Science and Public Policy **39** (2012) pp. 30–38
Advance Access published on 17 January 2012
doi:10.3152/030234212X13113405157822

Classifying US nano-scientists: Of cautious innovators, regulators, and technology optimists

Youngjae Kim[1,*], Elizabeth A. Corley[1] and Dietram A. Scheufele[2]

[1]*School of Public Affairs, Arizona State University, 411 N. Central Avenue, Suite 450, Mail Code 3720, Phoenix, AZ 85004-0687, USA,* [2]*Department of Life Sciences Communication, University of Wisconsin-Madison, 309 Hiram Smith Hall, 1545 Observatory Drive, Madison, WI 53706-1215, USA*
**Corresponding author. Email: ykim128@asu.edu.*

Government regulations to address technological risks are important for the successful development and application of nanotechnology, but there is an ongoing debate in the USA about who is responsible for the regulation of nanotechnology. In a mail survey of leading US nano-scientists, we examine scientists' perceptions about nano-regulation, including the government level (local, national, or international) at which the scientists believe nanotechnology regulation should be implemented. This regulatory discussion is important because international regulations are often difficult to adopt and implement; yet, local or state-level regulations could lead to the nanotechnology equivalent of the pollution haven hypothesis. We conclude that leading US nano-scientists have varying perceptions about nanotechnology regulations with some scientists supporting local regulations, but most scientists supporting national-level or international-level regulations. Additionally, our results show the emergence of three distinct categories of nano-scientists that have unique perspectives on nano-regulation: 'cautious innovators', 'nano-regulators', and 'technology optimists'.

Keywords: nanotechnology regulation, risk perceptions, survey data collection, scientist attitudes.

1. Introduction

Nanotechnology is embodied within a suite of the most promising technologies in the 21st century and is expected to be the technological foundation for future innovations (Pitkethly 2004; Retel et al. 2009; Roco 2004; Siegrist et al. 2007). Research and development investments in this field are growing rapidly throughout the world enabling wider applications of the technology (Roco et al. 2011). However, in proportion to its present and potential benefits to society, concerns about nano-risks to health and the environment associated with the development, production, use and disposal of nano-materials have been increasing (Hester 2006). Demands for appropriate actions to address potential risks are intensifying and regulations on nanotechnology are deemed necessary to protect workers, the public, and ecosystems that could all be exposed to nano-materials (Balbus et al. 2006).

Risk is a central factor to be considered in the early stage of an emerging technology (Meili 2006) and government regulations to address potential scientific risks can play a key role in the successful development and application of nanotechnology. Yet, appropriate regulation of nanotechnology is challenging because of the diverse and broad applications of the research area, as well as the risks and benefits that have not yet been fully identified (Marchant et al. 2009). Additionally, government regulations at the local, national, and international levels could potentially overlap and conflict with each other. Thinking carefully about government levels for regulatory implementation is essential because international regulations are often difficult to adopt and implement (Marchant and Sylvester 2006), and region-specific regulations could lead to the nanotechnology equivalent of the pollution haven hypothesis (PHH) (Levinson and Taylor 2008). Therefore, there is an ongoing debate in the USA about

who is responsible for the regulation of nanotechnology (Morris et al. 2011). Since expert opinions can play a key role in forming public opinion about a technology and, therefore have a significant impact on policy-makers (Ho et al. 2010), it is important to explore the perceptions about regulation held by leading US nano-scientists early in the regulatory process. In this paper, we present scientists' perceptions about this issue. We also identify clusters of scientists, based on their individual values and characteristics, as well as their unique patterns of support for regulation at different levels of government, to capture the diversity of opinions that different groups of nano-scientists might have about nano-regulation. Our results demonstrate that there are three distinct groups of nano-scientists that have unique perspectives on nano-regulation: 'cautious innovators', 'nano-regulators', and 'technology optimists'. Our analysis is based on data from a 2007 mail survey of 363 leading US nano-scientists conducted through the Center for nanotechnology in Society at Arizona State University (CNS-ASU).

