

The Role of Science in Nanotechnology Decision-making:

Toward Evidence-based Policy Making

by

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ABSTRACT

Science can help inform policy decisions by providing information on the risks and benefits of a technology. In the field of nanotechnology, which is characterized by high degree of complexity and uncertainty, there are high demands for scientists to take an active role in policy debates with regulators, policy-makers and the public. In particular, policy-makers often rely on scientific experts to help them make decisions about regulations. However, scientists' perceptions about policy and public engagement vary based on their individual characteristics, values, and backgrounds. Although many policy actors are involved in nanotechnology policy process, there are few empirical studies that focus on the establishment of coalitions and their impact on policy outputs, as well as the role of scientists in the coalitions. Also, while the Environmental Protection Agency (EPA) has regulatory authority over nanoscale materials, there is a lack of literature that describes the use of science on EPA's decision making of nanotechnology.

In this dissertation, these research gaps are addressed in three essays that explore the following research questions: (1) how are nano-scientists' individual characteristics and values associated with their perceptions of public engagement and political involvement? (2) how can the Advocacy Coalition Framework (ACF) can be applied to nanotechnology policy subsystem? and (3) how does the EPA utilize science when making regulatory decisions about nanotechnology? First, using quantitative data from a 2011 mail survey of elite U.S. nanoscientists, the dissertation shows that scientists are supportive of engaging with policy-makers and the public about their results. However, there are differences among scientists based on their individual characteristics. Second, qualitative interview analysis suggests that there are two opposing advocacy

groups with shared beliefs in the nanotechnology policy subsystem. The lineup of coalition members is stable over time, while the EPA advocates less consistent positions. The interview data also show a significant role of scientific information in the subsystem. Third, the dissertation explains the EPA's internal perspective about the use of science in regulatory decision making for nanotechnology. The dissertation concludes with some lessons that are applicable for policy-making for emerging technologies.

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Chapter 1

INTRODUCTION

Policy-makers, international organizations, and citizen groups have increasingly called for science-based public policies (Guston & Sarewitz, 2006). The demands reflect the expectations that scientists' involvement in political debates can improve the quality of the policy decision-making (Mazur, 1981; Sarewitz & Pielke, 2000; Steel, List, Lach, & Shindler, 2004). The trends of a science-based approach to policy-making are particularly appropriate for decision-making about emerging technologies including nanotechnology. In the field of nanotechnology, decision makers often depend on scientists' contribution in risk assessment and management to make policy decisions (Corley, Scheufele, & Hu, 2009).

In this circumstance, the role of scientists or science in the process of establishing policies for nanotechnology has received scholarly attention (Jenkins-Smith, Silva, Gupta, & Ripberger, 2014). Although used interchangeably in many studies, the notion of science and scientists should be distinguished. Science is "the pursuit of knowledge about how the world works" (Lubchenco, 1998, p. 8). It is considered as objective information, therefore apolitical and value-free (Rykiel Jr, 2001). Scientists, on the other hand, are not completely objective and disinterested. They use heuristics when making decisions and their opinions vary based on their background and individual value-predispositions (Sutherland & Burgman, 2015; Corley, Kim, & Scheufele, 2013; Kim, Corley, & Scheufele, 2012). Therefore, many scientists today often advocate their values (Rykiel Jr, 2001). Among the policy network theories, Advocacy Coalition Framework (ACF) seeks to explain the political behavior of actors in the policy process and under the framework, scientists are active members in advocacy coalitions (Sabatier, 1988; Jenkins-Smith, Silva, Gupta, & Ripberger, 2014; Weible & Sabatier, 2007).

Also, the role of science and the role of scientists in the policy process are conceptually different from each other. While the role of science in the policy process is informing policy decision (Lubchenco, 1998), the role of scientists in the policy process is providing expertise about scientific data and findings that other actors in the policy-making process can use to make decisions (Steel, List, Lach, & Shindler, 2004). Scientists' role as policy advisers, therefore, improves the role of science in decision-making (Barraza et al., 2016). Likewise, science and scientists represent a different unit of analysis and I use the two concepts distinctively throughout the dissertation.

Also, among the federal agencies, the EPA is one of the most important and most active regulatory agencies that use scientific advice (Elliott, 2003). Science is important for providing the best-quality foundation of the agency's decisions and the agency has supported academic research and enhanced scientific information for regulatory decisions (Darnall, Jolley, & Handfield, 2008; Kyle et al., 2008; NRC, 2012).

Despite these scholarly attentions on the role of science and scientific information in policy decision making, there are at least three research gaps. First, there is lack of literature focusing on scientists' individual differences. Although nanoscientists are often recognized as one of the policy actors on complex nano-science issues, the exact role that scientists play in the policy processes is not clearly defined. Moreover, scientists' expert opinions in policy disputes often vary, and these differences are likely to affect their political participation (Sutherland & Burgman, 2015). Scientists' individual value-predispositions and perceptions about nanotechnology are diverse, which can cause adverse consequences (Corley, Kim, & Scheufele, 2013; Ho, Scheufele, & Corley, 2010; Kim, Corley, & Scheufele, 2012). However, there are few studies that analyze scientists' perceptions about public engagement in the field of nanotechnology.

The second research gap is associated with use of science at the EPA. Assessing potential risks of an emerging technology is critical when making regulations, therefore the agency needs to depend on science. However, despite many studies on EPA's role and function (EPA, 2012a, 2012b, 2013), there is little study focusing on its use of science for emerging technology policy making. Specifically, while the agency has regulatory authority over nanoscale materials, there is a lack of literature that describes the use of science on EPA's decision making of nanotechnology.

The third research gap is that prior research lacks empirical studies that focus on the establishment of coalitions and their impact on policy outputs, as well as the role of scientists in the coalitions. Existing ACF studies are mostly theoretical and lack empirical investigation across a large number of observations (Spruijt et al., 2014). The framework need to be tested empirically in a variety of settings (Sabatier, 1988). Moreover, as yet, ACF has not been used to explain the policy subsystem surrounding emerging technologies where evidence of potential risks on human and environmental health are lacking.

There is an intellectual debate between constructivist approach and realist approach. Constructivism argues that reality is a construct of the mind and thus, it is a function of perception and is subjective (Mertens, 2005). This reality construction depends both on the properties of the object and the mental activities of a person, therefore different people experience reality differently (Elkind, 2004). The constructivist approach is considered to take an empirical and skeptical view of science (Guston, 2007). On the other hand, realists argue that a reality exists independent of the observer (Speed, 1991; Casti, 1989) and it can be discovered and understood exactly as it is (Held, 1990; Chalmers, 1976). Basically, realism contends that "the position that

reality exists, can be discovered by people in an objective way and thus determines what we know" (Speed, 1991, p. 396).

At a glance, the realist approach seems to be more appropriate for scientific research since it posits that the role of scientific research is to study objective reality, which exists independent of the human mind (Campbell, 1998). However, a purely realist approach to science without considering the social and historical context would not accurately address the research gaps because the gaps are focused on the differences among individuals with diverse background and opinions and further study interactions among policy actors. On the other hand, the constructivist approach to science treats science as a social activity and provides the close, empirical, and rational explanation of scientific work that is essential for informed policy making (Guston, 2007). In this sense, from an epistemological point of view, I adopted a moderately constructivist approach retaining some realist underpinnings rather than fully constructivist position (Jones, 2002). Based on a moderately constructivist approach, I address each of the research gaps in three essays.

In the first essay, using quantitative data from a 2011 mail survey of elite U.S. nanoscientists, I provide general understanding of nano-scientists' perceptions about public engagement and show that a broad diversity of opinions of the nano-scientists. I also suggest how nanotechnology policy makers should approach the differences. Also, I demonstrate that scientists' certain characteristics are particularly important for scientists' decision making about their public engagement. The research examines at the level of individual nanoscientists, therefore nanoscientists are the unit of analysis of the first essay.

In the second essay, I explore the current use of science at the EPA primarily focusing on nanotechnology policy based on recent organizational structure of the

agency. Using two of the EPA’s nanotechnology policies as cases, I examine qualitative interviews with EPA officials who were involved in the policy making processes focusing on the agency’s use of science. Then, I provide internal perspectives about the use of science at the EPA in nanotechnology decision making. The unit of analysis of the second essay is the EPA’s use of science.

In the third essay, I examine how ACF can be applied to nanotechnology policy making using qualitative interview analysis. In the field of nanotechnology, few studies discuss the existence of advocacy coalitions, their policy core beliefs, or the degree of consensus among the coalition members. Through the lens of ACF, I identify the advocacy coalitions in nano-policy subsystem and further identify the role of scientists as stakeholders in policy making for the case of EPA’s Nanoscale Materials Stewardship Program (NMSP) and new Nano Reporting Rule. The primary unit of the analysis is the nanotechnology policy subsystem.

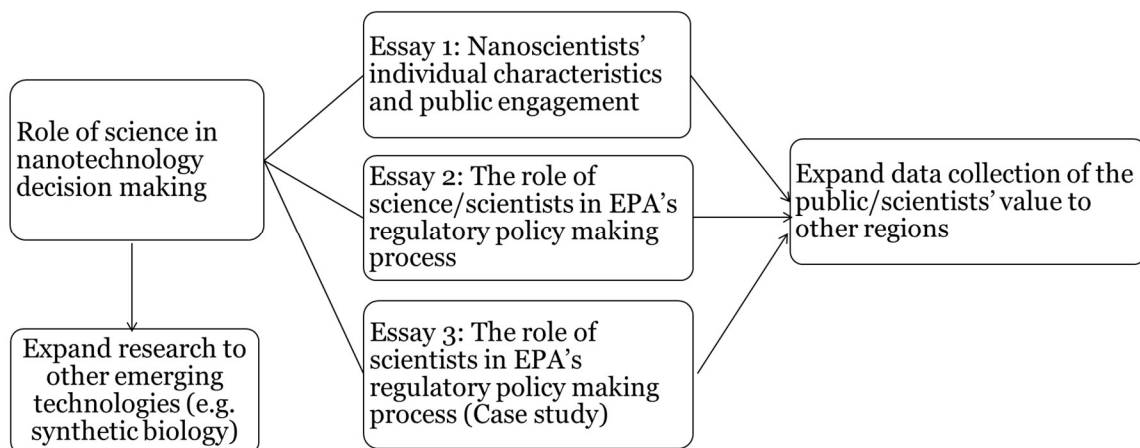


Figure 1.1: Overview of the three-essay dissertation and future research plan, developed by Kim, 2017

Figure 1.1 is a diagram that describes the overview of the three essays and a future research plan. Under the theme of the role of science in nanotechnology decision making, the three essays discuss the important topics of the nanotechnology policy issues: scientists' individual characteristics and their public engagement, the role of science in EPA's regulatory policy making process, and the role of scientists in the nanotechnology policy subsystem.

The challenges of new and emerging technologies, such as nanotechnology, characterize high pressure, unusual circumstances for policy makers and government (Anderson & Slade, 2013). Scientific uncertainty as well as ethical, legal, and social implications represented significant challenges to nanotechnology policy makers (Guston & Sarewitz, 2002). In this challenging situation, nanoscientists can provide information and analyses of the technology that are necessary for policymaking and thus, play a key role in the complex nanotechnology policy issues. However, scientists often hold diverse views depending on their personal backgrounds, approaches and subjective judgements. Thus, understanding which perceptual factors are associated with scientists' perceptions about public engagement would be useful for policymakers who wish to involve scientists in policy the development. In this sense, the first essay of the dissertation explores nanoscientists' individual perceptions associated with their political engagement.

The EPA is an official actor in technology policy processes. It has the "statutory authority to regulate nanomaterials" (U.S. EPA Office of the Inspector General, 2011, p. 3), however, its regulatory authority is limited to certain regulatory mechanisms such as Toxic Substances Control Act (TSCA) and Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). According to the GAO's report to Congress on EPA's handling of nanomaterial issues, EPA faces technical challenges to enforcing its statutory

authorities for nanomaterials, because they may be harder to detect in air, water, or waste (GAO, 2010).

Despite the limitations, the EPA is one of the most important and most active regulatory agencies that use scientific advice (Elliott, 2003). As reviewed in the first essay, scientists can play a significant role in the governments' policy making process and in fact, many reports and articles show that science has indispensable for providing the basis of EPA's decisions (National Research Council, 2012a). However, there is an intense controversy in the U.S. currently about the EPA's use of science for regulatory decision-making. Under the Trump administration, the House passed the "HONEST Act" and the "EPA Science Advisory Board Reform Act" which will make it harder for the EPA to use scientific research to protect health and the environment.¹ Moreover, the current administration has recently requested significant budget cuts from the EPA's science programs.² In response to these changes, large numbers of people including science organizations joined the March for Science in Washington DC, and over 600 other cities across the world to express their support for science and defend it from political attacks.³ In this circumstance, examining the proper role of science and scientists in EPA policy making is a worthy subject for a research. Therefore, the second essay explores the role of science at the EPA and the contributions of scientists to EPA's regulatory policy decision-making.

¹ Union of Concerned Scientists. 2017. Why the EPA Science Advisory Board Reform Act Is Bad for Science. Retrieved from <http://blog.ucsusa.org/genna-reed/why-the-epa-science-advisory-board-reform-act-is-bad-for-science>

² New York Times. 2017. Trump Budget Would Cut E.P.A. Science Programs and Slash Cleanups. Retrieved from <https://www.nytimes.com/2017/05/19/climate/trump-epa-budget-superfund.html>

³ The Washington Post. Why people are marching for science: 'There is no Planet B'. Retrieved from https://www.washingtonpost.com/national/health-science/big-turnout-expected-for-march-for-science-in-dc/2017/04/21/67cf7f90-237f-11e7-bb9d-8cd6118e1409_story.html

The third essay of the dissertation further explores the EPA's policy making process and the scientists' role in the process. Using EPA's two nanotechnology policies as cases, this final essay examines the network of policy actors in the nanotechnology policy subsystem. The trends to decentralize policy decisions and involve nongovernmental actors in the complex task of coordinating policies across government agencies have made the policy networks study critical to understanding governance (Feiock & Scholz, 2009). Policy researchers have found that the complexity of public policy can be simplified with the use of theoretically grounded frameworks. In this respect, the third essay explores how the policy network and interactions among the policy actors affect policy changes and outcomes using the Advocacy coalition framework (ACF) as a theoretical framework (Weible & Sabatier, 2007). According to the ACF, the EPA and scientists, which I discussed in the previous two essays, play role as active members of specific coalitions. Especially, the ACF assumes that scientists are not neutral policy actors and therefore (Weible & Sabatier, 2007), scientists with different opinions and values will have commitments to different advocacy coalitions.

Finally, for the future research, I would like to expand data collection about the social aspect of emerging technologies to regions beyond the U.S.. For the survey data, for example, I expect that scientists with different cultural and geographical background would have different value predispositions and would perceive technology and society differently. Also, while emerging technologies share similar issues, each have unique features that are difficult to predict in terms of public policy. Questions such as what forms of governance will need to put in place and which areas of research will need to be regulated can be raised in different technologies (Sandler, 2016). .

Chapter 2

ELITE NANOSCIENTISTS AND PUBLIC COMMITMENT: WHICH INDIVIDUAL CHARACTERISTICS ARE CORRELATED WITH ELITE SCIENTISTS' SUPPORT OF PUBLIC ENGAGEMENT?

Policy-makers, international organizations, and citizen groups have increasingly called for science-based public policy (Guston & Sarewitz, 2006). For example, the President's Executive Order 13563 (issued on January 2011) highlights regulating emerging technologies based on scientific evidence, emphasizing the objectivity of scientific and technological information to gain public trust. Moreover, the 2015 World Science Forum (WSF) made a declaration on the enabling power of science and supported the use of scientific evidence in policy making.⁴ These demands reflect the expectations that scientists' political involvement (including scientific advice) can improve the quality of the policy decision-making (Mazur, 1981; Sarewitz & Pielke, 2000; Steel, List, Lach, & Shindler, 2004). The trends of a science-based approach to policy-making are particularly appropriate for decision-making about emerging technologies, such as nanotechnology. Nanotechnology is characterized by an increasing degree of scientific complexity and uncertainty which requires scientific knowledge when making policy decisions. Therefore, decision makers often rely on scientists' input about risks and regulation to make policy decisions (Corley, Scheufele, & Hu, 2009).

While scientists themselves realize the need for participation in public policy deliberation (Lackey, 2007), they report feeling frustrated when they believe their views receive inadequate attention (Gamble & Kassardjian, 2008; Stilgoe, 2007). Therefore, many scientists are reluctant to contribute beyond publishing their scientific findings in

⁴ Declaration of the 2015 Budapest World Science Forum: Retrieved from <http://www.sciforum.hu/declaration/index.html>

scholarly journals (Lach, List, Steel, & Shindler, 2003). Even when they participate in the policy-making process, some scientists work as policy advocates while others provide policy-neutral information. Also, variation in scientists' value-predispositions and interests can cause adverse consequences such as the "politicization of science by scientists," which can be a threat to their credibility (Pielke, 2007).

