THE ROLE OF TECHNOLOGY ENTREPRENEURSHIP IN NANOTECHNOLOGY ADOPTION: AN EXPLORATORY STUDY

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The purpose of this paper is to examine the relationships between nanotechnology innovation and nanotechnology adoption and the role of nanotechnology in creating entrepreneurial wealth and economic growth. Prior research has focused almost exclusively on nanotechnology science, while research on the nanotechnology innovation potential to contribute to the economy growth is limited. We test the effect of three latent variables on nanotechnology adoption. Our results validate the conceptualization of the nanotechnology adoption. Nanotechnology firms have to balance the management of high technical and high market risk. Each new nanotechnology innovation also creates opportunities for entrepreneurs.

Keywords: nanotechnology, entrepreneurship, business model

1. Introduction

Nanotechnology is a relatively new and multidisciplinary field of science that studies and manipulation of atoms and molecules in the range of nanometres. It is the result of interdisciplinary cooperation between material science, biotechnology, physics, chemistry and engineering. Nowadays innovativeness and new technologies are imperative for the flexible and agile businesses developed in a complex and dynamic globalizing world. Nanotechnology is a platform technology that has the potential to be used in a wide range of applications and products. For example, a carbon nanotube that is used to transport a substance can be used in medicine or to build electronic circuits and devices that studying assemblies of atoms and molecules. Nanotechnology falls into the category of converging technologies and is one of main determinants of technological innovation.

Previous research efforts have often focused on nanotechnology research, in attempts to explain or predict the use of outcomes. However, existing studies

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lack the systematic analysis of the role of nanotechnology in creating entrepreneurial wealth and economic growth by examining the business model to exploit the opportunities of nanotechnology. Despite extensive literature on entrepreneurship, little attention has been given in technological entrepreneurship to the convergence of multiple scientific disciplines around a technology. New business model has become a critical concern for the business managers and entrepreneurs in dealing with the emerging technology. Thus, we think can make a worthy contribution to enrich the literatures in nanoscience and technology management. The practitioners in this field can greatly benefit from an examination of the barriers to nanotechnology transfer.

The main purpose of this study is to provide an empirical analysis of the role of nanotechnology in creating entrepreneurial wealth and nanotechnology adoption. It is known that nanotechnology research offers new opportunities for engineers and entrepreneurs. R&D efforts require a relatively large amount of capital investment, but this field offers a wide range of opportunities for entrepreneurs to establish successful new businesses. In this paper, we will investigate how the nanotechnology innovations can be translated into commercially successful products and processes through using of appropriate business models.

This paper aims to identify expert opinion on factors influencing how nanotechnology innovation is commercialised and contribute to sustainable development of the economy and society. Technology-based innovation is a key growth driver in the economic growth. In this respect, this paper contributes to a better understanding of the relationships among nanotechnology, technology entrepreneurship, new business models and economic growth. To achieve this objective a survey was conducted to analyze the critical factors that contribute to commercialised of nanotechnology and generate a competitive advantage.

The methodology adopted in this study includes two phases. In the first, after analyzing the literature and consulting a group of experts in the nanotechnology area a conceptual model was developed. In the second, the data were collected using a questionnaire was administrated to a sample of researchers. With these data, the model proposed was tested empirically. Finally, several findings were derived from analysis of results.

The rest of this article is organized as follows. We review prior literature regarding the nanotechnology role in creating entrepreneurial wealth. The research questions and methodology are then defined and clarified. Afterward research analyses, findings and implications have so far been presented and directions for further research are proposed.

2. Theoretical background and hypotheses development

The literature review reveals the nanotechnology is recognized as a very strong innovation driver and is therefore seen as a strategic technology for the world's future economy. The nanotechnology is a platform technology with a potential to transform many industries (Bozeman et al., 2007). Romig et al. (2007) emphasize that nanotechnology may have different impacts on different industrial sectors.

Due to the versatility of this fascinating cross-sectional technology, it has the potential to change the existing firms' business models and level of demand. This technology can affect the competitive positions of different companies. Nanotechnology drug particles could be designed to release therapeutic molecules in the body only after reaching their targeted diseased tissue. Therefore, new business models have become a key concern for entrepreneurs in dealing with nanotechnology innovations (Nikulainen and Palmberg 2010).

Nanotechnology innovation is, in many cases, a radical innovation. Thus, the performance of a result product will be deep improved. For example, production of silicon based nanoparticles which could significantly reduce costs and weight for liquid crystal displays. The slow speed of nanotechnology commercialization is caused by the timeline of new product platforms and scientific uncertainty. For example, in nano-biotechnology product, new drug development typically taking 15 years, and the regulatory process is more uncertain (DiMasi, 2001).