2. Nanotechnology regulations and policy implementation: A case from Wisconsin

In order to contextualize the current discussion about nano-regulations at the intersection of academe and policy, we introduce a brief case study to illustrate the current policy debate surrounding local nano-regulations in the US state of Wisconsin. Wisconsin is just one of several US states that have recently explored the regulation of nanotechnology at a state level; and the issue has been hotly debated in the state's capitol (Madison, WI). The debate began around September 2010 when a special study committee was convened by the Wisconsin State Legislature. This special legislative committee was given the task of examining the human health and environmental risks associated with nano-materials and subsequently developing legislation to address these risks (Wisconsin Legislature's Special Committee on nanotechnology 2011). In particular, this committee planned to: (1) complete a review of current regulatory initiatives at all levels of government; (2) establish a Wisconsin nanotechnology information hub for nanotechnology businesses; (3) explore the role of 'first response' personnel who could contain any emergency release of nano-materials into an open environment; (4) monitor nanotechnology jobs in the state; and (5) conduct some research to understand whether or not scientists and firms address potential risks and meet regulatory requirements.

Some university scientists in Wisconsin are proponents of this recent push for local and state-level nano-regulations, arguing that state agencies have authority to regulate nanotechnology based on existing state and federal laws. In addition, these supporters of state and local nano-regulations argue that current federal law cannot address the urgent environmental health and safety aspects of nanotechnology (Powell 2010).

On the other hand, some regional trade groups and university scientists in Wisconsin are concerned about the technological and economic effects of local regulations, specifically the potential decline in Wisconsin nano-research and the reduction of nano-related industry jobs in the area. These proponents of federal-level nano-regulations argue that Wisconsin could lose its competitive advantage in the area of nanotechnology in relation to other regions in the USA if it adopts local or state regulations for nanotechnology (Scheufele 2010).

These concerns expressed by Wisconsin university scientists about local or state-level regulations echo a concept from environmental policy studies known as the PHH. Specifically, the PHH suggests that strict regulations in one local or regional geographical area will encourage companies to relocate their pollution-intensive factories and plants to other places with more relaxed regulations. In the case of environmental policy regulations, for example, this might mean that pollution-heavy industries will move to developing nations, taking advantage of the often less restrictive environmental standards in these countries (Strohm 2002). Thus, the PHH postulates that jurisdictions (or regions/countries) with weaker environmental regulations will attract polluting industries that move from locations with stricter regulations (Temurshoev 2005). Although this hypothesis has not been confirmed in all cases (Levinson and Taylor 2008), translating the PHH to the case of nanotechnology might mean that these industries would move from local/state areas in the USA with restrictive regulations to other regions where regulations are less strict. In many cases this shifting of nano-industries across US states or localities could be reduced if regulations on nanotechnology were implemented across the USA at the federal level. This might not stop companies from moving outside the USA for particularly risky nano-research, but it would supply a more level playing field for nanotechnology research and commercialization within the USA. Before presenting the results of our survey, we briefly introduce some relevant literature on the levels of government appropriate for the regulation of nanotechnology.

3. Addressing nano-risks at different levels of government

In the USA, policy change and implementation at the federal level can take an extended period of time. This characteristic of the policy process often translates into a more reactive than proactive stance by the federal government on policy issues; and sometimes important policy issues reach (or even exceed) a critical stage before an

appropriate regulatory action is taken (DiLoreto 2010; Marchant et al. 2007).

As we briefly mentioned when introducing the Wisconsin case, this time lag in the adoption and implementation of federal-level regulations has driven some experts to support local or state-level regulation of nanotechnology. When the federal government fails to take action, local governments might choose to implement regulatory policies because they can move more quickly than the federal policy process. Those who advocate regulation of nanotechnology at the local level argue that federal statutes, although they provide some legal authority to address nano-risks, are unlikely to solve the potential risks of nanotechnology in 'proactive and preventive ways' (Davies 2006; Powell et al. 2008). For example, Powell et al. (2008) stress the disadvantage of national-level regulation of nano-materials and argue that state and local government can address the risks and concerns of nanotechnology. Assuming that the federal government is failing to address nano-related risks, Keiner (2008) suggests that state and local governments need to fill the nanotechnology regulation gaps. In another example of local regulation, Berkeley, CA developed its own reporting guidelines for nanotechnology risks and became the first US city to regulate nanotechnology in 2006.