For these reasons, there are calls for a clear understanding of appropriate roles and responsibilities of science, scientists, and policy advocacy (Lackey, 2007). Although nanoscientists are often recognized as one of the policy actors on complex nano-science issues, the exact role that scientists play in the policy processes is not clearly defined. Moreover, scientists' expert opinions in policy disputes often vary, and these differences are likely to affect their political participation. However, there are few studies that analyze scientists' perceptions about public engagement in the field of nanotechnology. This research offers three contributions to scholarly research. First, this study provides general understanding of nano-scientists' perceptions about public engagement such as political involvement and public communication. Second, my research shows a broad diversity of opinions of the nano-scientists and suggests how nanotechnology policy makers should approach the differences. The third contribution of the study is that it shows certain characteristics of scientists are particularly important for scientists' decision making about their public engagement.

This study addresses these concerns by exploring the factors that are associated with elite U.S. nanoscientists' perceptions about scientists' public engagement and how these scientists form opinions about their public engagement. This study focuses on most highly-cited nanoscientists because they are believed to have more influence and impact on the field (Pei & Porter, 2011). Publication and citation counts are clear indicators of prolific scientists in a field (Simonton, 1999, 2004; Heinze and Bauer,

2007) and highly-cited scientists are frequently asked to participate in the policy process (Hart & Victor, 1993). This study asks how scientists' individual characteristics and values are associated with their perceptions of public engagement in the field of nanotechnology and explores four categories of nanoscientists' perceptions: risk and benefit perceptions, opinions on public and society, political views, and ideas on worker protections. Using survey data, it examines which perceptual factors are associated with scientists' perceptions about public engagement in three forms: political involvement, public communication, and regulation of nanotechnology research.

Role of scientists in policy decision making

In the past, there was a general assumption that public officials, including policy makers, have the expertise and therefore left unchallenged when they carry their duties. But in recent years, this culture of public trust has been heavily weakened. In the United States and many other countries, there has been an increasing calls for science-based policy by policy makers (Guston & Sarewitz, 2006). These calls have grown louder as a well-educated and well-informed public began requiring greater reassurances of the use of their tax dollars (Nutley, Davies, & Smith, 2000). Instead of traditional judgment-based decision-making, the notion of evidence-based policymaking (EBPM) became more important and it now central to the scientific agenda (Cairney, 2016).

EBPM is a process for making decisions about a program, practice, or policy that is grounded in the best available research or experiential evidence from the field and relevant contextual evidence (Puddy & Wilkins, 2011). It argues that policymakers should base their decisions primarily on scientific evidence (Jennings & Hall, 2012). EBDM was first originated from the idea of evidence-based medicine and expanded to all areas of public policy (Marston & Watts, 2003). The notion of EBDM is an objective

rather than an accomplishment (Head, 2010), so some define EBDM as an aspiration to “avoid making major policy changes before relevant research or detailed analysis has been conducted” (Adams & Hairston, 1994, p. 17).

Recently, the Pew-MacArthur Results First Initiative published a report on the issue of the Evidence-based policymaking called, “Evidence-based Policymaking: A Guide for Effective Government” (PEW, 2014). This guide provides the details, tips, and strategies that policymakers can use to instill evidence in decision-making at all levels of government. Acknowledging lack of comprehensive road map that provides clear guidance on using EBPM, this report is the first comprehensive framework that policymakers can follow to build a system of evidence-based governing. According to the report, EBPM uses the best available research and information to guide decisions at all levels of the policy process in each branch of government, and by using the EBPM, governments can reduce wasteful spending, expand innovative programs, and strengthen accountability (PEW, 2014). In EBPM studies, scientists are considered to play key roles as advisors (Jasanoff, 2009; Pielke, 2007).

Nanotechnology is “research and technology development at the atomic, molecular, or macromolecular levels using a length scale of approximately one to one hundred nanometers in any dimension” (Sellers et al., 2008, p. 12). One of the biggest challenges in nanotechnology innovations today is managing environmental, health and safety (EHS) risks. However, scientific uncertainty surrounding the technology causes regulatory ambiguity for policy makers (Hoerr, 2011). It also causes public fear and creates an ambiguous atmosphere for business investment and technological development. When policy design is characterized by these complex and technical issues, scientific experts can play a key role in decision-making. With their expertise, scientists can provide information and analyses of the technologies with high

uncertainty. Therefore, decision makers often rely on scientists' input about risks and regulation to make policy decisions (Corley et al., 2009).

Traditionally, society assumes that scientific expertise provides objective solutions to policy problems which are unaffected by personal values (Rip, 1985). According to this model, value choices should be made only by elected public officials (Sabatier & Zafonte, 2005). However, political scientists have long viewed this model of a clear separation between value-laden politics and value-neutral administration as naive (Appleby, 1949), in large part because science is socially constructed (Lackey, 2007). Different value judgments lead different interpretations of the scientific evidences (Haller & Gerrie, 2007). For example, scientists can take data and "legitimately assemble and interpret it in different ways to yield competing views" (Sarewitz, 2004, p. 389). In fact, there are increasing concerns that the experts become biased by their personal interests and do not provide fair analysis in certain situations (Stine, 2009). Likewise, scientists' decision-making processes are value-laden because individual values, opinions, and social influences are a part of science (Lélé & Norgaard, 1996). Therefore the variation of individual scientists' opinions should not be overlooked. If individual nano-scientists hold different worldviews or value predispositions, they may perceive their ideas of public engagement differently even though they have the same scientific information.

Scientists' perceptions about public engagement

Scientists often have varying opinions about nanotechnology and policies for the oversight of nanotechnology. For example, their ideas about the risk and benefit of nanotechnology differ by their demographic background and value predispositions (Corley, Kim, & Scheufele, 2013; Ho, Scheufele, & Corley, 2010; Kim, Corley, &

Scheufele, 2012) and preferences about societal priorities (Pielke, 2004). Scientists' opinions also vary based on their "values, mood, whether they stand to gain or lose from a decision, and by the context in which their opinions are sought" (Sutherland & Burgman, 2015, p. 317), which can threaten the accuracy and reliability of their scientific advice. Scientific experts are often unaware of these subjective influences which leads to overestimation of their own objectivity and reliability (Sutherland & Burgman, 2015) that affect government oversight.

Scientists are generally positive about scientists' political participation or involvement in political debates. According to a recent survey of U.S. scientists who are members of the American Association for the Advancement of Science (AAAS), most scientists (87%) believe it is important to participate in public policy debates and almost half use social media to discuss or follow science (PEW, 2015). Since the members of the AAAS are not necessarily scientists, this survey does not reflect authentic scientists' perspectives and it is difficult to generalize from these samples to overall scientists (Scheufele, 2009). However, there is lack of literature on comprehensive survey data about scientists' perceptions about political involvement. Therefore, the results of the survey show that involvement in political debates has received broad attention within the scientific community (Kim, Corley, & Scheufele, 2016). Also, 91% of the U.K. scientists agree that "scientists have a responsibility to communicate the social and ethical implications of their research to policy-makers" (MORI/Wellcome Trust, 2001). Studies focusing on scientists in specific fields, such as biology, ecology, and nanotechnology commonly argue that scientists' contribution to the policy process is not only the right thing to do, but scientists are also obligated to do so (Corley, Kim, & Scheufele, 2016; Lackey, 2007). However, scientists' perceptions about political involvement are not unanimous. For example, the 2015 survey of U.S. scientists says 13% of scientists

support constricted view that “Scientists should focus on establishing sound scientific facts and stay out of public policy debates” (PEW, 2015).

Scientific community leaders in the U.S. are calling on scientists to meaningfully engage with the public (Dudo & Besley, 2016). Existing studies find that such interactions can improve the relationship between science and society (Leshner, 2003). Scientists are engaged in activities outside their immediate scientific community, but there is no clear definition of public engagement (Bauer, Jensen, Bauer, & Jensen, 2011). Scientists’ public engagement literature suggests a wide range of activities such as lecturing in public or in schools, giving interviews to newspapers or other media, active involvement in policy making, association as advisors, and more (Bauer et al., 2011; Poliakoff & Webb, 2007).

To measure scientists’ public engagement perception, this research adopted three sets of survey questions: questions on scientists’ political involvement, public communication, and the need for regulation. The first two questions, scientists’ political involvement and public communication are definite forms of public engagement. Then, scientists’ perceptions about nano-regulation can measure scientists’ policy preference which affect the general public. The first question is: “It is appropriate for scientists to become actively involved in political debates about issues such as nanotechnology or stem cell research” (1 = Strongly disagree; 5 = Strongly agree). Secondly, the survey question that captures respondents’ perceptions about public communication is: “Communicating with the public does not affect public attitudes toward science” (1 = Strongly disagree; 5 = Strongly agree). Finally, two survey questions capture respondents’ normative perceptions about nano-regulation: (1) “Academic nanotechnology research should be regulated” (1 = Strongly disagree; 5 = Strongly agree)

and (2) “Commercial nanotechnology research should be regulated” (1 = Strongly disagree; 5 = Strongly agree).

Scientists’ perceptions about nanotechnology

Scientists’ Perceptions about Political Involvement

Previous research has shown that risk and benefit perceptions about nanotechnology are significantly related to the perceptions about the regulation of the technology (Satterfield, Conti, Harthorn, Pidgeon, & Pitts, 2013; Satterfield, Kandlikar, Beaudrie, Conti, & Herr Harthorn, 2009). Several studies have further demonstrated this relationship for both the general public (Anderson, Brossard, Scheufele, Xenos, & Ladwig, 2014; Cacciatore, Scheufele, & Corley, 2011; Satterfield et al., 2009; Scheufele & Lewenstein, 2005) and nano-scientists (Corley et al., 2013; Corley et al., 2009).

These relationships between risk/benefit perceptions and policy perceptions are applicable to other technology areas as well. A study on risk perceptions finds that public perceptions are influenced not only by scientific and technical information of danger but also by diverse psychological and social factors, including personal experience, emotion, trust, values and worldviews (Slovic, 2000). Leiserowitz (2006) argues that the public’s risk perceptions are strongly related to the political, economic and social engagements they take to address political issues. For example, in climate change discourse, public support or opposition to climate policy or regulation is significantly influenced by individuals’ risk perceptions about global climate change (Leiserowitz, 2006). In other words, as climate change, risk perceptions such as holistic concern increase so does support for national policies to address global warming. Similarly, a study on the public acceptance of nuclear power concludes that the public’s risk perceptions about nuclear energy are significantly associated with the lack of

support for the construction of new nuclear power plants (Peters & Slovic, 1996). Also, a study on the acceptance of gene technology also concludes that people's perceived benefit and perceived risk determine acceptance of biotechnology (Siegrist, 2000).

Likewise, existing studies demonstrate that risk and benefit perceptions about certain technology are important determinants for one's perceptions about policy actions. In addition, existing literature also show that scientists have conflicting opinions and even though scientists are more optimistic about the technology in general, this does not mean scientists only see benefits (Priest & Gillespie, 2000). In particular, scientists' assessment of risks and benefits of a new technology plays a key role in their policy decision-making (Corley et al., 2009). Since debates on nanotechnology policies necessarily include both regulation and promotion policies for the technology, I expect that both scientists' risk and benefit perceptions would impact their political decision making. For these reasons, I posit that nanoscientists' risk and benefit perceptions are associated with their sense of political participation.

Hypothesis 1a: Scientists with higher nanotechnology risk perceptions will be more likely to support the statement that scientists should be actively involved in political debates.

Hypothesis 1b: Scientists with higher nanotechnology benefit perceptions will be more likely to support the statement that scientists should be actively involved in political debates.

Existing literature shows that scientists generally underestimate public opinion (Besley & Nisbet, 2013; Michael & Brown, 2000; Moore & Stilgoe, 2009). However, the impact of public opinion on public policy is strong and significant (Burstein, 2003;

Gilens, 2012). The impact of public opinion remains sturdy even after the activities of governments and elites are considered (Burstein, 2003). Since the issue of the relationship between public preference and policy has been an essential concern of the literature on representative democracy (Soroka & Wlezien, 2010), I speculate that scientists who pay more attention to public opinion would have a higher interest in the policy-making process. This leads the second hypothesis.

Hypothesis 2: Scientists who pay attention to the wishes of the public when they make decisions about nanotechnology will be more likely to say that scientists should be actively involved in political debates about issues such as nanotechnology.

In American politics, religion has always played an important role and despite declination of various forms of civic involvement, participation in religion has persisted over time (Scheufele, Nisbet, & Brossard, 2003; Wuthnow, 1999). Religious beliefs could be part of the value systems people use when they make decisions. For instance, those who engage in church-based political discussions are less likely to engage in political discussions within secular settings, while church-based political discussions were positively related to political knowledge and political involvement (Scheufele et al., 2003). Church attendance has a positive and significant relationship with electoral participation (Jones-Correa & Leal, 2001). Religion, whether Catholic or Protestant, offers significant encouragement for electoral engagement. Religious activity can promote political activity because of the similarities of the tasks (Peterson, 1992). However, other evidence suggests that those who value religious activity more than political activity are less likely to engage in politics (Djupe & Grant, 2001).

Related to nanotechnology, a study based on public demonstrates that there is a relationship between religiosity and attitudes toward nanotechnology including views on policies (Scheufele, Corley, Shih, Dalrymple, & Ho, 2009). This study shows that religious individuals appears less likely to support nanotechnology and therefore require stronger regulation on nanotechnology. Although approval or refusal of the nanotechnology does not indicate one's opinion on political involvement directly, religious beliefs affect scientists' opinions on the nanotechnology policy making. In fact, the debate about the role of religion in politics and public policy influencing science to make it worth examining the religious beliefs and characteristics of scientists (Ecklund & Scheitle, 2007). For these reasons, I hypothesize that scientists who believe we depend too much on science (and not enough on faith) will be less likely to support scientists' active involvement in political debates.

Hypothesis 3: Scientists who believe we depend too much on science (and not enough on faith) will be less likely to support the statement that scientists should be actively involved in political debates.

Scientists' Perceptions about Public Communication

With strong levels of public trust and approval, scientists are among the prominent experts called upon in political debates giving media interviews, testifying before Congress, and so on (Nisbet & Scheufele, 2009). Therefore, it is increasingly important to understand how scientists form their opinions about the public and the communication process.

Scientists tend to believe the public is inadequately informed about scientific issues and further believe that the public is indifferent about becoming more informed

(Besley & Nisbet, 2013; Burningham, Barnett, Carr, Clift, & Wehrmeyer, 2007).

Scientists point out the public's limited ability when describing their justification for public engagement (Besley & Nisbet, 2013), while not having confidence that the public trusts scientists (Burchell, 2007; Young & Matthews, 2007). As such, scientific illiteracy may create opposition to new technologies, environmental action or sufficient science funding (Davies, 2008).

However, at the same time, scientists also believe the importance of science public communication. For example, nanoscientists acknowledge the important connection between the public communication of research findings and public attitude about science, suggesting that nanoscientists are open to the future engagement with policy makers and the public about issues of nanotechnology (Corley, Kim, & Scheufele, 2011). Similarly, while critical of media coverage generally, scientists tend to believe their interactions with journalists are important both for encouraging science literacy and for their career advancement (Besley & Nisbet, 2013). Scientists also strongly believe that they should have a role in public debates (Besley & Nisbet, 2013), and thus, understand the importance of public communication.

Scientists also believe that public communication is a good tool for ensuring the public is well informed about science and technology and its benefits to society (Escutia, 2012). Informing beneficial effects of the scientific findings to the public is one of the reasons for public communication (Irwin & Wynne, 2003). In a similar vein, scientists strongly believe the public should know about the risks and benefits of nanotechnology among other types of information about the technology (Corley et al., 2011). These consistent research results indicate that one of the important roles of public communication is informing the public about the potential benefits and limits of the technology and this leads to the following hypothesis.

Hypothesis 4a: Scientists with higher nanotechnology risk perceptions will be more likely to support the statement that communicating with the public affect public attitudes toward science.

Hypothesis 4b: Scientists with higher nanotechnology benefit perceptions will be more likely to support the statement that communicating with the public affect public attitudes toward science.

Scientists' Perceptions about Regulations

There are concerns about the safety of nanoscale materials (Gaskell, Ten Eyck, Jackson, & Veltri, 2004; McCarthy & Kelty, 2010; Scheufele et al., 2007). A general agreement is that more information on environment, health, and safety (EHS) implications of nanotechnology is needed to create regulatory environment that can encourage careful investment in the field of nanotechnology (Sargent, 2016).

Risk and benefit perceptions can have influence on scientists' regulatory perceptions (Corley et al., 2013). When scientists hold higher risk perceptions, they show higher levels of support for environmental regulation (Silva & Jenkins-Smith, 2007) as well as nanotechnology regulation (Besley, Kramer, & Priest, 2008). Also, nanoscientists with higher risk perceptions were more supportive of nanotechnology regulation (Corley et al., 2009). On the other hand, a study based on the public survey on knowledge and attitude toward nanotechnology shows that the public tends to rely on perceptions of benefits when making policy decisions (Scheufele & Lewenstein, 2005). These lead the fifth hypothesis of the study.

Hypothesis 5a: Scientists with higher nanotechnology risk perceptions will be more likely to support the statement that academic/commercial nanotechnology research should be regulated.

Hypothesis 5b: Scientists with higher nanotechnology benefit perceptions will be less likely to support the statement that academic/commercial nanotechnology research should be regulated.

Also, even the elites' opinions about the safety of new technologies including nuclear energy and genetic engineering come largely from political ideology (Plutzer, Maney, & O'Connor, 1998). In addition, economic conservatism was negatively associated with support for regulation (Corley et al., 2009). That is, economically conservative nanoscientists were less supportive of nanotechnology regulation. In other words, even after controlling for scientific rank, discipline, and perceived risks and benefits, a scientist's political ideology is an important predictor of their opinions on the need for more regulations in the field of nanotechnology (Corley et al., 2009). This leads the sixth hypothesis.

