firm ("effect" uncertainty), and uncertainty about the response viable to the firm ("response" uncertainty).

1. Introduction

Emerging technologies [3] of the 21st century are important for both public [4] and private sectors. They are often not acknowledged and not valued by the public [5], although their effects on the economic context are multiple, including opening up of new markets, increase or decrease of competition in an industry, location of production of goods/services, demand for factors of production such as labor and capital, implications for skills demand, consequences for wages and employment, and impact on the environment etc. [6].

Nanotechnology stands as a prominent example for these emerging technologies in this century [7]. Some economists hope that it would prove to be magic by 2025 [8]. The numbers from different sources seem to support this hope and may also give us a clue about the vitality of the concept. The National Science Foundation (NSF) of the USA has projected that the world market of nanotechnological products will reach 1 trillion USD in 2015. In a study completed in 2004, Lux Research

☆ Gidley [1] defines 4 types of futures in a study investigating the effect of the Steiner education system on the views and visions of the future of the youth. In this study she uses the term "probable future" that is a product of trend analysis and surveys and later Eckersley [2] employs the term "expected" instead of the "probable and possible" to define the type of the future that is about to happen depending on the views shared by the majority. In this paper, we will be using the term "expected scenarios" to emphasize the fact that scenarios are based on the assessments of survey questions by individuals revealing their expectations on the development and usage of nanotechnology in Turkey.

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has estimated a world market of 2.6 trillion USD for the year 2014 [9], whereas Tegart [10] reported an anticipated market size expected to reach 1 trillion USD by 2015. These statistics however can be problematic for the fact that in some studies even if the nanotechnology use of the product is limited and is just an input, researchers take the whole value of end product as the nanotechnological product, and in others they only consider the nanotechnology-used part [11].

It is hard to assess the real economic potential of nanotechnology [11,12], yet, it has already been applied in various fields, such as computer electronics, communication, energy production, medicine and food industry [13], probably requiring novel regulatory methodologies [14]. Economic and social promises and opportunities of nanotechnologies are very important for human beings considering the impact they would have on the public life in terms of quality and wealth creation.

On the other hand, nanotechnology possesses serious risks and dangers besides potentially huge benefits that are mentioned here. The nanomaterials that are incorporated into consumer products are claimed to be relatively inactive. Succeeding waves of nano-based products are expected to have far greater and more profound societal implications, especially as the worlds of nanotechnology, biotechnology, and information technology continue to converge and intersect with one another [15]. Concerns associated with nanotechnology are in line with problems expressed with the management of emerging technologies in general [16]. The issues such as “public perception” and “sustainable governance of nanotechnology” are important concepts and have to be analyzed carefully [17,18]. It is very likely that public perception of nanotechnology will be crucial for the realization of technological advances [19–21]. There are health and environmental concerns on future implications of nanotechnologies. These concerns may affect the willingness-to-buy behaviors of individuals [22,23,18].

There is certainly a need for gathering and assessing public opinion on nanotechnology and products incorporating nanotechnology, as individuals' considerations of the future are highly influenced by their identities and worldviews. The factors that influence the development of nanotechnology will inevitably shape the evolution of this technology and will determine its destiny [24]. Hopes can turn into a “miracle” or can be a “nightmare” for humanity. The state of it just being a “failure” is also among the possibilities. Hence, future research has been suggested to focus on better unraveling these relationships and on understanding their implications for future-oriented policy making [25,26].

There have been various applications of scenario construction for the development of emerging technologies and socio-technical systems which also include nanotechnology. Wiek et al. [27] employed an empirical qualitative system [28] to analyze many possibilities and utilized special software for producing and filtering the scenarios according to the pre-set criteria, with the perspectives of consistency, coherency and diversity. They presented a scenario study on the possible future developments of nanotechnology in Switzerland for the reference year 2020. Their analysis provided a typology of nanotechnological applications named “focus variables” and a set of “context variables” which are suggested to be relevant for the development of nanotechnology (see Section 3). Their conceptual framework produced five possible scenarios for the development of nanotechnology in Switzerland for five distinct market conditions.

The scenario construction methodology of the present study has been based on the answers to nanotechnology issues survey constructed using the focus variables and context variables reported in Wiek et al. [27]. The goal was to identify patterns in expectations of our respondents that would generate development scenarios of nanotechnology in Turkey. The Turkish government assessed nanotechnology as one of the 8 essential technologies in 2005 and research centers along with graduate programs at some universities were established [29]. This paper intends to assist the efforts of the Turkish government by developing futures scenarios of nanotechnology development and usage in Turkey based on a survey and cluster analysis.

The paper is structured as follows. Section 2 shows the literature review on nanotechnology futures. The scenario construction process is explained in the methodology section. The fourth section illustrates the anticipated changes in contexts of 2009 and 2029 and the expected scenarios of nanotechnology use in Turkey. Discussion and conclusions of the research are the final sections of this paper.

2. Nanotechnology futures and scenarios

Studies from various countries indicate different futures scenarios regarding nanotechnology. The effect of the emerging technologies in Finland by 2020 was explored based on a panel of experts [30] in 2004 with the result that nanotechnologies will still be under research in 2020, although there might already be some uses in the industry. Tegart [10] reported 3 scenarios for 2015 for APEC countries titled as; “nano-paradox”, “green energy triggers collapse in energy markets”, and “nanotech wins the war”. The Danish nanotechnology foresight project [31] was also carried out with experts. In this study, time horizons for some nanotechnological products in certain areas are analyzed through a survey assessing the 32 statements under 7 headings:

- Nano-medicine and drug delivery
- Biocompatible materials
- Nano-sensors and nano-fluidics
- Plastic electronics
- Nano-optics and nano-photonics
- Nano-catalysis, hydrogen technology, etc.
- Nano-materials with new functional properties.

The statements were assessed by 133 experts. According to the responses, the periods in which those statements will become a reality were estimated. These periods are defined as “before 2010, 2011–2015, 2015–2020, and 2021–2025”. The corresponding nanotechnological applications in 7 distinct areas are expected to be either in a *developing state* with a definite goal or prototype, or in a *practical application* stage, indicating a niche use of the product in a niche market, or in a *wide application* stage where the product is extensively used and gained significant acceptance from the public with a strong market position. Among the various results indicated concerning distinct sectors were:

- Practical application of intelligent systems in drug delivery systems which monitor the state of cells in the body and

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