However, local or state regulations have a much more limited scope of impact and enforceability than national or international regulations. For this reason, local regulations might ultimately be challenged at the federal level after they are adopted by a state or municipality. Additionally, as we highlighted when discussing the PHH effect, local regulations can create incentives for nano-companies to move their most dangerous and risky research to regions or countries with weaker regulations. Even though some scientists support local regulations, they also recognize the risks of companies and researchers moving their resources to less regulated areas (Powell et al. 2008). In addition, state and local agencies are relatively more exposed to pressures from interest groups and industries (Rosenbaum 2005). Although Keiner (2008) advocates local and state regulations of nanotechnology, she also argues that it is an 'interim approach' until a national system is passed by Congress and becomes a comprehensive law which is supervised by federal agencies. Thus, she is acknowledging the dangers of having different regulations across the country. Given the limitations of federal-level or state-/local-level regulations, what about international regulation of nanotechnology?

When we consider the risks involved in nanotechnology in the areas of environmental and human health, an international approach to nanotechnology regulation has many advantages. For example, international regulation can address the potential risks of nanotechnology that transcend national borders and can encourage international cooperation in nanotechnology development while rejecting a race to less stringent environmental or labor conditions (Marchant and Sylvester 2006). Marchant and Sylvester (2006) argue that 'much of nanotechnology's coming regulations will inevitably fall into transnational frameworks' because of these advantages. Yet, international agreements for the regulation of technologies take much time, money, and effort because there are multiple players with diverse regulations and values. For example, gaining an international consensus on definitions, common nomenclature, and standards for classification and testing of nanotechnology and nano-materials could be extremely difficult (Bowman and Hodge 2007). Furthermore, even after an international policy has been adopted, the issue of policy enforcement is particularly difficult at an international level. Now that we have provided a brief overview of the existing literature on the levels of the regulation of nanotechnology, we will present our results that outline how leading US nano-scientists think about this issue.

4. Methods

The data used in this study were collected in a mail survey of 363 leading US nanotechnology scientists and engineers in 2007. The survey was conducted by the University of Wisconsin Survey Center under the auspices of the CNS-ASU. The survey was administered in three waves using the Dillman tailored design method (Dillman et al. 2009). The final response rate was 39.5% based on standard formulas developed by AAPOR (2008), the leading professional association in public opinion research. The sample was based on a complex sampling frame, designed to identify the first authors and contact authors for the most highly cited, recent nanotechnology publications that were indexed in the ISI Web of Knowledge database. To establish which publications were within the multidisciplinary field of nanotechnology, we drew on work by another group in the CNS-ASU. A detailed description of this group's refinement process for the definition of nanotechnology using specific bibliometric search terms is outlined by Porter et al. (2008). In order to develop the final sample, Porter and his colleagues supplied our team with a database of 91,479 nanotechnology publications that were published between January 2005 and July 2006. Through a series of filtering steps, we removed the following categories from the database: non-US-affiliated scientists, graduate students, and first or contact authors who were cited less than five times in the publication database. The final filtering process produced 1,022 names, which yielded 363 completed questionnaires.

5. Results

The scientists in our sample varied across a series of demographic variables. As Table 1 demonstrates, about 86% of the respondents were male and the mean age was 45 years

old. The majority of the scientists worked in universities (94%) and 46% of the respondents were tenured professors. Only about 6% of the scientists worked in industrial laboratories.

5.1 Local, national, and international supporters

To examine scientists' perceptions about whether local, national, or international nano-regulations were most appropriate, we focused our initial analysis on three questions from the survey data. These questions are the following (and responses for each question were recorded on a scale of 1 = strongly disagree to 5 = strongly agree): (1) regulation of nanotechnology should be implemented at the local level; (2) regulation of nanotechnology should be implemented at the national level; and (3) regulation of nanotechnology should be implemented at the international level. To determine how many of the scientists were most supportive of each level of regulation of nanotechnology, we defined 'highly supportive' of a particular level of regulation as a response of 4 or 5 (i.e. agree or strongly agree) on the questionnaire. The distribution of scientists who were highly supportive and less supportive of each governmental level for the regulation of nanotechnology is shown in Fig. 1.