Hypothesis 6: Scientists who identified themselves as more liberal are more likely to support the statement that that academic/commercial nanotechnology research should be regulated.

Although protecting workers from unhealthy exposure to nanomaterials is one of the important aspects of nanotechnology regulations (Poland et al., 2008), there are few formal regulations about protecting manufacturing and laboratory workers in the field (Corley et al., 2016).

On the other hand, the survey data show that elite U.S. nanoscientists have a strong sense of ethical obligation to protect laboratory workers in both university and industry environment from unhealthy exposure to nanomaterials (Mean=4.67; SD=0.72, Mean=4.72; SD=0.69). Also, scientists' ethical obligation for worker safety issues is positively correlated with both regulation perceptions (Corley et al., 2013). Based on these premises, I speculate that nanoscientists with stronger sense of ethics regarding protecting workers would support stronger regulation. This leads the seventh hypothesis.

Hypothesis 7: Scientists who perceive stronger ethical obligations for nanotechnology workers are more likely to support the statement that academic/commercial nanotechnology research should be regulated.

Data Collection & Methods

Quantitative data were drawn from a nationally representative study of elite U.S. nanoscientists. The survey was conducted by mail between June and September 2011, and it was administered by the University of Wisconsin Survey Center in four waves following Dillman's Tailored Design Method (Dillman, Smyth, & Melani, 2011). The final response rate for the survey was 31.6% (AAPOR RR-3: 31.6%) (AAPOR, 2008). The sampling design was based on identifying the authors for the most highly cited nanotechnology publications that were indexed in the ISI Web of Knowledge database in 2008 and 2009. In order to thoroughly establish which publications were within the multidisciplinary field of nanotechnology, the data were drawn from the work by the group in the Center for Nanotechnology in Society at Arizona State University (CNS-ASU) that has refined the definition of nanotechnology using specific bibliometric terms.

For a more detailed description of this group’s refinement process for nanotechnology search terms, see the article by Porter, Youtie, Shapira, and Schoeneck (2008) that outlines and explains the process.

In order to develop the final sample for the 2011 scientist survey, Porter and colleagues developed a database of 189,014 nanotechnology publications from ISIWeb of Knowledge that were published in 2008 and 2009. These records were cleaned to remove any duplicate names, non-U.S.-affiliated scientists, graduate students, and authors who were cited less than 39 times in the two-year period of 2008–2009. This filtering process was used to ensure that the survey sample focused on the most highly cited, most active, U.S.-affiliated scientists within the nanotechnology field. The final filtering process produced 1,405 names with complete addresses, and this yielded 444 completed questionnaires.

Table 2.1: Descriptive Statistics of the Respondents

	Mean	SD
<i>Demographic Variables</i>		
Respondents’ Age	46.071	12.016
Percent Male (<i>Gender</i>)	82.529	N/A
Percent Caucasian (<i>Ethnicity</i>)	63.514	N/A
Percent Asian	31.757	N/A
<i>Political Party Affiliation</i>		
Percent Republican	6.306	N/A
Percent Democrat	45.270	N/A
Percent Independent	45.045	N/A
<i>Career Variables</i>		
Ph.D. Year	1993.674	12.980
Percent in university-based positions	74.155	N/A
<i>Disciplinary Variables</i>		
Percent in Biology	11.486	N/A
Percent in Chemistry	30.631	N/A

Percent in Math & Engineering	13.739	N/A
Percent in Material Sciences	13.964	N/A
Percent in Medicine	3.153	N/A
Percent in Physics	16.441	N/A
Percent in Other Disciplines	3.378	N/A
Percent with no disciplinary response	7.207	N/A

Table 2.1 illustrates the basic descriptive information of the survey respondents. About 63.5% of the scientists identified themselves as Caucasian, 31.8% as Asian, 2% as Hispanic, and 0.5% as African American. Regarding political party affiliation, about 45% of the respondents identified themselves as Democrats, 45% as Independents, and about 6% as Republicans. Table 2.1 also shows that 82.5% of the respondents were male. The mean age for respondents was about 46 years old and the mean year for receiving a doctoral degree was 1994. Finally, about 74% of the respondents said that they had a university-based research position and 44% of the respondents answered that they were tenured.

Dependent Variables

Four dependent variables capture scientists' perceptions about public engagement. The first dependent variable indicates elite U.S. nano-scientists' perceptions about political involvement. The survey question that captures respondents' perceptions about political involvement is: "It is appropriate for scientists to become actively involved in political debates about issues such as nanotechnology or stem cell research" (1 = Strongly disagree; 5 = Strongly agree). For this statement, many of the responses were on the high end of the scale (Mean=4.406; SD=0.985) and therefore non-normally distributed with skewness of -1.897 (SE=.117) and kurtosis of 3.202 (SE=.233).

To use binary logistic model, I recoded the dependent variable as a binary variable. Because of the highly skewed distribution of the variable, the dependent variable was dichotomized by recoding “strongly agree” and “agree” into the category of “1” and recoding “strongly disagree,” “disagree,” and “neither agree nor disagree” into the category of “0”. I conceptualized the skewed distribution as consisting of two parts (DeCoster, Iselin, & Gallucci, 2009): respondents who irrefutably agree with the idea that scientists’ should involve in political debates (i.e., binary recoded variable with responses of 1) and those who do not (i.e., binary recoded variable with responses of 0). In this way, these two groups have distinct opinions in terms of endorsement of political involvement.

The second dependent variable is scientists’ perceptions about public communication. The survey statement that captures respondents’ public communication perceptions is: “Communicating with the public does not affect public attitudes toward science” (1 = Strongly disagree; 5 = Strongly agree). The descriptive statistics show that many of the responses were on the low end of the scale (Mean=1.816; SD=1.079) which shows inverse pattern of responses on political involvement. This statement is non-normally distributed with skewness of 1.391 (SE=.117) and kurtosis of 1.217 (SE=.233). And for the same reason in the first model, dichotomized measure can represent the data more appropriately. To examine factors that affect scientists’ perceptions about public communication in a positive way, the variable was reversed. Then, to use binary logistic model, I recoded the dependent variable as a binary one by recoding 1-3 into 0 and 4-5 into 1. In this way, the variable indicates respondents’ perceptions about public communication.

The third and fourth dependent variables are scientists’ regulatory perceptions about nanotechnology. There are two survey questions that captures respondents’

normative perceptions about nano-regulation: (1) “Academic nanotechnology research should be regulated” (1 = Strongly disagree; 5 = Strongly agree), and (2) “Commercial nanotechnology research should be regulated” (1 = Strongly disagree; 5 = Strongly agree). By recoding 1-2 into 1, 3 into 2, and 4-5 into 3, I created three ordinal scale variables from one to three where one indicates disagree and three indicates agree with the statement that academic/commercial nanotechnology research should be regulated.

Table 2.2 presents the summary statistics for the dependent variables: scientists’ sense of political involvement, scientists’ opinions about public communication, and scientists’ normative regulatory perceptions.

Table 2.2: Dependent Variables (Elite U.S. Nanoscientists’ Perceptions about Political Involvement, Public Communication, and Nano-regulation (N=444))

	Mean	SD
<i>Perceptions about Political Involvement statement</i> (1=Strongly disagree; 5=Strongly agree)		
“It is appropriate for scientists to become actively involved in political debates about issues such as nanotechnology or stem cell research.”	4.406	0.985
<i>Public Communication statement</i> (1=Strongly disagree; 5=Strongly agree)		
“Communicating with the public does not affect public attitudes toward science.”	1.816	1.079
Scientists’ communication perceptions Reversed statement above	4.185	1.079
<i>Regulatory perception statements</i> (1=Strongly disagree; 5=Strongly agree)		
“Academic nanotechnology research should be regulated.”	2.616	1.309
“Commercial nanotechnology research should be regulated.”	3.434	1.305

Independent Variables

In the models, I included a series of independent and control variables.

Respondents' ethnic background, political views, and gender are controlled and I introduced the rationale behind selecting the independent variables in the hypotheses section. Table 2.3 shows the descriptive statistics for the independent variables.

Table 2.3: Independent Variables

	Mean	S. D.
<i>Risk and Benefit Perceptions</i>		
<i>(1=Strongly Disagree; 5=Strongly Agree)</i>		
“Nanotechnology is risky for society.”	2.418	1.206
“Nanotechnology is useful for society.”	4.773	0.602
<i>Public and Social Perceptions</i>		
<i>(1=Strongly Disagree; 5=Strongly Agree)</i>		
“Scientists should pay attention to the wishes of the public, even if they think citizens are mistaken or do not understand their work.”	3.570	1.193
“Scientists should do what they think is best, even if they have to persuade people that it is right.”	3.850	1.081
“We depend too much on science and not enough on faith.”	1.554	0.968
<i>Political Views (1=Very conservative; 5=Very liberal)</i>		
“In general, would you describe your political views as...”	3.475	0.820
<i>Laboratory/research ethics index (Cronbach's alpha=0.932)</i>		
<i>(1 = strongly disagree; 5 = strongly agree)</i>		
“Directors of university-based laboratories have an ethical obligation to protect their workers from unhealthy exposure to nanomaterials.”	4.674	0.718
“Directors of industry-based laboratories have an ethical obligation to protect their workers from unhealthy exposure to nanomaterials.”	4.717	0.693

Among the three variables regarding public and social perceptions, the first statement measures the beliefs in democratic processes and deference toward public opinions when making decisions. Anderson et al. (2011) recognized this concept and called it as “participatory attitudes toward science.” I believe the phrase captures the meaning of the statement and I will use the term hereafter when describing this variable. In a study of public opinion on agricultural biotechnology, Brossard and Nisbet (Brossard & Nisbet, 2007) constructed “deference toward scientific authority” that captures the idea that lay people should not develop their own ideas about what is good or bad when there is a scientific controversy because legitimate authorities have already made decisions (Lee & Scheufele, 2006). Although this term was developed to describe public attitudes, it could be applied to the second statement that measures scientists’ perceptions about their own authority. Thus, I will use the term hereafter when recounting the statement. The third statement of the public and social perceptions measures one’s religiosity which means “strength of religious beliefs” (Brossard, Scheufele, Kim, & Lewenstein, 2009). I will use this term hereafter, instead of recounting the whole statement.

Also, in the survey, there are two statements about laboratory/research ethics. The first statement captures scientists’ perceptions about the ethical obligations of lab directors for university-based nanotech labs and the second statement is about the industry-based nanotech labs. I created a summative index of the two statements and used it as an independent variable about ethical obligations and laboratory workers (Cronbach’s alpha = 0.932).

Empirical Models

In case of skewed distribution, a dichotomized measure can represent the data more appropriately (DeCoster et al., 2009; MacCallum, Zhang, Preacher, & Rucker, 2002). Many studies contend that a dichotomized indicator could perform better when the variable is highly skewed (DeCoster et al., 2009). For example, in a study of attitudes about obesity treatment, Davis, Shishodia, Taqui, Dumfeh, and Wylie-Rosett (2008) dichotomized likert scale responses by incorporating strongly agree and agree into one category, and strongly disagree, disagree, and neutral into another category. Also, because of the highly skewed distribution of the dependent variable, dichotomized 5-point likert scale variable of patient's perceived reciprocal concerns into "strongly/somewhat agree" and others. Similarly, for the first two dependent variables, I created dichotomous dependent variables of satisfaction with decision-making (yes/no) with higher average scores (4-5) representing satisfaction and lower average scores (1-3) representing dissatisfaction. Then I conducted binary logistic regressions to make predictions regarding factors that are associated with the two dependent variables: scientists' perceptions about political involvement and scientists' perceptions about public communication.

To examine scientists' perceptual factors that are associated with their regulatory perceptions, I used ordered probit regressions because of the ordinal structure of the two dependent variables. Ordered probit regression estimates a specific score as a linear function of the independent variables and a set of cut-points (Jackman, 2009). To predict scientists' levels of regulatory perceptions and independent variables, I conducted two ordered probit regressions using scientists' perceptions about regulating academic and commercial nanotechnology research as dependent variables.

To analyze the data, Statistical Package for Social Sciences (SPSS) software was used. Based on the literature I reviewed, I speculated that multiple factors are associated with nano-scientists' perceptions about political participation, perceptions about public communication, and perceptions about nanotechnology research regulation. To examine the relationship among these factors, multivariate analyses were conducted. For the analyses, the effects of gender and ethnicity of the scientists were controlled.

Results

Table 2.4: Binary logistic regression for Scientists' Perceptions about Involvement in the Political Debate (N=444)

	B	S.E.	Wald	df	Sig.	Exp(B)
Model 1: Dependent Variable ("It is appropriate for scientists to become actively involved in political debates about issues such as nanotechnology or stem cell research.") [†]						
<i>Risk and Benefic Perceptions</i>						
Nano Risk Perception	.279	.141	3.897	1	.048	1.322*
Nano Benefit Perception	.409	.215	3.637	1	.056	1.506
<i>Public and Social Perceptions</i>						
Participatory attitudes toward science	.427	.129	11.052	1	.001	1.533**
Deference toward scientific authority	.277	.138	3.990	1	.046	1.319*
Strength of religious beliefs	-.614	.150	16.691	1	.000	.541**
<i>Ethical obligations</i>						
Laboratory/research ethics index	-.086	.115	.560	1	.454	.917
<i>Political ideology</i>						
Political Views	.045	.206	.049	1	.826	1.047
<i>Controls</i>						
Caucasian	.940	.320	8.610	1	.003	2.560**
Female	-.041	.379	.012	1	.913	.959
Constant	-2.030	1.823	1.241	1	.265	.131

[†] -2 Log likelihood = 280.498; Chi-Square = 49.214 (p<0.01); Pseudo R-squared = .114

B is the estimated logit coefficient; Exp(B) is the "odds ratio" of the individual coefficient.

Significance level: * p<0.05, **p<0.01.

To test the first three hypotheses, I conducted a binary logistic regression analysis. As stated in the previous sections, I expected that multiple variables are associated with scientists' sense of political involvement, therefore conducted a multivariate analysis for this model. The regression findings are presented in Table 2.4. The goodness of fit test (-2 log likelihood test) show that the modeled probabilities fit the data.

Table 2.4 shows that respondents with high risk perceptions about nanotechnology are more likely to support scientists' involvement in the political debates about scientific issues ($\exp(B)=1.322$, $p<.05$). On the other hand, scientists' benefit perceptions are not significantly associated with their perceptions about political involvement at the 0.05 significance level. Although there is no absolute rule, an alpha value of 0.05 is used as the cutoff for significance in the majority of analyses (Fisher, 1950). For this reason, I use it as the significance level of the study. In other words, scientists' perceptions about the potential risks of nanotechnology (but not benefit perceptions) are significantly related to their opinions about scientists in political debates. Therefore, the first hypothesis was confirmed only for the scientists' risk perceptions.

Yet some scholars use a higher alpha value of 0.1 as a cutoff for significant results. At the 0.1 significance level, scientists' benefit perceptions are also significantly associated with their perceptions about political involvement. Although a p value between 0.05 and 0.10 is considered of borderline statistical significance (Wainwright et al., 1996), it can be interpreted as a trend, or a weak support for a hypothesis (Dadvand et al., 2013; Verhoef, 2005). In this case, the results can be interpreted that both risk and benefit perceptions are positively associated with scientists' perceptions about the political involvement.

Then, I tested the two hypotheses examining the relationship between scientists' public and social perceptions and their perceptions regarding political involvement. The results indicate that scientists' perceptions about science and society have influences on their views about their involvement in political debate. As Table 2.4 illustrates, the three variables, "participatory attitudes toward science," "deference toward scientific authority" and "strength of

religious beliefs” were all significantly associated with scientists’ perceptions about political involvement. The results confirmed the second hypothesis that scientists who pay more attention to the wishes of the public are more likely to support scientists’ involvement in political debates about controversial scientific issues such as nanotechnology or stem cell research ($\exp(B)=1.533$, $p<.01$). The third hypothesis that scientists with a higher devotion to (religious) faith are less likely than their peers to believe that scientists should be engaged in political debates was also confirmed ($\exp(B)=0.541$, $p<.01$).

Related to the control variables, the results show that the ethnicity variable has a significant impact, showing that Caucasian respondents were 2.6 times more likely to have a positive attitude about scientists’ involvement in political debates about issues like nanotechnology or stem cell research (Table 2.4). On the other hand, the regression results indicate that respondents’ gender was not significantly associated with the likelihood of having a positive view toward scientists’ political involvement perceptions when controlling other variables.

As a robustness check, I ran the same regression with a revised dependent variable. To test whether or not including a mid-point category (Neither agree nor disagree) in the model changes the results, I dropped the neutral category and dichotomized the dependent variable. Thus, the dependent variable was dichotomized by recoding “strongly agree” and “agree” into the category of “1” and recoding “strongly disagree” and “disagree” into the category of “0”. The results are very similar to those presented in Model 1, except that “Deference toward scientific authority” lost its statistical significance, probably because the number of observations dropped by 33. Since not much differences were present between the primary regression results and the above regression results, I will not report the estimation results of these robustness checks in this paper.

