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Globalization at the nano frontier: The future of nanotechnology policy in the United States, China, and India

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ABSTRACT

The field of nanotechnology offers the possibility of transforming the international science and technology (S&T) policy landscape and making a significant impact on the direction of research and development for a wide range of nations and companies. Nanotechnology endeavors in the United States, China, and India remain some of the most interesting because of the opportunities and challenges this field poses for future competition and collaboration between these three nations. This paper examines how nanotechnology will raise new science and policy questions—and lead to new strategic linkages—that will have a major impact on the futures of these nations for decades to come. Then the paper analyzes and compares the current state of nanotechnology in these three countries, discusses some of the main drivers of collaboration, investigates current and potential uncertainties associated with nanotechnology, and offers policy suggestions on ways that these difficulties may be addressed.

1. Introduction

A new field of science and technology (S&T) has emerged that has the potential to transform international S&T policy and make a significant impact on the direction of research and development for a wide range of nations and companies. This new field is nanotechnology, defined by the National Nanotechnology Initiative (NNI) [1] in the United States as the "understanding and control of matter at dimensions of roughly 1–100 nm, where unique phenomena enable novel applications"—where new products, observation tools, and manufacturing methodologies are being invented and discovered at a rapidly increasing pace. Researchers are exploring ways to see and build at this small scale by re-engineering familiar substances like carbon, silver, and gold to create new materials with novel properties and functions. Nanotechnology applications in areas as diverse as healthcare, energy storage, agriculture, water purification, and security are envisioned, and some experts predict nanotechnology will be as important as the steam engine, the transistor, and the Internet in terms of its societal impact [2].

Nanotechnology will have a similarly large impact on the economy. According to Lux Research, it is estimated that by 2014, the market for nanotechnology-enabled goods will grow to $2.6 trillion, while governments and corporations worldwide spent over $10 billion on nanotechnology R&D in 2005 alone [3]. There are already more than 600 manufacturers of nanotechnology consumer goods on the market [4]. Most importantly, there is a growing realization that nanotechnology will have an impact on countries both in the developed and developing world by transforming the commodities market, global production, value chains, and the nature of scientific collaboration itself.

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What is striking about the rise of nanotechnology is the *global* nature of the field itself. When the US Congress passed the 21st Century Nanotechnology Research and Development Act in 2003, formally establishing nanotechnology as a central investment and policy priority, there was little understanding of how big a role nanotechnology could play on the international level. However, a study investigating the global impact of nanotechnology found that as of 2005, 62 countries supported some degree of nanotechnology activity; 18 of which occurred in "transitional" countries and 19 of which occurred in "developing" countries [5].

Nanotechnology endeavors in the United States, China, and India are some of the most interesting because of the opportunities and challenges this field poses for future competition and collaboration between these nations. To investigate this topic, the first part of this paper provides a brief background on the current state of nanotechnology in each of the three countries. The second part enumerates some of the main drivers of collaboration that are emerging between the United States, China, and India as nanotechnology moves forward. Subsequent sections address the challenges nanotechnology poses to each country and offer suggestions for policy actions that might be useful for resolving these challenges. We conclude that nanotechnology raises new questions and leads to new linkages that will have enormous impact on the futures of these nations for decades to come.

2. Leaders and followers

One of the first instances of government support for nanotechnology occurred in the United States, where investments in this technology are expected to rise to nearly $1.5 billion in 2008—more than triple the initial investment of more than $450 million in 2001 [6]. Nanotechnology has also become a key component of the American Competitiveness Initiative (ACI) aimed at increasing and sustaining America's economic viability in the high-tech and manufacturing sectors. For this reason, many US government science agencies—including the National Science Foundation (NSF), the Department of Energy (DOE) Office of Science, the Environmental Protection Agency (EPA), and the National Institute of Standards and Technology (NIST)—saw their 2008 nanotechnology budgets increase markedly. In addition, many individual states in the United States have developed nanotechnology investment and management plans; in particular, California [7], New York [8], and Massachusetts [9] have made nanotechnology a central component of their state and regional economies. Both Berkeley, California and Cambridge, Massachusetts [10] have adopted or are considering adopting nanotechnology oversight strategies in the hope of creating a rational and transparent regulatory system that will entice nanotech companies to locate in these areas while also proactively addressing public concerns about the potential downsides of these technologies.

Although the United States has undoubtedly been a leader in supporting the rise of nanotechnology, its dominance in the field is by no means assured. China has emerged as a fast follower in nanotechnology. In its recently released *National Medium- and Long-term Science and Technology Development Plan*, nanotechnology is identified as a "priority mission area" and as a key frontier technology over the next 15 years [11]. As Cao, Suttmeier, and Simon note, nanotechnology is one of four "megaprojects" explicitly mentioned in the plan [12], and a report from the Asian Technology Information Program indicates that China is well on its way to bolstering its nanotechnology R&D capacities by constructing new nanotechnology research centers in Beijing, Shanghai, Tianjin, and Suzhou by the end of 2008 [13]. China has also surged forward in terms of its scientific output, measured by published journal articles and patents, with a number of studies indicating that China is a candidate for upper-echelon status in the global nanotechnology endeavor [14,15]. Such results have led Appelbaum and Parker [16] to conclude that, with respect to nanotechnology, China is truly "closing the gap" that once existed between itself and the United States, Europe, and Japan. However, China is also beginning to face a range of nanotechnology governance challenges—such as addressing low public awareness, developing a robust risk research strategy, and implementing an effective oversight system—that are very similar to those concerning the United States [17].

Finally, instead of being characterized as a leader or a fast follower, India remains a laggard in the field of nanotechnology, although it is taking increasingly impressive steps to move beyond its initial slow support. For example, while one estimate puts China's investment in nanotechnology R&D at $250 million in 2005 alone, some estimates for India's investment in this technology come to a mere $22.8 million from 2002 to 2007 [18]. The Indian government has begun to support a Nano Science and Technology Initiative and is looking to "actively" promote links between its research institutes and relevant industries [19] by boosting investment and support for nanotechnology R&D through 2011. Regional investment in nanotechnology is also occurring at the state level; the state of Karnataka is working to open a new "nanopark" on the outskirts of the city of Bangalore to act as a hub for the nation's nanotechnology R&D [20]. India has also begun to leverage its work with international partners, developing bilateral cooperative agreements with more advanced nanotech nations, such as the European Union, Germany, Italy, and Taiwan. More recently, India announced a new, three-way partnership with Brazil and South Africa to link each country's nanotech efforts and fund targeted research areas that include advanced materials, healthcare, clean water, and energy [21].

3. Drivers of nanotechnology collaboration

Despite differences in the extent and sophistication of each country's nanotechnology portfolio, this technology will continue to create important reasons for collaboration between the United States, China, and India. In particular, there are