Table 1. Mean responses for demographic and career variables ($N = 363$)

	Mean
Demographic variables	
Percent male	85.59
Respondent's age	44.94
Career variables	
Percent working in universities	94.20
Percent working in industry	5.80
Percent tenured at a university	46.30

Only 13.5% of the scientists were highly supportive of regulation at the local level, while 55.2% supported national-level regulation and 43.3% supported international regulation. These results demonstrate that the majority of the scientists in our sample supported national-level regulation of nanotechnology and a significant group supported international regulation. Yet, scientists' support for local regulation was relatively low. To further explore the characteristics of the scientists who supported each level of regulation, we used statistical significance tests to compare the responses of those scientists who were highly supportive of each level of government regulation with the other survey respondents. We compared these groups with a series of three t-tests. First, we compared the scientists that were highly supportive of local regulation (i.e. those that chose a 4 or 5 on the questionnaire for this question) with all other respondents to see what sorts of significant differences in values, beliefs and perceptions emerged. Second, we compared the scientists who were highly supportive of national-level regulation with all others. Lastly, we compared the scientists who were highly supportive of international regulation with all other respondents. Analyzing the data in this way allowed us to capture differences between high-level supporters for each level of regulation and neutral or lower-level supporters in order to explore any patterns or trends. We present the significant results of this analysis in Table 2. All of the results displayed in Table 2 represent statistically significant differences (at the 0.05 level) between the high-level

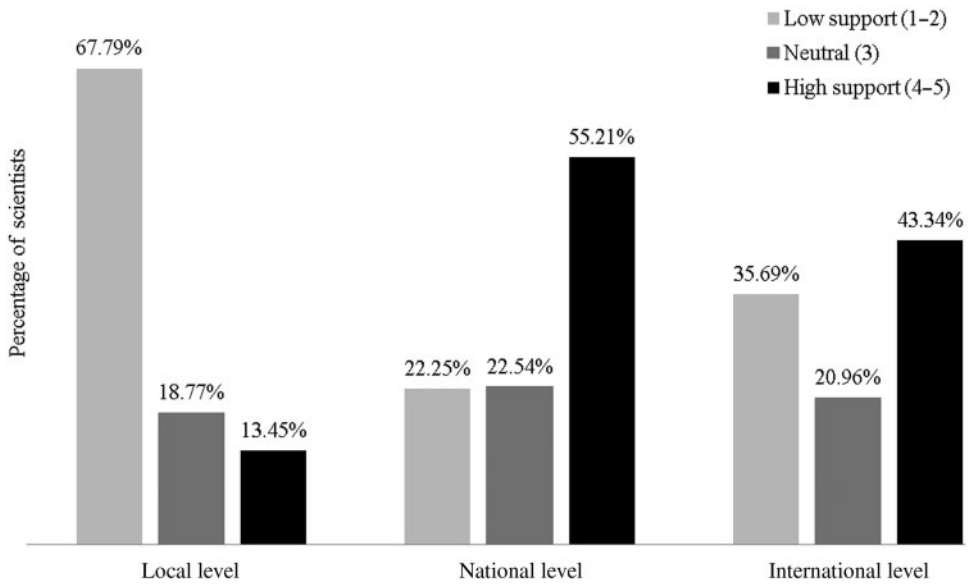


Figure 1. Nano-scientist support for three levels of government regulation of nanotechnology.

Table 2. Characteristics of high-level supporters[a] of various levels of regulation of nanotechnology

Supporters of local nano-regulation	Supporters of national regulation	Supporters of international regulation
• Prefer open and immediate communication with public about scientific results • Are positive about role of public opinion in policy making • Think improvement in human abilities is an important benefit of nanotech • Tend to be younger	• Believe that US Congress and regulatory agencies should play a role in public communication about risks and benefits of nanotechnology • Believe government should protect the public from nanotech risks • Believe that scientists should pay attention to public's wishes	• Are more likely to think that an arms race is a potential risk of nanotechnology • Are likely to support national-level regulations as well as international regulations

[a]High-level supporters were scientists who were supportive of each level of regulations (in other words, they chose either agree (4) or strongly agree (5) for the survey statements which had response categories in the range 1–5)

supporters for each level of government (i.e. local, national or international) and the lower level supporters for that level of government regulation.

This analysis showed that high-level supporters of local nano-regulation were more likely than other scientists to prefer immediate communication with the public about scientific results; they were also more likely to have a positive opinion about the role of public opinion in policy-making. In addition, supporters of local nano-regulation were younger than the other respondents in the survey. In fact, the average age of these scientists was 40, which is significantly younger than the high-level supporters of national regulations (average age 44.6) or international regulations (average age 44.7).