Table 2.5: Binary logistic regression for Scientists' Perceptions about Public Communication (N=444)

	B	S.E.	Wald	df	Sig.	Exp(B)
Model 2: Dependent Variable ("Communicating with the public does affect public attitudes toward science.") [†]						
<i>Risk and Benefic Perceptions</i>						
Nano Risk Perception	.005	.115	.002	1	.968	1.005
Nano Benefit Perception	.508	.205	6.161	1	.013	1.661*
<i>Public and Social Perceptions</i>						
Participatory attitudes toward science	.194	.111	3.037	1	.081	1.214
Deference toward scientific authority	-.017	.124	.018	1	.894	.984
Strength of religious beliefs	-.154	.137	1.264	1	.261	.857
<i>Ethical obligations</i>						
Laboratory/research ethics index	.120	.085	1.989	1	.158	1.127
<i>Political Ideology</i>						
Political Views	.512	.183	7.845	1	.005	1.669**
<i>Controls</i>						
Caucasian	.915	.272	11.321	1	.001	2.496**
Female	-.165	.341	.236	1	.627	.848
Constant	-4.715	1.603	8.654	1	.003	.009**

[†] -2 Log likelihood = 365.004; Chi-Square = 38.412 ($p < 0.01$); Pseudo R-squared = .090

B is the estimated logit coefficient; Exp(B) is the "odds ratio" of the individual coefficient.

Significance level: * $p < 0.05$, ** $p < 0.01$.

Model 2 demonstrates characteristics that are associated with scientists' perceptions about public communication. The goodness of fit test (-2 log likelihood test) show that the modeled probabilities fit the data.

One of the important roles of public communication of scientists is informing the public about the potential benefits and risks of the technology (Corley et al., 2011; Escutia, 2012; Irwin & Wynne, 2003). I hypothesized that risk and benefit perceptions about nanotechnology could have a significant influence on scientists' perceptions about public communication. The results show that scientists' benefit perceptions were positively associated with their beliefs about the influence of public communication ($\exp(B)=1.661$, $p<.05$). In other words, those who believe nanotechnology is useful for society are more likely to support the statement that communicating with the public affect public attitudes toward science and this confirms the fourth hypothesis on perceived benefits of nanotechnology (but not on perceived risks).

One interesting finding is that unlike Model 1, political views are positively related to the dependent variable in Model 2 ($\exp(B)=1.669$, $p<.01$). In Model 1, the political ideology variable does not affect scientists' perceptions about whether they should be involved in political debates. On the other hand, Model 2 shows that liberal scientists are more likely to agree that communicating with the public influences public attitude toward science.

Related to the control variables, the ethnicity variable has a significant impact. It shows that Caucasian scientists were 2.5 times more likely to believe that communicating with the public affect public attitudes toward science than their peers.

As in the Model 1, I ran the same regression with a revised dependent variable as a robustness check. To test whether or not including a mid-point category (Neither agree nor disagree) in the model changes the results, I dropped the neutral category and dichotomized the dependent variable. The dependent variable was dichotomized by recoding "strongly agree" and "agree" into the category of "1" and recoding "strongly disagree" and "disagree" into the category

of “o”. In this robustness check, I found similar results and the coefficient signs to those presented in Model 2. However, scientists’ benefit perceptions lost its statistical significance. Since the primary interest of the dependent variable is to capture whether scientists agree with the impact of public communication, I believe including mid-point category into the one with who do not entirely agree with the idea that communicating with the public affect public attitudes toward science makes more sense. Also, in the alternative model, the number of observations dropped by 39. For these reasons, I placed greater emphasis on the original model.

Table 2.6: Ordered Probit Regression for Scientists' Regulation Perceptions (N=444)

	Model 3: "Academic nanotechnology research should be regulated."			Model 4: "Commercial nanotechnology research should be regulated."		
	Coeff	S.E.	Sig.	Coeff	S.E.	Sig.
<i>Risk and Benefic Perceptions</i>						
Nano Risk Perception	.225**	.052	.000	.234**	.053	.000
Nano Benefit Perception	-.005	.105	.962	.058	.108	.591
<i>Public and Social Perceptions</i>						
Participatory attitudes toward science	.048	.052	.356	.065	.052	.214
Deference toward scientific authority	-.131*	.056	.020	-.068	.058	.235
Strength of religious beliefs	.013	.071	.859	-.056	.071	.433
<i>Ethical obligations</i>						
Laboratory/research ethics index	.178**	.055	.001	.134**	.044	.003
<i>Political Ideology</i>						
Political Views	.149	.081	.064	.100	.082	.221
<i>Controls</i>						
Caucasian	-.333*	.131	.011	-.332*	.133	.013
Female	.397*	.165	.016	.376*	.174	.031
-2 Log Likelihood			704.150			685.993
Pseudo R-squared			.154			.127

Significance level: * $p < 0.05$, ** $p < 0.01$.

I used ordered probit regression models to investigate which perceptual factors were associated with scientists' perceptions about nanotechnology research regulations. The analysis generated two models: a model using scientists' regulatory perception about academic nanotechnology research as a dependent variable and a model using scientists' regulatory perception about commercial nanotechnology research as a dependent variable. I also expect that multiple variables are associated with scientists' opinions about regulation on nanotechnology research, therefore conducted a multivariate analysis for these models. The goodness of fit test for both models (-2 log likelihood test) show that the modeled probabilities fit the data.

I hypothesized that both risk and benefit perceptions about nanotechnology could have a significant influence on scientists' perceived need for regulation of the technology. Table 2.6 demonstrates that for both Model 3 and 4, risk perceptions had a positive and a significant relationship with the scientists' perceptions about regulation ($\beta=.225$, $p<.01$; $\beta=.234$, $p<.01$). However, different from the public who tend to rely on benefit perceptions when making policy decisions (Scheufele & Lewenstein, 2005), in both models, benefit perceptions were not significantly related with the scientists' nanotechnology regulation perceptions. Therefore, the fifth hypothesis was confirmed only for the scientists' risk perceptions.

Also, the laboratory/research ethics index was significantly associated with scientists' perceived need for regulation of both academic and commercial nanotechnology research ($\beta=.178$, $p<.01$; $\beta=.134$, $p<.01$). The results show that scientists with a stronger sense of ethical obligation to protect workers within a laboratory environment were more likely to agree that nanotechnology research should be regulated, which confirms the seventh hypothesis.

Based on the literature, I hypothesized that respondents with liberal political views would be more likely to support regulating nanotechnology research (Corley et al.,

2009). However, the political ideology variable is not significantly associated with scientists' perceived need for regulation in both models 3 and 4. These results mean that we can reject the sixth hypothesis. In other words, the results show that nano-scientists' political views do not affect their policy decision-making on research regulation.

Existing literature shows that public and elites' opinions about new technologies often come from their political ideology (Plutzer, Maney, & O'Connor, 1998). However, the results of the four regression models show that scientists' political ideology was associated only with their perceptions about public communication and not with their perceptions about political involvement or research regulation. Considering concerns about scientists' political bias or politicization, I believe the results suggest that the relationship between scientists' political ideology and their political behavior should be discussed in more detail.

Related to the control variables, table 2.6 also shows that both respondents' ethnicity and gender are associated with their perceptions about nanotechnology regulation. That is, scientists who identified themselves as Caucasian are less likely to support the statement that nano-research should be regulated; while female nanoscientists are more likely to support the statement than their male peers.

Overall, the two models generated similar results but one variable, "deference toward scientific authority" was statistically significant only in Model 3 ($\beta = -.131, p < .05$) but not in Model 4. That is, respondents who defer more to the authority of science are less likely to support the regulation of academic nanotechnology research. Also, at the 0.1 significance level, political ideology is significantly associated with scientists' perceptions about regulation of academic nano-research. In this case, the results can be interpreted that scientists who are more liberal are more likely to support the regulation of academic nanotechnology research, while political ideology is not associated with regulation of commercial nanotechnology research.

To examine the robustness of the two models for the scientists' regulatory perceptions, I conducted Ordinary Least Square (OLS) regression using the original likert-scale variable. The significance of the coefficients indicates that the perceptual factors that are associated with each dependent variable are very similar to the results in each model. However, as shown above, the dependent variables are ordinal variables taken from a truncated population and in this case, linear regression is inappropriate (Greene, 2003). Therefore, I placed greater emphasis on ordered probit regression results.

Overall, the estimated models have low pseudo R-squared values meaning that the independent variables fail to explain much of the variation in the dependent variables. Low R-squared values are typical of these types of models (Caplan, 2001) and the value for the pseudo R-squared is not expected to be as high as a conventional OLS R-squared because it is unlikely that the predicted values of the probit model will be exactly one or zero (Wooldridge, 2003). However, I speculate that the explanatory power of the models can be increased by including more detailed information about the respondents. The limitations associated with the sample of the survey will further be discussed in the next section.

Conclusions

The complexity of policy issues and their scientific and technical aspects have made public officials heavily rely on science and scientists. Despite expectations and calls for scientists to take a more active role in scientific policy debates (Jennings & Hall, 2012; Leshner, 2003), there have been few studies focused on individual scientists' perceptions about public engagement. This research looks into scientists' perceptions in association with public engagement in the field of nanotechnology. It demonstrates perceptions about nanotechnology among U.S. nano-scientists and examines the

influence of scientists' individual perceptions on their perceptions about public engagement, including political involvement, public communications, and regulations.

This study offers four important summary points to take. First, at a time when the calls for scientists to actively engage in politics (Besley & Nisbet, 2013; Dudo & Besley, 2016), this study contributes to the understanding of scientists' perceptions about public engagement. There is a strong urge from science policy makers for more responsible scientists, aware of the consequences of their research for the society at large (Bensaude-Vincent, 2012). The results of the study show that scientists are willing to provide their expertise to the public and decision makers. More specifically, nanoscientists generally agree that scientists should be actively involved in political debate and believe communicating with the public does affect public attitudes toward science at the same time. I believe the results of the study encourage the use of science for government agencies that wish to involve scientists and drive better public engagement of scientists in policy development. I also hope that the findings can help those who manage conversations between scientists and the public.

The second contribution of this research is that it demonstrates one of the barriers in the use of science in policy making: a broad diversity of opinions among nano-scientists regarding their public engagement. Public policy controversies are often driven by value differences rather than technical deficiencies (Weible, 2007), therefore scientists' diversity of opinions affect their political decision making. A recent OECD report contended that for scientific advice to be incorporated into policy making in a sound and effective manner, the diversity of scientists must be handled properly (OECD, 2015). My research findings proved that there was a diversity of opinions among nano-scientists. Therefore, policy makers in this field should understand that scientific judgment is made within a value-rich context and consider nano-scientists' diverse views depending on their fields, approaches, and subjective judgments.

The third contribution of the research is that it proves nanoscientists' risk and benefit perceptions affect their public engagement perceptions differently. Results show that scientists' risk perceptions of nanotechnology were positively associated with their ideas about political involvement or regulation establishment. In other words, scientists with higher risk perceptions of the technology are more likely to participate in policy making and more likely to agree with nanotechnology regulation. Since nano-scientists' support for regulation is significantly related to their risk perceptions, it will be important for policy makers to include scientists in their decision-making processes about developing new regulatory policies for nanotechnology. On the other hand, scientists' benefit perceptions were associated with acknowledging the importance of public communication. Previous study showed that public tends to rely on their perceived benefits (rather than perceived risks) when making decisions about nanotechnology (Scheufele & Lewenstein, 2005) and in this sense, nano-scientists seem to communicate effectively with the public.

The fourth contribution of the research is that it shows positive relationship between scientists' ethical obligations for worker safety and their support for establishing nanotechnology regulations. One of the primary areas of concern in the field of nanotechnology is the potential adverse impact on workers (Schulte et al., 2014). Although ethical aspects of nanotechnology have to be taken into account from its early stage (Bensaude-Vincent, 2012), there is lack of nanotechnology laboratory specific regulations for worker safety (Ahn, Kim, Corley, & Scheufele, 2016). My research findings suggest policymakers to consider nano-scientists' strong concern over worker safety issue and its connection with calls for appropriate regulations.

Despite these contributions, this study also has some limitations associated with the sample for the survey. Although the survey includes questions regarding respondents' demographic such as gender, age, and ethnicity, it lacks some detailed

information, such as nationality of the respondents or consideration of self-selection bias. For example, U.S. scientists who are not native U.S. citizens may have different opinions about nanotechnology, society, and their political engagement than U.S.-born citizen scientists. Similar differences can be found between scientists who respond to the surveys and scientists who do not respond to the survey. These types of potential problems can be addressed by adding or modifying a few questions for future survey data collection. In addition, the small number of female scientists and self-identified Republicans in the survey can be problematic because they raise concerns about the distribution of demographic variables. Future survey data collection should reflect these limitations for future sampling design.

Nanotechnology provides a good case for new ideas about public engagement, and science and democracy. Exploring the relationship between scientists' individual values and their perceptions about public engagement can shed light on how (and when) scientists should be brought into meaningful conversations with the public. I believe this research can be a guide for policy makers who want to induce science into government decision making. It can also be a useful tool for scientists' who want to more public engagement activities, bridging the gap between science and decision making.

Chapter 3

ROLE OF SCIENCE AT EPA: HOW DOES EPA USE SCIENCE IN REGULATORY DECISION MAKING ON NANOTECHNOLOGY?

“Science has been the backbone of the most significant advancements EPA has made in the past four decades and continues to be the engine that drives American prosperity and innovation in the future.”

– EPA Administrator Gina McCarthy, Remarks at the National Academy of Sciences (04/28/2014)

The mission of the US Environmental Protection Agency (EPA) is to protect human health and the environment.⁵ Since its establishment in 1970, EPA holds a leadership role in developing many fields of environmental science and engineering. Among the government institutions, the EPA is considered to be one of the most important and most active regulatory agencies that use scientific advice (Elliott, 2003). During the past four decades, science has been “the backbone of the most significant advancements the EPA has made,”⁶ and science is important for providing the best-quality foundation of the agency decisions. Also, the EPA has supported academic research and enhanced scientific information that is a foundation for regulatory decisions (Darnall, Jolley, & Handfield, 2008; Kyle et al., 2008; NRC, 2012).

⁵ US Environmental Protection Agency Retrieved from <https://www.epa.gov/aboutepa/our-mission-and-what-we-do>

⁶ EPA Administrator Gina McCarthy, Remarks at the National Academy of Science, April 28, 2014.

However, despite EPA's efforts and advisory organizations, some scholars suggest that science is underrepresented in policymaking at EPA (Elliott, 2003). They argue that science is often not the highest consideration in EPA's rulemaking (Powell, 1999). In addition, since EPA is a regulatory agency and is not fundamentally a science agency, the EPA's role of supporting science can sometimes be challenging (NRC, 2012). Moreover, science does not drive EPA's policy and regulatory decisions directly even though it informs and supports those decisions (EPA, 2012a) along with other non-scientific factors.

Additionally, there is lack of literature that describes the use of science on EPA's decision making of emerging technologies. Assessing potential risks and hazards associated with an emerging technology is critical for regulatory policy-making, therefore the agency is bound to rely heavily on science. However, despite numerous studies and reports on EPA's role and function (EPA, 2012a, 2012b, 2013), there is little study focusing on its use of science for emerging technology policy making.

This paper offers two contributions to existing literature. First, it gives internal perspectives about the use of science at the EPA in nanotechnology decision making. There is no existing literature conducting personal interviews with the members of the agency regarding its use of science even though qualitative interview analysis can provide unique perspectives to the study of this topic. Second, this paper provides the overview of the current use of science at the EPA. It explores EPA's use of science primarily focusing on nanotechnology policy based on recent organizational structure of the agency.

The purpose of this paper is to better understand the role of science at the EPA and the contributions of scientists to EPA's regulatory policy decision-making. I will first review the current use of science at the EPA, followed by difficulties for the use of

scientific information at the agency. Then, using two of the EPA's nanotechnology policies as cases, I will examine interviews with EPA officials who were involved in the policy making processes focusing on the agency's use of science.

Use of science in policy making

Reaching to a consensus of the “use of science in policy making” is unlikely (National Research Council, 2012b). The term “use” can be interpreted differently depending on the perspectives (Neilson, 2001) and researchers conclude that various definitions of use are needed for different purposes (Rich, 1997; Weiss, 1979). Given the context-dependent nature of the use of science, a frequently cited typology about the types of uses of science in policy making is that of Weiss (Weiss, 1979; Weiss, Murphy-Graham, & Birkeland, 2005).

- Instrumental uses occur when research knowledge is directly applied to decision making to address particular problems.
- Conceptual uses occur when research influences or informs how policy makers and practitioners think about issues, problems, or potential solutions.
- Tactical uses involve strategic and symbolic actions, such as calling on research evidence to support or challenge a specific idea or program, such as a legislative proposal or a reform effort.
- Imposed uses (which is perhaps a variant on instrumental uses) describe mandates to apply research knowledge, such as a requirement that government budgeting be based on whether agencies have adopted programs backed by evidence.

In addition, other scholars added a fifth category of symbolic or ritualistic use, which is collecting information with no real intention to take it seriously, except to persuade others or to delay action (Leviton & Hughes, 1981; Shulha & Cousins, 1997). Weiss emphasizes that these uses can be found in particular situations; but that no one of them offers a complete picture (National Research Council, 2012b; Weiss et al., 2005).

However, some scholars have claimed that it is difficult to expect a clear typology for the use of science in policy. They argue that typologies cannot be easily applied empirically, even though they are heuristically valuable (National Research Council, 2012a). The empirical application is difficult because use is “a dynamic, complex and mediated process, which is shaped by formal and informal structures, by multiple actors and bodies of knowledge, and by the relationships and play of politics and power that run through the wider policy context” (Nutley, Walter, & Davies, 2007, p. 111).