Technology entrepreneurship is the process through which newness is created and exploits new opportunities. Technology and human intellectual capital are increasingly becoming the key drivers for wealth creation. The economic value of a technology remains latent until it is exploited by using a business model. The nanotechnology is a platform technology with a potential to transform many industries (Bozeman et al., 2007). Romig et al. (2007) emphasize that nanotechnology may have different impacts on different industrial sectors. Thus, nanotechnology could transform or replace existing products and industries.

Small business may lack the resources needed to bring new nanotechnology materials, tools, processes or products to market. For example, lack the capital, infrastructure or distribution channels. Different technologies have different particular logics of operation and create different value for their stakeholders (Roco and Bainbridge 2002). Human capital resources play a key role in commercial transfer of nanotechnology because it is a facilitator and the main indicator of accumulated knowledge residing at employees. Since tacit knowledge is embodied in individuals, collaborations and networks are the ways of mobilizing tacit knowledge. Education is going to have to be complemented by training in how to work in interdisciplinary teams.

Each new discovery creates opportunities for entrepreneurs to establish successful new businesses. Entrepreneurs want to translate the nanotechnology innovations into commercially successful products and processes. However, entrepreneurs who come from scientific or technical areas have relatively little experience with business issues. It is very difficult as the lab-scale invention to be scaled up in manufacturing process. Entrepreneurs need to understand how establishing a new nanotechnology venture.

Science-based business faces technical and market uncertainty because technology is likely to be immature developed and customers are not familiar with new products. Basically, the market demand is not enough high. Nanotechnology ventures are much more likely to face with higher market uncertainty, capital intensive and unknown potential impact of technology (Yadev et al., 2013). Nanotechnology is commercialized by science-based businesses and it is far more capital intensive than software, for example (Helmus, 2007).

Technology entrepreneurship is a vehicle that facilitates formation, development, and growth of technology-based new businesses. It involves a technology idea and finding a high-potential commercial opportunity, gathering resources such as knowledge, talent and capital for creating and capturing value for new ventures. Each new discovery creates opportunities for entrepreneurs to profit by bringing the nanotechnology innovation to the market. Thus, we propose the following hypothesis:

H1: *Nanotechnology innovation will be positively related to technology entrepreneurship*

New business models. Companies commercialize new technologies through their business models. A company needs to evaluate technical and commercial potential of new technologies through its own business model. A business model "describes the design or architecture of the value creation, delivery and capture mechanisms employed" (Sanchez and Ricard, 2010). It refers to the logic of the business and how it creates and captures value for its stakeholders. A business model defines the way by which the business responds to customer needs, how it delivers value and customer pay for value and their payments leads to profit through the proper design and operation of activities and processes. Value proposition must provide social, environmental and economic value through offering products and services (Boons and Ludeke, 2010).

There are three main types of business processes: management processes - that govern the operation of a system; operational processes - that constitute the core business and create the primary value stream and supporting processes - that support the core processes. Business architecture is the diagrams that describe the architectural structure of the business. Business model describe the workflow (sequence of operations) or the integration between business processes. It can be constructed in multiple levels (Subramaniam and Youndt 2005).

A potential new technology need to find an appropriate business model in order to be able to capture value from this technology. Business model refers to the logic of the firm, the way it operates and how it creates value for its stakeholders. It is the business's ability to capture value in the process of serving customers. Business model takes into consideration the alignment of the business's strategy with the organization's structure, operations, and the environmental factors in achieving competitive advantage.

Start-ups ventures are established on the basis of research results from university laboratories are viable mechanisms for nanotechnology commercialization. Many of these ventures are closely tied with university laboratories (Zucker et al., 2007). Professors may start nanotechnology ventures to commercialization important innovation from their laboratories. But these professors need support in their entrepreneurial actions. The nanotechnology ventures need financing, a base of capabilities complementary and a sound commercialization strategy. Thus, the scientist-entrepreneur can develop a core technology platform and will prepare a business plan needed to raise funds.

Entrepreneurs attempts to incorporate both efficiency and novelty in their business model. In nanotechnology field the novelty-centered business model is the key because nanotechnology has the potential to provide radically new customer value propositions. Capitalizing on such opportunities a new business model is necessary. Companies commercialize new technology through their business models. They need to have the ability to innovate and adapt their business model. This leads to the formulation of the following hypotheses.