On the other hand, high-level supporters of national-level nano-regulation were more likely than their peers to believe that federal entities like Congress and regulatory agencies (such as the US Food & Drug Administration (FDA) or US Environmental Protection Agency (EPA)) should play a formal role in communicating with the public about the risks and benefits related to nanotechnology. These supporters of national-level regulation were generally more supportive of nano-regulation than their peers, which is demonstrated by their strong beliefs that government should protect the public from the risks associated with nanotechnology. Not surprisingly, the high-level supporters of international nano-regulation were more concerned than their peers about risks of nanotechnology related to an arms race. Additionally, those scientists who were supportive of international regulations were also likely to be highly supportive of national regulations.

5.2 Clusters of scientists

Since we found a series of significant differences across the high-level supporters of local, national and international regulation, the next step was to conduct an analysis of scientists' perceptions to explore how the scientists were grouped into clusters. To do this, we completed a hierarchical cluster analysis using Ward's method. In our analysis, we included a series of variables from the survey that focused on scientists' general perceptions about science, nano-regulation, and public communication of scientific findings. The full list of variables included in the cluster analysis is listed in Table 3, organized by the three clusters of nano-scientists. Fig. 2 shows the dendrogram results from the cluster analysis. As Table 3 demonstrates, our cluster analysis yielded three groups of scientists: (1) cautious innovators; (2) nano-regulators; and (3) technology optimists.

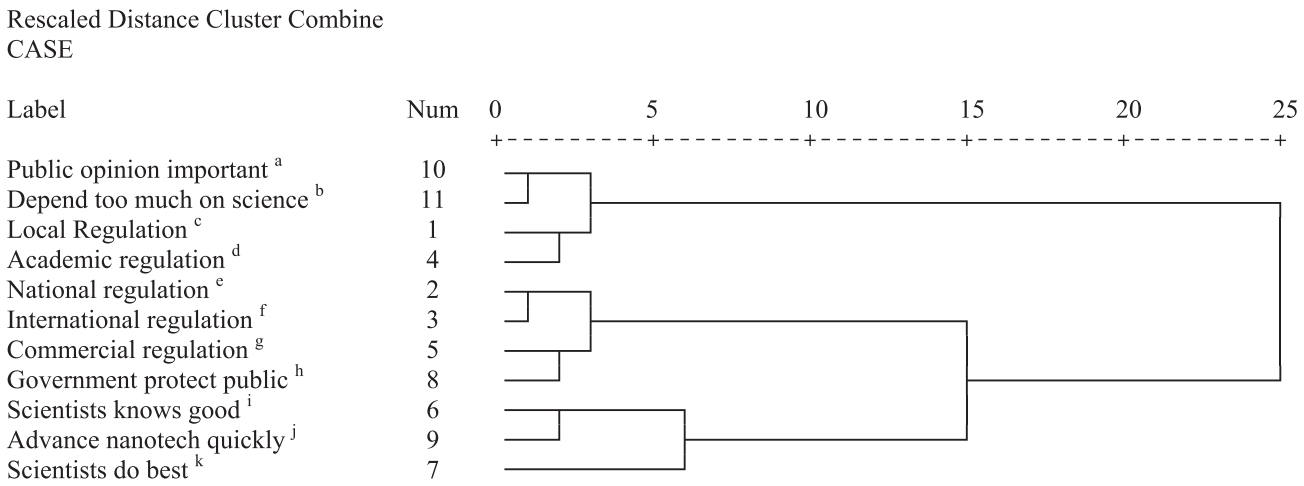
The 'cautious innovators' ($n = 93$, 27.1%) in our sample were more supportive of implementing regulations for nanotechnology at the local level. Additionally, these scientists thought that public opinion is more important than scientists' opinions for research decision-making and that we depend too much on science and not enough on faith. This group was also more likely than their peers to support the regulations of academic nanotechnology research. The second group of scientists was the 'nano-regulators' ($n = 109$, 31.8%). These scientists were more likely to say that the government should protect the public from unknown risks associated with nanotechnology. These 'nano-regulators' were also more supportive than their peers of regulating nanotechnology at the national and international levels. Lastly, they were more likely to support the regulation of commercial nanotechnology research.

While many scientists in our sample acknowledged the importance of nano-regulation, some scientists were less supportive of restricting advances in nanotechnology using regulations—i.e. the 'technology optimists' ($n = 141$, 41.1%). These scientists were more likely to think that advancing nanotechnology is more important than protecting society from its potential risks. These respondents also believed that scientists know best when it comes to making scientific decisions that can impact the public.