In addition, importing scientific peer reviews for regulatory decision making can be a form of use of science in government agencies. The scientific peer review process helps produce knowledge that policy makers can rely on and therefore improve the quality of decisions (Jasanoff, 1990). Although the practice of peer review varies across government agencies (Guston, 2003), the General Accounting Office (GAO) defines that “all of the agencies’ definitions or descriptions of peer review contained the fundamental concept of a review of technical or scientific merit by individuals with sufficient technical competence and no unresolved conflict of interest” (General Accounting Office (GAO), 1999, p. 3). The EPA also declares that the Agency’s strict scientific peer review processes are designed to ensure that all decisions made by the agency are founded on

credible science and data.⁷ Under these premises, in this paper, the term “use of science” is broadly understood to mean that science is incorporated into policy arguments.

EPA’s use of science in the rulemaking process

Regulatory Peer Review

Science provides the foundation for EPA’s policies, actions, and decisions made on behalf of the American people.⁸ The EPA applies forms of peer review in its regulatory, evaluative, or assessment tasks and EPA’s Science Advisory Board (SAB) is an example of such mechanisms (Guston, 2003). Among other federal agencies, the EPA has made most intensive effort to increase the application of peer review to the use of science in its own decision making during 1990s (Guston, 2003). When scientific and technical information is used as part of the basis for a public-policy decision, peer review can significantly improve not only the quality but also the integrity of the scientific or technical basis for the decision (National Research Council, 2000). The EPA published multiple documents emphasizing the importance of peer review and the use of the best science in EPA’s decision makings. In recent years, the EPA is keep developing innovative ways to communicate how science informs its policies in sophisticated but accessible ways (EPA, 2011). Further, under Integrated Risk Information System (IRIS), EPA solicits written comments from external expert peer reviewers, the general public, and from other federal agencies (Dudley, 2012).

⁷ Role of Science at EPA. Retrieved from <https://www.epa.gov/research/role-science-epa>

⁸ Role of Science at EPA. Retrieved from <https://www.epa.gov/research/role-science-epa>

Science Advisory Organizations

The EPA uses science to support its decisions in various ways. The Office of Research and Development (ORD) has the primary responsibility for its science and technology. For example, regulation development groups within the EPA involve an ORD scientist or engineer in doing their work (Goldstein, 2010) and this individual can check whether a proposed regulation is based on credible science. Further, advisory committees help the agency to make political decisions are reasonable, justifiable, and effective while promoting public acceptance (Brown, 2009). Table 3.1 shows the list of the EPA science advisory organizations and demonstrates summary of their roles.

Table 7: EPA Science Advisory Organizations – EPA’s use of scientific advice

Internal Science Advisory Organizations	Activities
Environmental Technology Council (ETC)	Enhances communication and coordination of all EPA technology activities.
Office of the Science Advisor (OSA)	Provides leadership in cross-Agency science and science policy development and implementation to ensure the best possible use of science at the Agency.
Office of Science Policy (OSP)	Coordinates and shares information among EPA's laboratories and centers, and provides expert advice on the use of scientific information.
Science and Technology Policy Council (STPC)	Addresses EPA's significant science policy issues that go beyond regional and program boundaries. Contributes guidance for selected EPA regulatory and enforcement policies and decisions.
External Science Advisory Organizations	Activities
Advisory Council on Clean Air Compliance Analysis (Council)	Provides advice on technical and economic aspects of reports EPA prepares on the Clean Air Act's effects.

Clean Air Scientific Advisory Committee (CASAC)	Provides advice on the technical bases for EPA's national ambient air quality standards program.
National Advisory Council for Environmental Policy and Technology (NACEPT)	Advises the EPA Administrator on a broad range of environmental policy, technology, and management issues.
Science Advisory Board (SAB)	Provides peer review and other types of expert advice on a wide range of topics in science and technology.

Note. Adapted from EPA's Science Organizations.

<http://www2.epa.gov/aboutepa/about-epas-science-advisory-organizations>

Scientific advisory committees are an essential part of any administrative state. They assess, review, and interpret complex scientific and technical information that advises policy making and regulatory engagements by federal agencies (Conley, 2007). Advisory committees provide the EPA with the capacity to review and govern issues surrounding science and technology, but they do not explicitly deal with emerging technologies. A recent report studying representative models for governance of emerging technologies selected six EPA advisory groups (ETC, OSA, OSP, STPC, NACEP, and SAB) as examples of EPA's governance of emerging technologies (Christou & Saner, 2012). Also, consultation between agencies and advisory committees has become routine even when not required by law especially for the issues of environmental, health, and safety regulation (Jasanoff, 1990).

Scientific Advisors – National Research Council (NRC)

In 2012, the National Research Council (NRC) convened the Committee on Science for EPA's Future and assessed EPA's activities. The committee notes that the EPA is well prepared to use many scientific and technologic advances and that EPA

scientists and engineers are leaders in some fields (NRC, 2012). The agency utilizes the expertise of many organizations and institutions with different mandates, which demonstrate the role and use of scientific advice at the EPA. And these scientific advisors are required to have proficiency in the relevant scientific disciplines as well as familiarity with the range of views of others within the field (OXERA, 2000). The EPA has scientific and technical assistants within its own organizational structure represented by ORD, and has independent external advisory organizations that can supplement possible problems from having internal organizations only. Despite these various approaches to promote its use of scientific advice, however, the EPA faces challenges for its use of science for decision-making.

Challenges for the Use of Science at EPA

Attempts to improve policies by applying scientific information often are not very successful (Adams & Hairston, 1994). The EPA also faces significant challenges in managing the development and analysis of science and using science to inform its decision making (RPPI, 2001). There are at least five existing and potential challenges that might hinder the use of science in decision-making particularly at the EPA.

The first challenge for the use of science at the EPA is scientific uncertainty. Scientific information about emerging technologies necessarily includes high degree of uncertainty and a lack of values consensus, which often causes room for multiple interpretations (Mossman, 2009). Scientific uncertainty also has dynamic nature because of the changes in scientific knowledge over time which make more difficult to adopt recommendations even if they are proposed by outstanding scientists. Especially, environmental policies often have to deal with issues “at the frontiers of scientific

knowledge where information is incomplete, inconclusive, and ambiguous” (Fein, 2011, p. 471).

The second challenge for the use of science at the EPA is the politicization of science (Guston, 2001; Jotterand, 2006). The success and legitimacy of scientific advisory committees depend on their independence from political or economic pressures. If scientists are influenced by these external pressures, they can only be a tool to advance politics “under the guise of science” (Conley, 2007, p. 165). Although using advisory committees can make significant contributions to policy decision-making at the EPA, the issues of politicization is problematic. For example, the members of the advisory committee generally disagree about the type of regulatory response and therefore, the most intense committee discussions are mostly on policy issues rather than science, even when there is scientific uncertainty (Ashford, 1984). Another good example of political pressure would be the case that occurred early in the Reagan Administration: after taking office, EPA Administrator Ann Gorsuch dismissed most of the scientists on EPA’s SAB and replaced them with scientists who were Republicans (Elliott, 2003). Likewise, the EPA has been swayed by political pressures which gave the agency a dishonorable reputation.

Some reports state that the EPA does not always utilize reliable science to support its rules and regulations and argue that EPA’s science program is impacted by various congressional mandates and affected by politics (OARM, 1993; RPPI, 2001). Also, they argue that the agency has a basic conflict between being a regulatory agency and having a role in deciding how science is utilized. For example, the EPA’s ability to conduct an “effective and coherent quality-science program is impacted by numerous congressional mandates and highly departmentalized appropriations” (OARM, 1993, p. 5). In the environmental issues, Congress often directs administrative agencies to make

their decisions based on science (Fein, 2011). Consequently, the EPA may pass regulations that could be insufficient to address immediate problems. Likewise, although science can provide some answers to the value neutral questions, many environmental problems are value-laden issues that can be defined politically rather than scientifically (Bryant, 2009).

The third challenge when using scientific advice in decision making process at the EPA is the issue of conflict of interest and ethics of the committee members. It is important that scientific advisory committees be 1) representative of the general body of science community with relevant expertise on the issue and 2) be free of conflicts of interest or biases that could affect their neutrality (Conley, 2007). The National Academies' policy on conflicts of interest states:

[I]f a report is to be not only sound but also effective as measured by its acceptance in quarters where it should be influential, the report must be, and must be perceived to be, not only highly competent but also the result of a process that is fairly balanced in terms of the knowledge, experience, and perspectives utilized to produce it and free of any significant conflict of interest (The National Academies, 2003, p. 1).

The GAO's report showed several limitations of the EPA SAB's policies and procedures for ensuring independence of peer-review panelists and for providing the public with adequate information about panelists' background or opinions (GAO, 2001). For example, SAB did not require panelists to disclose relevant financial information which raised public concerns about panelists' conflicts (GAO, 2001). Despite GAO's

recommendation to address the issues, advisory committees at the EPA did not take steps to enhance the integrity and transparency (GAO, 2009).

The fourth challenge for the use of science at the EPA is ineffective communications between its policy makers and scientists. In fact, EPA's limited ability to support and encourage its scientific experts has adversely affected EPA's decision making based on sound science (OIG, 2006). Jasanoff (1990) points out an institutional limitation that all EPA advisory committees' comments on the quality of the scientific support for policies are not binding on the EPA. Since the EPA is not bound by the committees or boards' judgment, they are often ignored by the agency which can be frustrating to the scientific advisors (Jasanoff, 1990).

In addition, there is a strong cultural difference between the role of science at EPA and the role of science in other agencies such as the FDA (Elliott, 2003). At other agencies, scientists speak with their highest authority on scientific issues and they can make policy recommendations as well; while at the EPA, scientists should adhere only to the scientific issue and cannot participate in policy decisions (Elliott, 2003). This limited power of scientific advisors in SAB at the EPA seems to be due to its stated mission, which makes SAB to give advice or review only on purely scientific and technical information.⁹

The fifth challenge for the use of science at the EPA is selecting unbiased members for the advisory organizations at the EPA. According to the hearing of the Environment Subcommittee entitled Improving EPA's Scientific Advisory Processes, although the EPA claims SAB as an "independent" organization, there were counterevidence such as excluding private sector expertise while assembling panels with

⁹ EPA. (2013). EPA Science Advisory Board (SAB), Retrieved from <http://yosemite.epa.gov/sab/sabpeople.nsf/webcommittees/BOARD>

individuals likely to support EPA's perspectives (Subcommittee on Environment, 2013, March 20). Moreover, many supposedly-independent advisors directly received grants from the EPA, and some panelists are neither neutral nor independent on issues they are advising about (Subcommittee on Environment, 2013, March 20).

While the literature focuses on official ways of using science and challenges to the use of science at the EPA, what remains unclear is empirical evidences that show how the agency use scientists or scientific information in individual cases. Using two of the regulatory policies as cases, this paper examines the use of science in the EPA's nanotechnology policy-making. The case of nanotechnology regulatory policy is particularly important because it can be an example of how the EPA addresses challenges from emerging technologies with high uncertainty.

Changes in the Political Context of the EPA's Use of Science

Recently, science organizations in the U.S. have expressed concern about waning policy influence, declining government funding, and the growing politicization of science (Gauchat, 2015). Under the Trump administration, the conflicts between the scientific community and the government seems to be intensifying. For example, the administration has requested significant budget cut from the EPA's science programs.¹⁰ Also, on February 7, 2017, a hearing on EPA's use of science titled "Making EPA great again" was held by the House Committee on Science, decision-making. One subject of discussion was about reintroducing "Secret Science Reform Act" which require EPA regulations to rely only on science that is both reproducible and publicly available.

¹⁰ New York Times. 2017. Trump Budget Would Cut E.P.A. Science Programs and Slash Cleanups. Retrieved from <https://www.nytimes.com/2017/05/19/climate/trump-epa-budget-superfund.html>

Although some endorsed the bill as a way to make government science more transparent, it received widespread criticism from scientists. Scientists argue that the Act could harm EPA's ability to function and will impede EPA's ability to use science.

Ever since, the administration officials including the head of the EPA have continually contended that they intend to return the agency to its "core responsibility" of protecting air and water quality. More recently, combating climate change by regulating carbon dioxide emissions, which was a key focus in the Obama administration, has vanished from the EPA's mission. Likewise, the agency's decades of efforts to protect public health and safety based on best available science are at risk of being damaged.

EPA's nanotechnology regulation and use of scientific information

Emerging technology is a technology with high potential risks and benefits but has not demonstrated its value or settled down into consensus (Cozzens et al., 2010). Lack of existing data on the technologies and difficulties of assessing potential risks of them make the development of adequate regulatory policies particularly challenging. Nanotechnology is an emerging technology that poses new challenges for the EPA (National Research Council, 2012a). One of the challenges for the EPA is to use science needed to assess and manage the widespread use of nanomaterials that have unknown risks (National Research Council, 2012a). It includes evaluating potential risks associated with emerging technologies and monitoring potential exposures and hazards. EPA has the statutory authority to regulate nanomaterials (U.S. EPA Office of the Inspector General, 2011). Under Toxic Substances Control Act (TSCA), the EPA has established various nanotechnology regulations. The EPA has maintained both a research and regulatory function at since its enactment of the National Nanotechnology Initiative (NNI) (Sargent, 2011). The agency owns research laboratories, funds academic

research, and uses scientific information from other sources to support its regulatory decisions (Morris et al., 2011). Moreover, the EPA was one of the earliest federal agencies to call for more information on the relative uncertainties surrounding nanotechnology in order “to establish a sound scientific basis for assessing and managing unreasonable risks that may result from the introduction of nanoscale materials into the environment” (Sargent, 2011, p. 33).

In 2009, the EPA announced the Nanomaterial Research Strategy (NRS) which is EPA’s research strategy to understand better how manufactured nanomaterials may harm human health and the environment (EPA, 2009a). The goal of the NRS is threefold: (1) to guide its own researchers and managers as they conduct EPA’s research program, (2) to assist scientists in other organizations as they plan research programs, and (3) to inform the public of how the EPA intends to generate scientific information to guide environmental decisions related to nanomaterials (EPA, 2009a). While understanding potential environmental implications from exposure to nanomaterials is an important subject for the EPA, other entities also conduct research on nanomaterial safety (EPA, 2009a). Therefore, the EPA is focusing on developing scientific information for nanomaterial decision support. Specifically, it emphasizes on four areas that take advantage EPA’s scientific expertise. The four research themes are:

- 1) Identifying sources, fate, transport, and exposure;
- 2) Understanding human health and ecological effects to inform risk assessments and test methods;
- 3) Developing risk assessment approaches, and
- 4) Preventing and mitigating risks.

Likewise, the EPA has made efforts to incorporate science into the two regulatory policies on nanotechnology: Nanomaterial Stewardship Program (NMSP) and Nano Reporting Rule.

Nanomaterial Stewardship Program (NMSP) and Nano Reporting Rule

Many of the EPA's regulatory changes include transitioning from a preference for voluntary reporting programs for nanomaterials to more mandatory reporting requirements (Corley et al., 2013). A good example of this trend is the development of two of the EPA's nanotechnology policies: Nanoscale Materials Stewardship Program (NMSP) and Reporting and Recordkeeping Requirements.

The EPA's efforts under TSCA first focused on voluntary regulation. The NMSP is a voluntary reporting program created in 2008 and ended at the end of 2009. NMSP requires participants to take two actions: 1) Implement a nanotechnology environmental, health, and safety (EHS) risk management program; and 2) Submit nano-related information for use in the EPA's future regulatory decisions (EPA, 2007).

To assess and manage potential EHS risks from nanoscale materials, the EPA needed a sound scientific basis. NMSP was developed to provide a stronger scientific foundation for regulatory decisions by encouraging submission and development of information for nanoscale materials (EPA, 2009b). Through this program, the EPA was able to receive some information about types of nanomaterials in commerce (EPA, 2009b). However, it also received criticism for the limited number of submission and unsatisfactory quality of the submitted data (Abbott et al., 2011; Duvall & Wyatt, 2011).

In 2017, the EPA issued a rule under Section 8(a) of the Toxic Substances Control Act (TSCA) establishing reporting and recordkeeping requirements for certain discrete

forms of chemical substances that are manufactured or processed at the nanoscale.¹¹ This rule requires companies that manufacture (including import) or process certain chemical substances already in commerce as nanoscale materials notify the EPA of certain information, including specific chemical identity; production volume; methods of manufacture; processing, use, exposure and release information; and available health and safety data.

The EPA expects that the new reporting and recordkeeping requirements will assist the agency in its “continuing evaluation of chemical substances manufactured at the nanoscale, informed by available scientific, technical evidence.”¹² Further, the EPA expects that the rule will facilitate assessment of risks and risk management, making decisions for nanotechnology based on best available scientific evidence, which is consistent with the President’s memorandums regarding Regulation and Oversight of Applications of Nanotechnology and Nanomaterials (Holdren, Sunstein, & Siddiqui, 2011).