H2: *Nanotechnology innovation will be positively related to new business model*

H3: *Technology entrepreneurship will be positively related to new business model*

Large firms are reluctant to commercialize radical innovation. They are willing to commercialize new technology (nanotechnology) only if their business model not be changed or if they can develop a new one business model without affecting the existing. We conceptualize a firm's business model as a system of independent activities to create value. It describes the architecture of activity system (content, structure and management). Therefore, small ventures have great potential to engage in the commercialization nanotechnology innovation through creating and capturing value for exploit new opportunities to solve economic and social problems, and gain a sustainable competitive advantage (Raesfeld et al. 2012. We thus hypothesize the following.

H4: *Technological entrepreneurship and new business model will be positively related to nanotechnology adoption*

This paper will outline these possibilities in order to generate hypotheses that can be tested empirically. A model depicting this combination of mediated relationships can be found in Fig. 1.

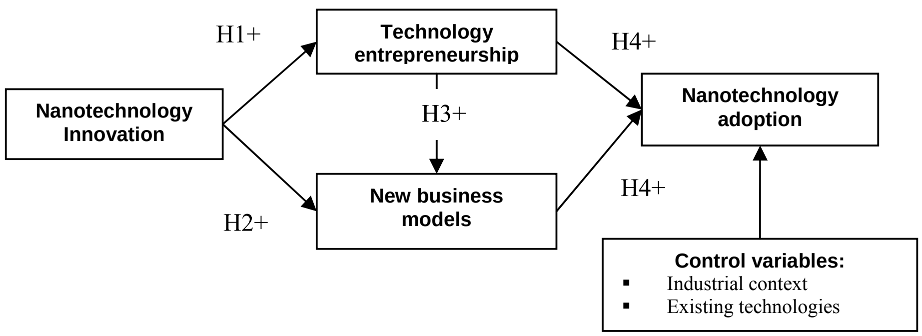

Fig. 1. Model of hypothesized relationships

Method

The methodology will now be discussed in terms of the measurement instrument, data collection, the sample, and data analysis.

Research setting

This study required data to test our hypotheses. We collected data through a survey. The sample of respondents was drawn from research environment. Survey data were collected in 2013 by using a structured questionnaire. Respondents were selected through the extent to which they were involved in research projects. A profile of the respondent is provided in Table 1.

The survey instrument was developed using new scales developed by the author and others adopted from the established scales. In the first step, the draft questionnaire was analyzed of some specialists form a research institute (ICPE). The detailed feedback was used to improve the questionnaire. The revised questionnaire was than administrated to respondents in the sample.

Table 1

Profile of respondents

		n	Percentage
Number of research project			
Over 1-5		3	43
Over 6-10		2	29
Over 11-20		1	14
Over 20		1	14
	Total =	**7**	100
Researcher degree			
Assistant Researcher		2	28
Researcher 2		3	43
Researcher 1		2	29
	Total =	**7**	100

Measures

The items used in this study were subjected to a careful analysis. The independent, mediator, and dependent variables were all measured with multi-item scale. Each of the scale items used a Likert-type response format ranging from 1 (strongly disagree) to 7 (strongly agree). In order to test construct validity, all multi-item measures were subject to alpha factoring with varimax rotation using SPSS version 11. Moreover, all item loadings exceeded the 0.5 cut-off suggested to represent practical significance by Hair et al (1998).

Nanotechnology innovation. This scale was adopted from Li and Atuahene-Gima (2001). The measure of nanotechnology innovation (Cronbach's α=0.68) was measured by three items. The respondents were asked for their degree of agreement with the following statements: (1) the number of new products/services based on nanotechnology innovation in the past five years increased steadily; (2) companies continuously improves their business processes using new nanotechnology solutions; (3) the number of laboratories and research centers which develop research in nanotechnology field in the past five years increased steadily.

Technology entrepreneurship (Cronbach's α=0.78) was measured by selected items of technological/process innovation from the scale used by Antoncic and Hisrich (2004). The statements refer to emphasis on (1) R&D and technological innovation; (2) pioneering and experimentation in technological development; and (3) designing new processes and methods of production.

New business models influence (Cronbach's α=0.92) was assessed by the respondents' agreement with the following three statements: (1) customer value proposition for customer in a better way than competitors; (2) how business makes money delivering the value proposition and (3) the key resources and key processes needed to fulfill these objectives.

Nanotechnology adoption (Cronbach's α=0.63) was measured by the assessment of the following two statements: (1) the number of start-ups established to nanotechnology commercialization and (2) the willingness of customers to purchase goods/services based on nanotechnology innovations.