To further demonstrate differences in mean responses for regulations and risk perceptions across the three groups of scientists we present the descriptive statistics

Table 3. Variables associated with each cluster

Variables	Three clusters
• Regulation of nanotechnology should be implemented at local level • Academic nanotechnology research should be regulated • Public opinion is more important than scientists' opinions when making decisions about scientific research • We depend too much on science and not enough on faith	1 Cautious innovators (CI)
• Regulation of nanotechnology should be implemented at national level • Regulation of nanotechnology should be implemented at international level • Commercial nanotechnology research should be regulated • Government should protect public from unknown risks of nanotechnology	2 Nano-regulators (NR)
• Scientists know best what is good for the public • Scientists should do what they think is best, even if they have to persuade people that it is right • Advancing nanotechnology quickly is more important than protecting society from unknown risks	3 Technology optimists (TO)



Complete Survey Questions (1=Strongly disagree; 5=Strongly agree)

a. "Public opinion is more important than the scientists' opinions when making decisions about scientific research."
b. "We depend too much on science and not enough on faith."
c. "Regulations of nanotechnology should be implemented at the local level."
d. "Academic nanotechnology research should be regulated."
e. "Regulations of nanotechnology should be implemented at the national level."
f. "Regulations of nanotechnology should be implemented at the international level."
g. "Commercial nanotechnology research should be regulated."
h. "The government should protect the public from the unknown risks of nanotechnology."
i. "Scientists know best what is good for the public."
j. "Advancing nanotechnology quickly is more important than protecting society from the unknown risks."
k. "Scientists should do what they think is best, even if they have to persuade people that it is right."

Figure 2. Dendrogram using Ward method.

for each of the variables in the cluster analysis in Table 4. The results of a one-way analysis of variance (ANOVA) for the variables demonstrate significant differences across the three groups for all variables.

6. Discussion

Our analyses have shown that leading US nano-scientists vary widely in their perceptions about technology and the regulation of nanotechnology. Some scientists support local regulations, but a majority support national-level or international-level regulations. High-level supporters of local, national and international regulation differed in terms of their perceptions about public engagement and the role of experts in government. For example, supporters of local nano-regulation were more likely than their peers to prefer open and immediate communication with the public about scientific results while supporters of

Table 4. Mean values for variables across the three clusters

		N	Mean	SD
Regulation of nanotechnology should be implemented at local level[b]	CI[a]	93	1.60	0.97
	NR[a]	109	2.64	1.32
	TO[a]	141	1.84	0.93
Regulation of nanotechnology should be implemented at national level[b]	CI	93	1.99	0.95
	NR	109	4.26	0.71
	TO	141	3.70	0.83
Regulation of nanotechnology should be implemented at international level[b]	CI	93	1.41	0.61
	NR	109	3.88	1.14
	TO	141	3.49	0.91
Academic nanotechnology research should be regulated[b]	CI	93	1.42	0.73
	NR	109	3.42	1.04
	TO	141	1.55	0.66
Commercial nanotechnology research should be regulated[b]	CI	93	1.88	0.98
	NR	109	4.27	0.73
	TO	141	2.70	1.07
Scientists know best what is good for the public[b]	CI	93	2.90	1.09
	NR	109	2.61	1.19
	TO	141	3.13	1.00
Scientists should do what they think is best, even if they have to persuade people that it is right[b]	CI	93	3.99	0.96
	NR	109	3.66	1.13
	TO	141	4.11	0.74
Government should protect public from unknown risks of nanotechnology[b]	CI	93	2.30	1.17
	NR	109	4.21	0.94
	TO	141	3.11	1.00
Advancing nanotechnology quickly is more important than protecting society from unknown risks[b]	CI	93	3.00	1.29
	NR	109	2.01	1.13
	TO	141	2.65	1.04
Public opinion is more important than the scientists' opinions when making decisions about scientific research[b]	CI	93	1.69	0.77
	NR	109	2.06	0.93
	TO	141	1.54	0.66
We depend too much on science and not enough on faith[b]	CI	93	1.66	1.07
	NR	109	2.12	1.18
	TO	141	1.29	0.60

[a]CI: cautions innovators, NR: nano-regulators, TO: technology optimists
[b]Mean differences are all significant at 0.05 level

national-level nano-regulations were more likely to say that Congress and federal agencies should play a role in engaging with the public.