Methods

In November 2016, I conducted in-person interviews with individuals who were involved in NMSP or Nano Reporting Rule. The interview candidates were selected based on two main sources: 1) groups and individuals who participated in the meeting on

¹¹ EPA. Information Gathering Rule. Retrieved from <https://www.epa.gov/reviewing-new-chemicals-under-toxic-substances-control-act-tsca/control-nanoscale-materials-under#info> rule

¹² Chemical Substances When Manufactured or Processed as Nanoscale Materials; TSCA Reporting and Recordkeeping Requirements. Retrieved from <https://www.federalregister.gov/documents/2017/01/12/2017-00052/chemical-substances-when-manufactured-or-processed-as-nanoscale-materials-tsca-reporting-and>

the NMSP conducted by the EPA in 2007¹³ and 2) groups and individuals who submitted comments to the EPA on the Nano Reporting Rule during the comment period in 2015. I sent out invitation emails to the potential candidates to schedule appointments for the interviews and 21 individuals agreed to the interview. The interviewees include nano-industry representatives, members of the environmental non-governmental organizations (ENGOS), and four EPA officials. Institutional Review Board (IRB) protocol for this research was approved in November 2016.

The interviews were originally conducted to explore the dynamics of complex policy processes within nanotechnology policy subsystems. Among several topics of the research, the role of scientists and scientific information in the process of establishing policies for nanotechnology is one of the important topics of the research. The interview question regarding the role of science is as follows: “In your own words, what do you think is the role of scientists and technical information within your institution with respect to nanotechnology policy?” A follow-up question was posed: “In your own words, what do you think is the role of scientists and technical information in the process of developing and implementing the 2007 NMSP program and its 2015 follow-up?”

On average, interviews were about 45 minutes in duration and the interview recordings were transcribed (Fontana & Frey, 2000; Yin, 2013). To record and track the analysis process, a qualitative software program Atlas.ti was used (Friese, 2014). Since the research focuses on the role of science at the EPA, I will focus on the interviews with the four EPA officials. However, I will also refer to interviewees affiliated with other organizations who had interactions with the EPA.

¹³ EPA (August, 2007) Meeting Summary Report: Nanoscale Materials Stewardship Program. Retrieved from <http://nanotech.lawbc.com/wp-content/uploads/sites/539/2007/10/00021299.pdf>

Results

NMSP and Nano Reporting Rule are EPA's approaches to regulate and collect information on the potential risks from nanomaterials. Both policies are to gather data that can be used as scientific evidence when making decisions for the agency's further regulatory actions. At the same time, science played important roles during the regulatory decision-making process.

According to the documents regarding NMSP (EPA, 2009b), the EPA went through two scientific peer consultations from the development stage of the program. In October 2006, the EPA conducted a peer consultation and asked participants for input on risk management practices of nanotechnology (EPA, 2009b). EPA clarified that NMSP was developed based on scientific literature and identified the National Institute for Occupational Safety and Health (NIOSH) document regarding approaches to safe nanotechnology as a primary resource (EPA, 2009b). The second peer consultation was held in September 2007 and the EPA collected data about material characterization of nanoscale materials through panel discussions.

When being asked about the role of scientific experts in the policy-making process of NMSP, an EPA official said, "One EPA stock phrase is you need good science [...] All of the TSCA Program, and NMSP assessments, all went through the TSCA new chemical process, which is a multi-disciplinary team of scientists." The interviewee continued, "It starts with chemists, it goes to Eco and human health toxicologists, it goes to chemical engineers and exposure experts, and lastly comes back to policy people, who also frequently are scientists [...] The scientists are involved along the way." In addition, many of the EPA officials in policy-making positions have science background. An EPA

official said, “I’m a chemist by training, a lot of people started as biologists or chemists, then came to the policy program.”

Also, representatives of nano-industry commonly agreed that regulatory policy of nanotechnology should be based on sound science. They said “scientists are critical when determining to the questions of ‘Does this material present a hazard? To what extent does it present a hazard? What kinds of hazards?’” and contended that industry also “heavily rely on experts” when making decisions. When being asked about positions on EPA’s two nanotechnology policies, an industry representative added a comment: “You want as much science used as possible when you’re forming your regulatory policy.”

An EPA official who were deeply involved in the decision-making of the Nano Reporting Rule stated an important reason for making this new policy: “As policy makers, we decided that the only way the public could have confidence in nanotechnology was to do reporting rule.” He added, “Where we haven’t yet succeeded is getting support for providing the information that’s needed for the public to be confident.” In other words, the public can have confidence that the nanomaterials are safe because they undergone scientific review process that is required by the Nano Reporting Rule.

The interviewee described some of details about how scientists and scientific community in and out of the agency played their role in the rule making process such as setting standards and assessing potential risks of the nanomaterials.

For the reporting rule, because if you look at it, the aspects of it are very technical, what distinguishes one form of nanomaterial from another. If you go from 10 nanometers to 20 nanometers, is that a different substance or not?

There, the scientific community was very involved, and it was involved across the

various agencies. We had the EPA scientists and other scientists who'd done research on the particles and they could be toxic. You would have people from the National Institute of Standards and Technology or NIST who have a program for measuring nanomaterials and looking at how changes in properties affect behavior. They were involved and how many standard deviations away from a mean distribution would actually result in a distinction of behavior, all these technical things, very much involved in those aspects of the reporting rule.

The EPA also sought scientific advice from outside scientific experts when making decisions about these policies. For example, the EPA proposed a new reporting rule in 2015 followed by a comment period during which the public including any interest groups can leave comments on the proposed rule. In this period, many industry representatives expressed their opinions based on their own research. An EPA official stated these comments influenced EPA's decision making only when they have "a sound scientific reason." He further explained that "Industry scientists tend to be more engineering technologist type and industry scientists, in their comments, brought what you could characterize as a practical consideration."

In order to secure scientists suitable for the field, the EPA even employed contractors and consulting firms. A consultant stated that, in the early phase of NMSP, he was hired by the EPA to help identifying and contacting the "right" scientists who are active in the field. He further detailed the importance of these experts in the early stage of the policy process:

The research scientists were very involved and very important and leave it at that. They provided information to kind of both sides of the fence. They would provide

information to EPA, because EPA needed to know, does nano X is toxic to humans? Are there only Eco toxin concerns? [...] Toxicologists were very very important.

However, a member of an ENGO who observed EPA's use of science in nanotechnology regulation for a long time showed some concerns about it. The concerns are associated with the challenges to the use of science at government agencies that were discussed in the previous sections such as politicization and conflict of interests.

I think the EPA wants to make sure that things are science-based. It's just, at the end of the day, our agencies are often more guided towards the opinions of industry and the science. There is something also called corporate science where science can be manipulated. There are many ways that you can take a scientific study and make it say several things. That's something we have to watch out for from all stakeholders is making sure that we're looking at science that is the highest quality and really best that we can do that's not just attached to making a profit.

An EPA official pointed out the role of scientists after the Nano Reporting Rule comes into effect. The statement indicates that science plays a consistent and overarching role throughout the agency's decision-making process.

Once the reporting rule goes out and people begin to report, then environmental scientists that look at the behavior of chemicals in air, water, soil and humans

will try to make a determination on whether the substances are reported based on the information we have need further attention.

Likewise, the EPA incorporates scientific information into policy decisions through various approaches. In addition to its own scientists, the agency solicited input from scientists in other government agencies and industry sectors. In the EPA's policy-making process, science played a role in the overall process rather than stage-specific. EPA's use of science is not only to make a better policy but to gain public confidence since the public feel safe if the policy went through scientific review. In this sense, an EPA official stated, "Science helps us to make not just better decisions, but decisions you can justify."

Discussions

One of the significant challenges that federal agencies dealing with emerging technologies face is data collection (Johnson et al., 2006). Articles and reports on EPA's use of science commonly recommend that the agency should strengthen its ability to collect scientific data (EPA, 2009a; National Research Council, 2012a). Nanotechnology is no exception. The Nanomaterial Research Strategy (NRS) lists EPA's research themes to develop scientific information for nanotechnology, and the first theme is "identifying sources, fate, transport, and exposure" of nanomaterials (EPA, 2009a). Also, the National Research Council (NRC) contends that the quality of effective regulation and policy relies on robust approaches to data collection and suggests that engaging the public is a way of gathering information (National Research Council, 2012a). Using nanotechnology as an example, NRC further contends that managing and interpreting

data will be a continuing challenge for the EPA since new technologies generate large amounts of data (National Research Council, 2012a).

In nanotechnology policy making, the EPA seems to take steps to collect more data on nanomaterials. Both NMSP and recent Nano Reporting Rule were established to provide the EPA with information on the health and ecological effects of nanomaterials and applications. NMSP was one of the EPA's programs focusing on submission of information about nanomaterial from industry and others in a voluntary manner and the recent reporting rule is expected to further collect risk-relevant information on nanoscale materials for the agency. The interviews with EPA officials showed that the agency not only makes policies to collect information needed to make sound decisions, but also uses scientific information when establishing the policies.

Another common recommendation for EPA's use of science in decision making for emerging technology is to promote collaboration (EPA, 2009a; National Research Council, 2012a). NRS suggests that the EPA should collaborate with other federal agencies, industry, and the international community for nanomaterial research (EPA, 2009a). NRC also emphasizes the importance of collaborations within and outside the agency. To strengthen scientific capacity of the agency, the EPA needs to work collaboratively with researchers in other agencies, therefore more effectively fill information gaps in emerging technologies (National Research Council, 2012a). NRC specifically points out that the delay in EPA's early intervention in health and safety of nanotechnology was partly because of the "lack of collaboration between material innovators and toxicologists and environmental scientists" (National Research Council, 2012a, p. 114).

The document analysis and interview analysis on NMSP and Nano Reporting Rule show that the EPA takes the recommendation of collaboration seriously. I found

that the agency conducted scientific peer consultations and encouraged input from experts from outside of the agency through public hearings and meetings. Also, the agency takes public comments from outside and reflects them when they are based on sound science. EPA officials also confirmed that the agency use scientific information from other government agencies as well. Overall, the EPA tries to collaborate with entities outside the agency, including scientific experts in other federal agencies, industry scientists, and ENGO scientists when making policy decisions.

Finally, one thing that should not be overlooked when considering the use of science in policy-making is that no individual is completely objective and disinterested (Sutherland & Burgman, 2015). While public and scientific communities themselves often claim scientific objectivity, everyone has his or her biases, personal interests, and ideological commitments (Richerson, 2016). Scientists' opinions also vary which can threaten the accuracy and reliability of their scientific advice, especially in new research areas. Scientific experts are often unaware of these subjective influences which leads to overestimation of their own objectivity and reliability that affect government oversight (Sutherland & Burgman, 2015). Therefore when there are major disagreements within large portions of the scientific community, consensus is not yet achieved, and taking policy actions can be quite challenging (Stine, 2009). Even though scientists working for the EPA's advisory organizations give the best information available, there may be other available opinions in the scientific community (Adams & Hairston, 1994). Plus, since many prominent scientists prefer working quietly and do not often risk getting involved in the policy arena (Adams & Hairston, 1994), recruiting experts as scientific advisors at EPA and sub-committees can also be problematic. Policy makers who want to use scientific advice for decisions should consider these factors when working with scientists.

Conclusions

Science has always been an integral part of the EPA's mission and it is indispensable for providing the basis of agency decisions (National Research Council, 2012a). Despite the importance of using sound science in public policy decision-making, the EPA have been criticized for not being clear about the role that science played in their decision-making processes (National Research Council, 1994, 2011). This paper focuses on how the EPA acquires and uses the scientific information when making decisions and sheds light on the understanding of the relationship between science and politics in the agency.

It offers three contributions to scholarship and practices. The first contribution of the paper is that it provides comprehensive document analysis of the use of science at EPA as well as existing challenges that constrain the use in decision-making process at the agency. The question of the proper role of scientists in the process of political decision-making is controversial (Haller & Gerrie, 2007). A review of the use of science by the EPA showed that the process of incorporating science into EPA's decision-making is coordinated by scientists and science organizations within as well as from outside the agency. Although use of science in policy is difficult to evaluate, the establishment of EPA's Nanomaterial Stewardship Program (NMSP) and Nano Reporting Rule demonstrated that the agency incorporates science based approaches to regulation of nanotechnology.

The second contribution of the paper is that it uses original interview data to explore the use of science at the EPA. Although there are many reports and recommendations for the EPA to better use of science in its policy making (Dudley, 2012; National Research Council, 2011; U.S. Environmental Protection Agency Office of the Inspector General, 2011), there are not many (or any) studies that have explored the role

of science in specific nanotechnology policy decisions through interview data collection. Using the nanotechnology policy process as a case, the interviews with EPA officials demonstrate the perspectives of those who oversaw the establishment of the nanotechnology policies from an internal perspective.

The third contribution of the paper is that it uses interview data to show how the EPA draws on scientific information from outside of the agency. This paper demonstrates that the agency already addresses some of the important recommendations for emerging technologies. Securing proper scientific expertise within the EPA is necessary to address complex environmental problems especially from new and emerging technologies. However, the EPA has also received recommendations that it needs to utilize science from outside the agency including private sectors to make anticipatory decisions for emerging technologies (National Research Council, 2012a, 2012b). This paper shows that the EPA used scientists and research being done in other organizations outside of the agency as well as experts and research within the agency.

In summary, this paper offers evidence that the EPA incorporate scientific information into nanotechnology policy decisions through various approaches. Especially, current members of the agency provide insights about the appropriate use of science in policy creation to meet the scientific needs of policy-makers. The case of nanotechnology is an example of how the EPA needs to approach many emerging technologies and challenges in the future. It can help policymakers and others better understand the factors and process that influence the EPA's use of science so that they can improve the decision-making capacity in policies and practices.

Chapter 4

THE ADVOCACY COALITION FRAMEWORK IN NANOTECHNOLOGY POLICY SUBSYSTEM: AN INVESTIGATION INTO THE ROLE OF SCIENTISTS

Environmental Protection Agency (EPA)'s Nanoscale Materials Stewardship Program (NMSP) asks companies to voluntarily report data on the engineered nanoscale materials they manufacture, import, process, or use (EPA, 2009b). The program provisionally ended in December 2009. However, the EPA recently proposed a new program which is more mandatory in early 2015 (EPA, 2015). The two policies raised much controversy involving many policy actors and coalitions in the decision-making process. Environmental Non-Governmental Organizations (ENGOS) suggested the program should be mandatory and nano-specific, while industry groups supported the voluntary provisions. Both groups claimed science or scientific findings supported their arguments. Because of this complexity of the political context, examining the policy processes of nanotechnology regulation is challenging.

Existing literature has explored the role of scientists in the policy process using Advocacy Coalition Framework (ACF) (Jenkins-Smith, Silva, Gupta, & Ripberger, 2014). The ACF seeks to explain the political behavior of actors in the policy process including the role of science in the policy process (Sabatier, 1988). Under ACF, scientists are active members in advocacy coalitions and the scientific information encourages policy-oriented learning and policy change (Weible & Sabatier, 2007). Under the premise that scientific and technical information are given a central role in the policy process, ACF views the policy process as a competition between coalitions of actors who advocate beliefs about policy problems and solutions.

However, existing studies are mostly theoretical and lack empirical investigation across a large number of observations (Spruijt et al., 2014). The framework need to be

tested empirically in a variety of settings (Sabatier, 1988) including its hypotheses about the nature of advocacy coalitions, roles of administrative agencies, and science in policy. Moreover, as yet, ACF has not been used to explain the policy subsystem surrounding emerging technologies where evidence of potential risks on human and environmental health are lacking, even though they require active role of scientific and technical knowledge in policy making.

This paper examines how ACF can be applied to nanotechnology policy making. In the field of nanotechnology, few studies discuss the existence of advocacy coalitions, their policy core beliefs, or the degree of consensus among the coalition members. Compared to many conflicts over policy issues that existing ACF studies have explored, uncertainty about nanotechnology risk poses a profound dilemma for policy stakeholders involved when making regulatory decisions (Falkner & Jaspers, 2012). Through the lens of ACF, this study identifies the advocacy coalitions in nano-policy subsystem and further identifies the role of scientists as stakeholders in policy making for the case of EPA's Nanoscale Materials Stewardship Program (NMSP) and new Nano Reporting Rule.

This study will add to the growing number of ACF application that use network data to identify coalitions (Weible, 2005; Weible & Sabatier, 2005). Assessing policy subsystem of the nanotechnology oversight will make a contribution to the policy subsystem literature. Examining the role of scientists in nanotechnology policy process can fill the knowledge gap of the nanotechnology policy making and help practitioners to strategically organize their advocacy efforts by demonstrating how scientific experts are being used in coalitions.

Advocacy Coalition Framework (ACF)

Milward and Provan (2000) described modern governments as “hollow states” which means “any joint production situation where a government agency relies on others (firms, non-profits, or other government agencies) to jointly deliver public services” (p. 361). In other words, in the modern governments, a single policy entity does not have power and authority to achieve their goals, and therefore policy networks among diverse policy actors are important to understand policy process. In this concept, a policy network indicates the relationships - formal as well as informal interactions - among policy actors from various affiliations, who try to influence the policy processes and outcomes in a policy subsystem (Weible, 2005). Policy network approaches attempt to explain the policy process and its outcomes according to the patterns of relationships among various actors (Kim & Roh, 2008). Acknowledging that single organizational affiliations are often incapable of implementing policies, policy networks have emerged as a tool to explain policy process over the past 30 years (Howlett, 2002).