Control variables. A number of factors that might influence the way through which the nanotechnology innovation can determine the growth economic were controlled by industrial context and existing technologies. *Industrial context* was operationalized as a dummy variable with 1 representing manufacturing industry, with 0 for others. *Existing technology* was measured by one question reflecting the stage of technology's life cycle in which a technology is and the possibility to be replaced by nanotechnology innovation. Thus, we asked respondents to evaluate the potential to replace of existing technology by nanotechnology solutions using a 7-point Likert scale.

Table 2

Correlations, means and standard deviations

	Mean	S.D.	1	2	3	4	5	6
1. Nanotechnology adoption	3.23	0.56	-					
2. Technology entrepreneurship	2.6	0.38	.45**	-				
3. New business models	4.3	0.97	.23*	.48**	-			
4. Nanotechnology innovation	2.34	1.2	.37*	.65**	.23*	-		
5. Industrial context	2.1	0.67	.56**	.38*	.19*	.35	-	
6. Existing technology	1.8	0.95	-.08	-.1	.12*	.29	.67**	-

Note * denotes significance at the 0.05 level (2-tailed), ** at the .01 level

Summary statistics and the correlation matrix of our data are given in Table 2. There is no evidence of the high correlations. A confirmatory factor analysis (CFA) was conducted to determine validity, and unidimensionality of the variables. All items were significantly loaded on their respective latent variables. The construct reliability was measured by Cronbach's alpha which exceeded 0.6, suggesting that these measures have good internal consistency.

Results

The hypothesized relationships were tested using hierarchical multiple regression analysis. Hierarchical regression enables analysis of the fraction of variation that is shared exclusively with each additional variable. Table 3 shows the standardized regression coefficients and change in R^2 across of the three models (Model 1 – control model, Model 2 – independent model, and M3 – interaction model). In a hierarchical analysis, Model 1 estimates a baseline model of controls, and it includes the control variables – industrial context and existing technology.

In the Model 2 we add the main variables – nanotechnology innovation, technology entrepreneurship, new business models and nanotechnology adoption. Model 3 is the full model including all variables. The results show that none of control variables has significantly impact upon nanotechnology adoption.

Table 3 summarize the results of the multiple regression analyses. The calculations were made using the ordinary least squares (OLS). Overall, the full model (Model 3) explains 32% of the variation in nanotechnology adoption. The incremental explanatory power from Model 1 to Model 2 is highly significant as indicated by the increase in adjusted R^2 (0.18), while the transition from Model 2 to Model 3 adding only 0.08 provides less incremental explanatory power. As predicted, we found that nanotechnology innovation had a significant positive interaction with technology entrepreneurship (β=0.18, p<0.01). These results support Hypotheses 1 and 3 respectively.

Table 3

OLS regressions results for nanotechnology adoption

Variables	Model 1	Model 2	Model 3
Industrial context	-0.14	0.00	-0.015
Existing technology	-0.23	0.09	0.05
Nanotechnology innovation		0,47**	0.43**
Technology entrepreneurship		0.32*	0.02
New business models		0.48**	0.05
Nanotechnology innovation x technology entrepreneurship			0.18**
Nanotechnology innovation x New business models			0.41**
R^2	0.06	0.24	0.32
Adjusted R^2	0.02	0.32	0.36
F	2.89	6.2**	4.86**
Change in R^2		0.31	0.09
Change in F		7.85***	5.12**

Single-tailed t tests have been used for all hypothesized variables; two-tailed t tests have been used for all control variables and non-specified main effects; *p<0.05; **p<0.01; ***p<0.001

Hypothesis 2 was supported, as the coefficient for the nanotechnology innovation had a significant effect on the nanotechnology adoption. On the other hand, Hypothesis 4 was not supported because the coefficient is not significant. The findings of this study suggest that the control variables didn't have significant contribution on nanotechnology adoption.

3. Conclusion

The present study addresses an important topic that has been neglected in entrepreneurship field. Although the research was centered on examining the role of the nanotechnology innovation, the implications of these findings are of significant importance to show that new business model is critical to translate the nanotechnology innovation into commercially successful products and process through nanotechnology adoption.

The limitations of our study are as follows. First, we were not able to capture longitudinal data to test our hypotheses. Second, it is possible that some additional variables might better explain the relationships within the model.

Finally, future investigations could explore different aspects of nanotechnology innovation to gain a better understanding of the impact of the technology entrepreneurship and new business model on nanotechnology commercialization. Future research could examine new constructs and their relationships.

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