Our cluster analysis further revealed three groups of scientists with different perceptions about regulation, risk and the role of science in society. High-level supporters of local level nano-regulations cluster in a group we called the 'cautious innovators'. Compared to the other scientists in our sample, this group was more likely to think that society depends too much on science and not enough on faith or public involvement when making policy decisions. The second group of scientists can be labeled 'nano-regulators' because they were more likely to support regulation at the national and international level, as well as the regulation of commercial nanotechnology research. This group also was more likely to think that the government has a responsibility to protect the public from nano-risks. The third and final group was 'technology optimists'. Compared with the other scientists in the sample, this group did not place a high priority on the regulation of nanotechnology. They tended to believe that science is more important than public opinion when making policy decisions—and that it is more important to advance nanotechnology quickly than it is to protect the public from risks.

Although technical and scientific knowledge is clearly not the only piece of information that policy-makers use to form regulations, scientists do have an important and influential contribution to make in the debate about emerging technologies (Cook et al. 2004). In particular, when there is a high degree of scientific uncertainty and/or a lack of evidence regarding the risks of the new technology, policy-makers often turn to experts for their perceptions about risk and regulation (Corley et al. 2009; Scheufele et al. 2009).

Our results are relevant for both policy-makers and nano-scientists. From a policy perspective, we have demonstrated that the majority of leading US nano-scientists

support regulation of nanotechnology at the national level. While some scientists support local nano-regulations, this is a smaller percentage in our sample. This finding reinforces the intensive efforts that federal agencies (like the FDA, EPA, and National Institute for Occupational Safety and Health) are currently undertaking to move forward with national-level regulations for nanotechnology. From a science perspective, our results indicate that scientists tend to take three different views of technology and nanotechnology regulation with supporters of local regulation falling into a different group from the national or international regulation supporters. So when scientists engage in debates about the levels of nanotechnology regulation (as we have seen in Wisconsin and other states), it is important for them to keep in mind that they might differ on more than just the level of regulation. They might actually be approaching the larger regulation discussion from different perspectives about technology (e.g. more cautious or more optimistic) and the role of science in society.

Acknowledgements

This paper is based on work supported by grants from the National Science Foundation (grant SES-0531194) and the University of Wisconsin-Madison Graduate School (grant 135GL82). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation or the University of Wisconsin-Madison Graduate School.

References

AAPOR. (2008) *Standard definitions: Final dispositions of case codes and outcome rates for surveys*. Lenexa, KS: American Association for Public Opinion Research.

Balbus, J. M., Florini, K., Denison, R. A. and Walsh, S. A. (2006) 'Getting it right the first time - Developing nanotechnology while protecting workers, public health, and the environment'. In: Mehlman, M. A., Soffritti, M., Landrigan, P., Bingham, E. and Belpoggi, F. (eds) *Living in a Chemical World: Framing the Future in Light of the Past*, pp. 331–4. Wiley-Blackwell.

Bowman, D. and Hodge, G. (2007) 'A small matter of regulation: an international review of nanotechnology regulation', *Columbia Science and Technology Law Review*, 8: 1–32.

Cook, G., Pieri, E. and Robbins, P. T. (2004) '"The scientists think and the public feels": Expert perceptions of the discourse of GM food', *Discourse & Society*, 15: 433–49.

Corley, E. A., Scheufele, D. A. and Hu, Q. (2009) 'Of risks and regulations: How leading U.S. nano-scientists form policy stances about nanotechnology', *Journal of Nanoparticle Research*, 11: 1573–85.

Davies, J. C.(2006) *Managing the Effects of Nanotechnology Project on Emerging Nanotechnologies*. Washington, D.C.: Woodrow Wilson International Center for Scholars.

Dillman, D. A., Smyth, J. D. and Christian, L. M.(2008) *Internet mail, and mixed-mode surveys: the tailored design method*. Wiley: Hoboken.

DiLoreto, J. (2010) 'We should have seen it coming: States regulating nanotechnology', <http://www.nanotech-now.com/columns/?article=484> accessed 15 June 2011.

Hester, T. (2006) 'RCRA Regulation of wastes from the production, use, and disposal of nanomaterials'. Chicago, IL: American Bar Association, Section of Environment, Energy, and Resources.

Ho, S., Scheufele, D. A. and Corley, E. A. (2010) 'Value predispositions, communication, and attitudes toward nanotechnology: The interplay of public and experts', *Science Communication*, doi: 10.1177/1075547010380386.