The theoretical basis for this study is the advocacy coalition framework (ACF) developed by Sabatier and Jenkins-Smith in the late 1980s (Sabatier & Jenkins-Smith, 1993). Among the policy-process approaches, the ACF holds an important position because it incorporates the idea of policy networks by explaining policy changes over time focusing on policy subsystems (Kim & Roh, 2008). ACF is a policymaking framework to deal with intense public policy problems (Sabatier & Jenkins-Smith, 1993). It defines policy process as “a broad structure in which a specific policy subsystem is constrained and impacted by the stability and dynamic nature of elements external to the subsystems” (Theodoulou & Kofinis, 2004, p. 87). Figure 4.1. Presents an overview of the role of advocacy within the policy subsystem and the effects of two factors outside of the subsystem that affects subsystem actors as constraints and opportunities over time.

Although there have been several versions based on the fields of research, this figure has been the core conceptual description of ACF since its inception (Sabatier & Weible, 2007).

ACF is a lens to understand and explain belief and policy change when there is goal disagreement and disputes involving multiple policy actors, including scientists. Many public policy frameworks ignore the scientific information or assume scientists are neutral players, however, ACF research has shown that scientists are often active members in advocacy coalitions (Weible & Sabatier, 2007). According to Sabatier and Jenkins-Smith, who developed ACF, a policy subsystem is determined by a substantive issue and geographic scope, consisting of various stakeholders including officials from all levels of government, representatives from interest groups, and scientists/researchers (Sabatier & Jenkins-Smith, 1999). A policy subsystem is generally composed of one dominating coalition controlling the executive branch and a number of minority coalitions seeking to alter the direction of public policy (Nohrstedt, 2009). ACF is based on bounded rationality and assumes the pursuit of self-interest through competition among coalitions (Schneider & Ingram, 2007). Likewise, actors aggregate into some advocacy coalitions consisted of people who share a set of beliefs (policy core beliefs) and often take coordinated action over time (Sato, 1999). These advocacy coalitions compete to translate their beliefs into public policy by mobilizing political resources, and as a consequence, policy change takes place (Sabatier & Jenkins-Smith, 1993).

ACF has been proven to be a useful policy framework (John, 2003) and since its development in early 1990's, ACF has become a groundwork for addressing core questions in policy process research including the role of scientists and scientific and technical information in policy making (Weible et al., 2011). Despite efforts to understand how science can influence policy-making (Jasanoff, 2009; Lee, 1994;

Macleod, Blackstock, & Haygarth, 2008), examining links between science and policies have demonstrated problematic (Anderson & MacLean, 2015; Kimmins et al., 2005; Sutherland et al., 2012). Scientists have been trying to inform managers, policy makers, and the public regarding environmental issues for decades (Ehrlich & Ehrlich, 1996; Likens, 2010).

According to ACF, scientists can influence the policy process primarily by providing competing advocacy coalitions with information (Sabatier & Jenkins-Smith, 1999). In other words, scientific experts will likely align themselves with a coalition based on shared beliefs (thereby perhaps aligning experts and coalitions by shared interests) because their information will likely support a coalition's arguments (Weible, Pattison, & Sabatier, 2010). Coalitions, on the other hand, seek scientists as allies because of the legitimacy of expert-based information in supporting their arguments. Consequently, scientists can be significant allies or opponents in coalition politics (Weible et al., 2010).

Also, ACF assumes that individuals are rationally motivated but are bounded by their imperfect cognitive ability (Simon, 1983). It postulates policy actors have a different set of beliefs and ACF individuals filter perceptions through their belief system: they ignore information that defies their beliefs and accept information that strengthens their beliefs (Weible & Sabatier, 2007). The ACF suggests a mechanism of policy change through belief change via policy-oriented learning from the gradual accumulation of information. For ACF scholars, beliefs bond people together across a variety of different levels and organizations into advocacy coalitions. The ACF defines policy-oriented learning as, "relatively enduring alterations of thought or behavioral intentions that result from experience and/or new information that are concerned with the attainment or revision of policy objectives" (Sabatier & Jenkins-Smith, 1999, p. 123).

One of the sources of the information that draws the policy-oriented learning is the scientific study and it affects the beliefs of actors within the policy subsystem, which can lead policy change over time.

However, even in the discussion of using the scientific advice in decision-making, there is a potential problem of politicization of science. Scientific information is often politicized and a dominant coalition can successfully challenge the data supporting policy change for a long period of time (Cairney, 2014). Freudenburg and colleagues (2008) argue that where decisions and action are required, science can offer valuable degrees of certainty but it can never offer a guarantee. In reality, certain cases such as global warming, teaching evolution in public schools, and abortion are still controversial because of the political reasons despite there is decisive scientific advice (Pielke, 2007). For this reason, skeptics argue that scientific advice is rarely useful for policy-makers (Collingridge & Reeve, 1986). They further argue that when there is policy consensus without scientific advice, the advice has little impact on policy; and when there a policy consensus is lacking, the scientific advice will face technical questioning. Advocacy Coalition Framework (ACF) predicts the possibility of politicization by the coalitions, arguing that the advocacy coalitions may simply fit the scientific findings into their belief systems rather than altering their core belief (Litfin, 2000).

There have been criticisms against ACF. For example, Schlager (1995) pointed out that ACF lacks an explanation for the collective action, especially the development of coalitions not only by shared beliefs but also by the shared pattern of coordination. Years later, however, researchers have responded with applications that show coalitions by both shared beliefs and coordination patterns (Henry, Lubell, & McCoy, 2010; Weible, 2005). Another criticism challenged ACF whether it can be applicable to the policy subsystems outside of the U.S. (Sabatier, 1988). This issue has also been addressed by

numbers of studies on different national contexts (Hirschi & Widmer, 2010; Kübler, 2001).

In this paper, using the EPA's NMSP and new Nano Reporting Rule as cases, I explored how ACF is applicable to the nanotechnology policy environment and see how ACF would help us to better understand the role of science and scientists when shaping policies about nanotechnology.

EPA's Two Nanotechnology Regulatory Policies

The Nanoscale Materials Stewardship Program (NMSP) is a voluntary reporting program created and managed by the EPA. In 2005, EPA announced its intention to pursue voluntary reporting program and the NMSP was developed through a collaborative process initiated in 2006, with interested parties invited to comment and participate at each stage of development (EPA, 2009b). On July 12, 2007, EPA released its draft Concept Paper for the NMSP Under TSCA (Concept Paper), which outlines EPA's initial thinking on the design and development of a voluntary NMSP.¹⁴ EPA announced NMSP on January 28, 2008, and it requires participants to take two actions: 1) Implement a nanotechnology environmental, health, and safety (EHS) risk management program; and 2) Submit nano-related information for use in the EPA's future regulatory decisions (EPA, 2007).

The NMSP formally ended at the end of 2009. EPA NMSP interim report notes that EPA received submissions from 29 companies on 123 of nanomaterials on the market (EPA, 2009b). Through the report, the EPA claims that "NMSP can be considered successful" (EPA, 2009b, p. 3) and says "the program has considerably

¹⁴ 72 Fed. Reg. 38081 (July 12, 2007).

increased the Agency's understanding of the types of nanoscale materials in commerce" (EPA, 2009b, p. 9). However, many other reports claim that it is unsuccessful or it ended with limited success (Duvall & Wyatt, 2011; Guston, 2010). For example, the EPA themselves estimated that companies provided information on only about 10 percent of the chemical substances manufactured at the nanoscale that may be commercially available in 2009 (EPA, 2009b). Also, the quality of the submissions was unsatisfactory (Abbott, Marchant, & Corley, 2011). The biggest problem of NMSP was that the number of participants was far less than expected. There are several reasons that construe the results. Many companies worried that participation would provide few benefits, but rather create potential costs (Abbott et al., 2011). Also, they were uncertain how the EPA would use the submitted data (Abbott et al., 2011).

Moreover, NMSP received criticism from many ENGOs and nanotechnology safety experts. They are mostly dissatisfied with the voluntary nature of the NMSP and are calling for reporting to be made mandatory (Trager, 2008). For example, Terry Davies, a former senior official at EPA and an advisor to the Project on Emerging Nanotechnologies (PEN) at the Woodrow Wilson Center stated, "There is no incentive right now for anybody to submit information" (Trager, 2008). Since some nanomaterials are considered existing rather than new chemicals under the TSCA, some criticize that EPA is ineffective authority to review or regulate them.

In early 2015, the EPA proposed a new reporting and recordkeeping rule for nanoscale materials. The comment period for the proposed rule was closed on August 5, 2015. For the new proposed rule, industry groups strongly opposed the proposed rule and called for EPA to withdraw it, while ENGOs argue that the proposed rule is "modest

and common sense-objective.”¹⁵ For example, NanoBusiness Commercialization Association (NanoBCA) and the NanoManufacturing Association (NMA) filed long comments challenging EPA’s proposal.¹⁶ Other industry groups also criticized the proposal, including the SOCMA, SOCMA’s Nanotechnology Coalition, the Chemical Users Coalition, and the ACC’s Nanotechnology Panel. Moreover, The Small Business Administration (SBA) submitted comments in August 2015 arguing that the proposed rule will impose burdens on small businesses (SBA, 2015) and ACC also submitted official comments urging the EPA to elaborate and clarify the proposed rule (ACC, 2015).

On January 11, 2017, after more than a decade of debate, EPA issued a final regulation requiring one-time reporting and recordkeeping of existing exposure and health and safety information on nanoscale chemical substances in commerce pursuant to its authority under TSCA section 8(a).¹⁷ This rule requires companies that manufacture (including import) or process certain chemical substances already in commerce as nanoscale materials notify EPA of certain information, including specific chemical identity; production volume; methods of manufacture; processing, use, exposure and release information; and available health and safety data.

¹⁵ EDF. Why is the nanotech industry so intent on keeping EPA from doing its job? Retrieved from <http://blogs.edf.org/health/2015/08/20/why-is-the-nanotech-industry-so-intent-on-keeping-epa-from-doing-its-job/>

¹⁶ Comments Of The Nanomanufacturing Association On The Proposed Information Collection Rule; Chemical Substances When Manufactured Or Processed As Nanoscale Materials; Retrieved from <http://nebula.wsimg.com/c14ec384d2be557ec6288b2400631ec4?AccessKeyId=AE1000B96B4DE9DDFA21&disposition=0&alloworigin=1>

¹⁷ EPA. Information Gathering Rule. Retrieved from <https://www.epa.gov/reviewing-new-chemicals-under-toxic-substances-control-act-tsca/control-nanoscale-materials-under#info> rule

ACF and nanotechnology policy subsystem

In this study, I used ACF policy framework to examine a case study of series of nanotechnology regulation policies, EPA's NMSP and new reporting rule in the U.S. The NMSP, EPA-led voluntary initiative caused significant controversies among some groups that advocate more stringent regulation of nanomaterials. Also, from its proposal step in 2015, chemical industry groups argued it would "confuse and unduly burden" nanotechnology businesses and criticized its mandatory nature.¹⁸ I used in-depth interviews to examine the applicability of ACF in nanotechnology policy subsystem and explored how scientists and science-based information influenced the development of the nanotechnology policies.

In an effort to test the applicability of the ACF framework for the case of nanotechnology, I tested four hypotheses about ACF and examined dynamics surrounding nanotechnology policy subsystem. The first two hypotheses examine the existence and the stability of advocacy coalitions that share policy core beliefs. Basically, they test whether the ACF is an appropriate theoretical lens for the case of nanotechnology policy subsystem. The next two hypotheses focus on the distinctiveness of the nanotechnology policy subsystem. The third hypothesis is about the unique positions of administrative agency in the policy subsystem, which is one of the controversial questions of the ACF. The fourth hypothesis examines the role of science and scientific experts, which is one of the important subject in the discussion of emerging technology policy processes.

The ACF assumes the primary unit of analysis is the policy subsystems, which is composed by public and private actors that actively seek to influence policy in an area

¹⁸ Scale back nanomaterial reporting proposals, industry tells EPA. Retrieved from <https://chemicalwatch.com/36989/scale-back-nanomaterial-reporting-proposals-industry-tells-epa>

(Nohrstedt, 2009). The ACF aggregates subsystem actors into advocacy coalitions consisting of “people from various governmental and private organizations that both (1) share a set of normative and causal beliefs and (2) engage in a nontrivial degree of coordinated activity over time” (Sabatier & Jenkins-Smith, 1999, p. 120). The success of coalitions depends upon their ability to translate their policy core beliefs into actual policy (Weible & Sabatier, 2007). Given the stability of a coalition's policy core beliefs and its desire to translate those beliefs into actual policies or governmental programs, the policy core attributes of such programs will not change easily (Jenkins-Smith & Sabatier, 1994). The ACF claims that these beliefs will remain stable over time (Weible & Sabatier, 2007).

Regarding the NMSP and the Nano Reporting Rule, the EPA has regulatory authority over nanoscale materials.¹⁹ According to the documents and reports on NMSP, ENGOs and business representatives seem to hold conflicting arguments on the program. For example, in 2007, a broad coalition of civil society, public interest, environmental and labor organizations declared *Principles for the Oversight of Nanotechnologies and Nanomaterials*. It contended that “voluntary initiatives are wholly inadequate to oversee nanotechnology” and argued voluntary initiatives delay or fail regulation and limit public access to environmental safety and health data (ETC Group, 2007, p. 5). Recent reports and documents from the ENGOs indicate that they seem to maintain their opposition to the voluntary initiatives and insist mandatory reporting of data on nanoscale materials.²⁰ On the other hand, in 2008, industry groups

¹⁹ TSCA gives EPA authority to regulate “chemical substances”

²⁰ Environmental Defense Fund. 2015. Comments on Chemical Substances When Manufactured or Processed as Nanoscale Materials; TSCA Reporting and Recordkeeping Requirements. Retrieved from http://www.eenews.net/assets/2015/08/06/document_gw_07.pdf

and their representatives released a joint statement in support of the NMSP.²¹ For the Nano Reporting Rule, however, they showed somewhat mixed reactions through their comments to the EPA and press release. This leads the first hypothesis of the study:

H1: In the nanotechnology policy subsystem where the policy core beliefs are in dispute, the lineup of allies and opponents (i.e. coalitions) tends to be rather stable over time.

ACF focuses particularly on the belief systems of coalitions as a major factor affecting the coalitions themselves as well as policy change. Based on the core beliefs, a coalition seeks to alter the behavior of governmental institutions in order to achieve its policy goals over time (Sabatier & Jenkins-Smith, 1993). All members of an advocacy coalition would not hold precisely the same belief system. However, ACF argues that most members of a coalition will maintain substantial agreement on policy core issues (Sabatier, 1988; Weible, 2007). The second hypothesis is based on these studies.

H2: Actors within each advocacy coalition in the nanotechnology policy subsystem show substantial consensus on issues pertaining to the policy core beliefs

The ACF views actors in positions of legal authority as potential members of advocacy coalitions (Sabatier & Weible, 2007). According to ACF, administrative agencies are often not policy neutral, but instead are active members of specific

²¹ Joint statement on EPA's Nanoscale Materials Stewardship Program. 2008. Retrieved from <http://www.nanowerk.com/news/newsid=6378.php>

coalitions (Jenkins-Smith & Sabatier, 1994). Therefore, government agency officials, legislators, and some judges can be a major resource to the coalition (Sabatier & Pelkey, 1987). To become a dominant coalition, it need to have more of its members in formal authority than other coalitions (Sabatier & Weible, 2007). Therefore, placing allies in authority can be one of the important strategies for coalitions.

About the positions of administrative agencies, previous studies suggest that agencies tend to occupy more moderate and less consistent positions within advocacy coalitions than other allies (Jenkins-Smith & Sabatier, 1994). For example, the Outer Continental Shelf (OCS) leasing policy case suggests that government agencies will generally take less extreme positions than their interest group allies (Jenkins-Smith & Clair, 1993; Jenkins-Smith, 2014). Also, in their study of Tahoe land use, Sabatier and his colleagues found that administrative agencies tended to have more moderate views than their interest group allies (Sabatier, Hunter, & McLaughlin, 1987). Further, there are cases that government agencies to take neutral positions or even to “switch sides” (Jenkins-Smith & Clair, 1993; Sabatier et al., 1987). However, some ACF studies contend that there no evidence supporting the arguments that administrative agencies hold moderate positions (Sabatier, 1993). Therefore, ACF scholars call that there is a need for renewed testing and development on this topic (Jenkins-Smith, 2014).

In the case of NMSP which is a form of voluntary initiative, the EPA not only had the authority but also shared arguments with industry (EPA, 2007). However, the EPA proposed a mandatory reporting rule in 2015 and received negative comments from industry. Based on the literature above, I expect that the EPA acts as a member of coalition which supports NMSP and the Nano Reporting Rule but it occupies more moderate and less consistent positions than their allies in the coalitions. This leads the third hypothesis of the study.

H3: Within nanotechnology policy subsystem, the administrative agency (EPA) will advocate more moderate or less consistent positions than its interest group allies.

Scientists or scientific experts have become acknowledged as one of the important policy actors in the complex modern governments. This phenomenon has been particularly emphasized in nanotechnology policy making. In 2011, the White House Emerging Technologies Interagency Policy Coordination Committee (ETIPC) developed a set of principles specific to the regulation and oversight of applications of nanotechnology, to guide the development and implementation of policies at the agency level. The memorandum, called *Policy Principles for the U.S. Decision-Making Concerning Regulation and Oversight of Applications of Nanotechnology and Nanomaterials* strongly encouraged the use of science and evidence-based regulatory approaches.