Keiner, S. (2008) 'Room at the bottom? Potential state and local strategies for managing the risks and benefits of nanotechnology'. Washington DC: Woodrow Wilson International Center for Scholars.

Levinson, A. and Taylor, M. (2008) 'Unmasking the pollution haven effect', *International Economic Review*, 49: 223–54.

Marchant, G. E. and Abbott, K. W. (2009) 'A new soft law approach to nanotechnology oversight: A voluntary product certification scheme', *UCLA Journal of Environmental Law & Policy*, 28: 123–52.

Marchant, G. E. and Sylvester, D. J. (2006) 'Transnational models for regulation of nanotechnology', *Journal of Law Medicine & Ethics*, 34: 714–25.

Marchant, G. E., Sylvester, D. J. and Abbott, K. W. (2007) 'Nanotechnology regulation: the United States approach'. In: Hodge, G., Bowman, D. and Ludlow, K. (eds) *New Global Frontiers in Regulation: The Age of Nanotechnology*, pp. 189–211. Cheltenham: Edward Elgar.

Meili, C. (2006) 'Nano-regulation: A multi-stakeholder-dialogue-approach towards a sustainable regulatory framework for nanotechnologies and nanosciences', a report. St Gallen: Innovation Society.

Morris, J., Willis, J., De Martinis, D., Hansen, B., Laursen, H. and Sintes, J. R. (2011) 'Science policy considerations for responsible nanotechnology decisions', *Nature Nanotechnology*, 6: 73–7.

Pitkethly, M. J. (2004) 'Nanomaterials - the driving force', *Materials Today*, 7: 20–9.

Porter, A. L., Youtie, J., Shapira, P. and Schoeneck, D. J. (2008) 'Refining search terms for nanotechnology', *Journal of Nanoparticle Research*, 10: 715–28.

Powell, M. C. (2010) Letter to the Wisconsin Legislature's Special Committee on Nanotechnology, <http://legis.wisconsin.gov/lc/committees/study/2010/NANO/files/ResponsetoSept25Scheufeleletter.pdf> accessed 17 June 2011.

Powell, M. C., Griffin, M. P. A. and Tai, S. (2008) 'Bottom-up risk regulation? How nanotechnology risk knowledge gaps challenge federal and state environmental agencies', *Environmental Management*, 42: 426–43, doi: 10.1007/s00267-008-9129-z.

Retel, V. P., Hummel, M. J. M. and Van Harten, W. H. (2009) 'Review on early technology assessments of nanotechnologies in oncology', *Molecular Oncology*, 3: 394–401.

Roco, M. C. (2004) 'Nanoscale science and engineering: unifying and transforming tools', *AIChE Journal*, 50: 890–7.

Roco, M. C., Mirkin, C. A. and Hersam, M. C. (2011) *Nanotechnology Research Directions for Societal Needs in 2020*. Springer.

Rosenbaum, W. A. (2005) *Environmental Policy and Politics*. Washington, DC: CQ Press.

Scheufele, D. A. (2010) Letter to Sen. Mark Miller and Rep. Chuck Benedict, <http://legis.wisconsin.gov/lc/committees/study/2010/NANO/files/scheufele_ltr.pdf>, accessed 17 June 2011.

Scheufele, D. A., Brossard, D., Dunwoody, S., Corley, E. A., Guston, D. and Peters, H. P. (2009) 'Are scientists really out of touch?', *The Scientist*, <http://classic.the-scientist.com/news/display/55875/>, accessed 7 June 2011.

Siegrist, M., Keller, C., Kastenholz, H., Frey, S. and Wiek, A. (2007) 'Laypeople's and experts' perception of nanotechnology hazards', *Risk Analysis*, 27: 59–69.

Strohm, L. A. (2002) 'Pollution havens and the transfer of environmental risk', *Global Environmental Politics*, 2: 29–36.

Temurshoev, U. (2005) 'Pollution haven hypothesis or factor endowment hypothesis: theory and empirical examination for the US and China', Working Paper No. 292, Charles University, Prague, <http://iweb.cerge-ei.cz/pdf/wp/Wp292.pdf>, accessed 5 May 2011.

Wisconsin Legislature's Special Committee on Nanotechnology. (2011), <http://legis.wisconsin.gov/lc/committees/study/2010/NANO/index.html> accessed 15 June 2011.