However, at the same time, many political scientists have expressed considerable skepticism about the objectivity of advice provided by scientists (Sabatier & Zafonte, 1999). Therefore, compelling theoretical frameworks that can show the role of scientists in public policy making is necessary. One of the assumptions of ACF is the central role of scientific and technical information in policy process (Weible, Sabatier, & McQueen, 2009). In ACF, scientists are explicitly identified as key members of advocacy coalitions. Particularly, the role of science has been a prominent factor in the strengthening of the environmentalist coalition (Bukowski, 2007). Scientists can become members of advocacy coalitions by active choice but they also become part of such coalitions because their research is appropriated by other members of the coalition as they try to maintain

their position and defend it against challenges from other advocacy coalitions (Fafard, 2008).

Likewise, ACF assumes a central role of scientific and technical information in the policy process and the role is related to learning within and between coalitions and policy change (Weible et al., 2009). And the role of scientific and technical information in the policy process is best understood in combination with the context of the policy subsystem (Weible, 2008). Ingold and Gschwend (2014) find that science can play different roles and take on divergent positions depending on the process at stake. More specifically, they find that the more conflictive a policy subsystem is, science plays a more crucial role (as full coalition member or as policy broker).

In a policy sector where scientific evidence of evidence of potential risks on human and environmental health are still lacking, scientific knowledge is an important resource in policy making (Ingold, Fischer, & Cairney, 2016). Therefore, policy actors seek new information and thus depend on those with scientific knowledge (Ingold et al., 2016). Nanotechnology deals with new materials and environmental, health, and safety (EHS) of nanomaterials is highly uncertain. This leads the fourth hypothesis of the study.

H4: In the nanotechnology policy subsystem, scientific actors play a central role within the subsystem.

Methods

I examined the existence and activity of advocacy groups and explore the role of scientists and scientific information in the process of establishing policies for

nanotechnology. To analyze how nanotechnology policy is produced through coalition behaviors, I used interviews and document analysis methods.

To collect the data of the research, I conducted 21 in-depth interviews with groups of relevant stakeholders, including scientists, policy makers at EPA, and members of the ENGOs. Since this research is about the nanotechnology policy process, which is highly complex and open to multiple participants, qualitative data analysis can provide meaningful information which cannot measure with quantitative data. This qualitative method can produce significant results when exploring “how” and “why” certain policy phenomena occur such as the influence of advocacy coalitions in the nanotechnology policy process (Yin, 2013).

The interviews are focused on the topic of nanotechnology policy decision making. To elicit specific, in-depth, qualitative information on specific topics semi-structured interviews are usually used (Kienzler & Pedersen, 2007). Semi-structured interviews consist of several key questions that help to describe the areas to be explored, but allow the interviewer or interviewee to diverge in order to track an idea or response in more detail (Gill, Stewart, Treasure, & Chadwick, 2008).

To first identify the key groups and actors in the debate about EPA’s NMSP and Nano Reporting Rule, I collected and analyzed documentary information sources, such as public meetings, citizen petitions, comments, hearings, available official documents from relevant government agencies published during the last ten years. Then I identified each actor’s and coalition’s activities in relation to the NMSP and Nano Reporting Rule. The list of documents for the document analysis are as follows:

1. ICTA (July 31, 2007). Principles for the Oversight of Nanotechnologies and Nanomaterials.

2. ERG (August 8, 2007). Meeting Summary Report Nanoscale Materials Stewardship Program (August 2, 2007 Meeting)
3. EDF (September 7, 2007). Comments on EPA's "Concept Paper for the Nanoscale Materials Stewardship Program under TSCA" and "TSCA Inventory Status of Nanoscale Substances – General Approach."
4. ICTA (May 1, 2008). Citizen Petition for Rulemaking to the United States Environmental Protection Agency, Petition Requesting EPA Regulate Nano-Silver Products As Pesticides.
5. SOCMA, ACC, and NanoBusiness Alliance (July 11, 2008). Joint statement on EPA's Nanoscale Materials Stewardship Program
6. EPA (January 2009). Nanoscale Materials Stewardship Program: Interim Report: Environmental Protection Agency.
7. ETC group (December 2010). The Big Downturn? Nanogeopolitics.
8. ACC (August 5, 2015). Comments on the U.S. Environmental Protection Agency's (EPA) proposed reporting and recordkeeping rule for nanoscale materials (Proposed Rule)
9. The Office of Advocacy at Small Business Administration (August 5, 2015) Comments on EPA's TSCA Reporting and Recordkeeping Requirements for Chemical Substances When Manufactured or Processed as Nanoscale Materials; Docket No. EPA-HQ-OPPT-2010-0572.
10. American Coatings Association (May 2016). No Small Issue: EPA's Proposed Nano Rule and the Paint and Coatings Industry. Issue Background

The analysis of these documents and reports were first used to identify policy stakeholders and advocacy groups. Using a modified snowball technique (Weible et al.,

2010), I identified organizations and individuals involved in EPA's two nanotechnology policies. The document analysis was also used to grasp the picture of policy environment surrounding nanotechnology. The next section describes the process of selecting interviewees.

Selecting Interviewees

The top priority interview candidates were the individuals participated in the meeting on the NMSP conducted by the EPA in 2007. The purpose of 2007 meeting was to discuss and receive comments on the development of the voluntary NMSP and the meeting brought together 124 participants, including stakeholders in academia, NGOs, government, industry, professional organizations, the press, international entities, and the public.²² I used a systematic process to identify interviewees from the list of 124 participants of the meeting. First, I excluded those who no longer work in the same field or do not live in the U.S. Also, I excluded participants if their current contact information is not available. From this process, I identified 34 individuals who are still active in the same field. This group of individuals was chosen because they observed and participated in the establishment of NMSP from its beginning.

Individuals who are involved in Nano Reporting Rule for nanotechnology are the second interview candidates. During the comment period, EPA received 69 comments (8 anonymous comments) from industry, private individuals, business associations, academia, NGOs, and other organizations. I added 13 individuals who submitted comments on the Nano Reporting Rule (I excluded those who submitted comments from

²² EPA (August, 2007) Meeting Summary Report: Nanoscale Materials Stewardship Program. Retrieved from <http://nanotech.lawbc.com/wp-content/uploads/sites/539/2007/10/00021299.pdf>

abroad or in his/her private capacity) as well as two EPA officials who were designated as recipients for the comments. Among these potential interviewees, five individuals participated both in NMSP in and the Nano Reporting Rule. Finally, I added three individuals from American Coatings Association (ACA) who recently published an *Issue Backgrounder*, titled “No Small Issue: EPA’s Proposed Nano Rule and the Paint and Coatings Industry,”²³ which focused on the EPA’s Nano Reporting Rule. The final list of potential interviewees produced 52 unique names. Institutional Review Board (IRB) protocol for this research was approved in November 2016.

For the interviews, I sent out invitation emails to the potential candidates to schedule appointments for the interviews with selected participants (please see invitation email: Appendix A). A total of 21 individuals agreed to the interview. In November 2016, 18 in-person interviews were conducted at mutually agreed upon locations near their workplaces and three phone interviews were conducted for those who were not physically available to assess.

Table 4.1: Summary of interview participants and their respective roles

	EPA official	Industry representative	Environmental Non-Governmental Organization (ENGO)	Others (Consultant)	Total
Number of participants	4	11	4	2	21
Participants code	EPA-01 EPA-02 EPA-03	IND-01 IND-02 IND-03	ENGO-01 ENGO -02 ENGO -03	OTHER-01 OTHER-02	

²³ American Coatings Association. “No Small Issue: EPA’s Proposed Nano Rule and the Paint and Coatings Industry,” Retrieved from <http://www.paint.org/documents/2016/05/may-2016-ib-no-small-issue-epa-nano-reporting-rule.pdf>

EPA-04	IND-04	ENGO -04
	IND-05	
	IND-06	
	IND-07	
	IND-08	
	IND-09	
	IND-10	
	IND-11	

Participants included EPA officials (4 interviews), nano-industry representatives (11 interviews), members of NGOs and ENGOs (4 interviews), and consultants (2 interviews). Table 4.1 provides a summary of the participants and their respective roles. On average, interviews were about 45 minutes in duration and interview recordings were transcribed (Fontana & Frey, 2000; Yin, 2013). Each interviewee was assigned a code (Table 4.1) to classify them individually while ensuring anonymity.

Interview Process

For the participants who agreed to interview, I sent out the email consent forms which explains the types of questions, how the data will be used, anonymity and confidentiality of the interview (please see consent document: Appendix B). In addition, prior to starting each interview, I gave a short introduction of the research to the interviewee which includes the research topic and the objective of the interview.

Previous studies on ACF using qualitative interviewing suggest that it is important to ask questions that can help identifying coalitions, and their policy beliefs (Han, Swedlow, & Unger, 2014). Also, when studying the application of ACF, asking interviewees to identify organizations with whom they coordinate and to describe their coordination activities are necessary (Weible & Sabatier, 2005). I created interview questions based on the existing literature and asked open-ended questions to understand

participants' subjective experience. Table 4.2 presents the summary of the questions. Open-ended questions were used, followed by targeted questions about the predetermined categories.

Table 4.2: Summary of interview questions

Topic	Questions
Background	<p>Could you please tell me how and why you became involved in nanotechnology policy initially?</p> <ul style="list-style-type: none"> - Could you please give me some details about your role in the development of nanotechnology policies in the past as well as the present? - How did your organization become involved in the process?
Policy Core Beliefs	<p>Could you please tell me your expert opinion regarding voluntary initiatives for nanotechnology? In other words, do you support the initiatives? And why or why not?</p> <ul style="list-style-type: none"> - What is your opinion about some of the conflicts surrounding the voluntary initiatives? - What do you think is the best way to resolve the problems and conflicts?
Existence of Coalitions	<p>Could you please tell me about the organizations that you've worked with on nanotechnology policy that are external to your own organization?</p> <ul style="list-style-type: none"> - Could you please describe the relationships among the organizations you worked with? - How did these relationships shift as decisions were made?
Resources & Strategies	<p>Please tell me about the strategies you and your organization have used to influence nanotechnology policy?</p> <ul style="list-style-type: none"> - Could you please describe the resources that you used to develop and implement those strategies? These could be human resources, financial resources, or any type of resource. <p>In your own words, what do you think is the role of scientists and technical information within your institution with respect to nanotechnology policy?</p> <ul style="list-style-type: none"> - In your own words, what do you think is the role of scientists and technical information in the process of developing and implementing the 2007 NMSP program and its 2015 follow-up?

Policy Change	<p>Could you briefly describe your original position on the 2007 NMSP? Over time, has your position changed? If so, how and why? Could you tell me about your organization's original position on NMSP of 2007? Over time, has your organization's position changed? If so, how and why?</p>
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Qualitative Data Analyses

There are numerous studies on how many interviews are needed in qualitative research, but scholars do not have consensus on the ideal qualitative sample size (Curry, Nembhard, & Bradley, 2009; Guest, Bunce, & Johnson, 2006; Warren, 2002). However, they do agree that an adequate sample size depends on a variety of factors such as the scope of research and characteristics of the participants (Baker, Edwards, & Doidge, 2012). When projects are limited in scope and participants have the high level knowledge and expertise in relation to the topic of inquiry, fewer qualitative interviews, ranging from 4 to 30, are needed (Griffin & Hauser, 1993; Romney, Weller, & Batchelder, 1986). Considering that the scope of the research is limited to a specific policy issue and the potential interviewees are well-informed with the policy, I planned to interview 20 to 25 key participants and successfully interviewed 21 individuals.

This study employed a qualitative content analysis to interpret the dynamics of complex policy processes take place within nanotechnology policy subsystems. Qualitative content analysis is a research method used for text data analysis, which focuses on the contextual meanings and subjective interpretations of text through a systemic classification process of coding (Budd, Thorp, & Donohew, 1967; Hsieh & Shannon, 2005; Lindkvist, 1981; McTavish & Pirro, 1990; Tesch, 2013). A code in qualitative inquiry is “a word or short phrase that symbolically assigns a summative,

salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data” (Saldaña, 2012, p. 3) and coding process is the key to content analysis (Weber, 1990).

I developed the coding frame based on directed content analysis (Hsieh & Shannon, 2005) using deductive coding approach (Bradley, Curry, & Devers, 2007; Elo & Kyngäs, 2008). I first developed an initial coding frame utilizing the key concepts identified by existing ACF theories and the four hypotheses for this study (Potter & Levine-Donnerstein, 1999). Then, I revised the coding frame based on published reports and documents regarding EPA’s two nanotechnology policies and on-going discussion surrounding nanotechnology policy that I observed. After completing all interviews, I revised the initial coding frame to reflect interviewees’ lived experience and knowledge of the nanotechnology policy subsystem. Finally, I coded the collected transcripts with the predetermined codes (Hsieh & Shannon, 2005). To record and track my coding process, I used a qualitative software program Atlas.ti (Friese, 2014).

Results

Advocacy Coalitions

The first two hypotheses of this study concern the nature of advocacy coalitions: that there are shared policy core beliefs that tie members of advocacy coalitions through which actors build resources and strategies to impact policy, challenging each other (McDougall, 2016). To address the first hypothesis, the existence of coalitions with shared beliefs should be verified first. I speculated that the policy core beliefs are in dispute in nanotechnology policy subsystem and there are two rival coalitions, which is the first aspect of the hypothesis. Most of the interviewees acknowledged the existence of two opposing coalitions and expressed pre-existing conflicts between coalitions on

EPA's voluntary initiatives which I presumed as one of the policy core beliefs. An EPA official mentioned, "Environmental groups typically have been very skeptical of voluntary approaches. [...] Industry, of course, doesn't want regulations, so they are more supportive of voluntary approaches" (EPA-01).

There were two real conflicting policies going on at the time [year 2006]. One was the EPA who was willing to work with industry to learn as much as they could about nanomaterials so as they could regulate it in the right way, was in direct conflict with the NGOs who were suggesting that we don't know anything about nanomaterials. We don't know enough. They could be a safety hazard. They could be real problems. (IND-03)

It seems obvious that just given the complexity, the voluntary approach toward something like this I think naturally makes sense because you have the willingness of the industry and I think it really tends to be a more efficient way of collecting information versus the administrative process which is very time consuming. (IND-02)

Likewise, interviewees noted that there were conflicts between two groups when EPA introduced NMSP: industry group who believed voluntary program is a sufficient policy and supported the program and ENGOs who believed mandatory rules are necessary and opposed NMSP. In fact, the NMSP faced stern opposition from the beginning of its making process. In 2005, a group of 17 advocacy groups including Greenpeace, the Natural Resources Defense Council and the Sierra Club said the EPA's proposal for the voluntary self-regulation will not provide enough protection against

potentially toxic nanomaterials (Carlstrom, 2005b). Citing laboratory tests that prove risks of certain nanomaterials, this advocacy coalition argued that nanomaterials should be considered as potentially harmful until proven otherwise. In 2007, a broad coalition of civil society, public interest, environmental and labor organizations concerned about nanotechnology's health, environmental, social, ethical, and other impacts submitted 'Principles for the Oversight of Nanotechnologies and Nanomaterials.' The declaration includes a precautionary approach, mandatory, nano-specific regulations (ETC Group, 2007) which are radically different from the NMSP and it criticizes EPA's voluntary regulatory approach. In fact, this declaration seems to criticize the soft law approach itself. The coalition of ENGOS argued: "Voluntary approaches are wholly inadequate to oversee nanotechnology. Voluntary programs lack incentives for 'bad actors' to participate, thus leaving out the entities most in need of regulation" (ETC Group, 2007). A lead scientist at the Environmental Defense Fund (EDF) made clear that EPA's approach is a "bad policy" because it pretends that nano-materials are nothing new, it eliminates any possibility of pre-market review, and it is very short-sighted (Denison, 2007). In the following year, a group of ENGOS filed a petition for rulemaking requesting that the EPA take a number of actions to regulate products containing nanosilver, including classifying nanosilver as a pesticide and requiring the registration of nanosilver products as new pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).²⁴ Overall, ENGOS contend for strong and comprehensive oversight of the nanotechnology. They even argue that EPA's voluntary framework is a

²⁴ Citizen Petition for Rulemaking to the United States Environmental Protection Agency. Retrieved from http://www.icta.org/files/2011/12/CTA_nano-silver-petition_final_5_1_08.pdf

“failure” and wrote comments, reports, petitions to the EPA for not implementing stronger regulations.

Likewise, in nanotechnology decision-making, ENGOs have been strong actors and were invited to attend as stakeholders (Hodge, Bowman, & Maynard, 2010). I examined articles and reports that expressed these groups’ arguments and identified four themes they share: 1) apply precautionary principle; 2) apply mandatory regulation; 3) treat nanomaterials as new material (nano-specific regulations); and 4) increase public participation (ETC Group, 2007; Hodge et al., 2010). One of the interviewees mentioned the ENGOs were better organized coalition than industry when the NMSP was first introduced: “The antis, the people who are against something are always better organized than the people who are trying to move something forward” (IND-04).

On the other hand, the competent authorities and industry show different perspectives. For example, nanotechnology advocates such as the President's Council of Advisors on Science and Technology (PCAST) stated any potential risks are outweighed by scientific advances that may provide extraordinary treatments for cancer and solutions for problems such environmental cleanup (Carlstrom, 2005a). Also, American Chemistry Council (ACC), an organization representing chemical companies says, “The level of participation in the EPA's stewardship program has been encouraging. Looking over a list of the first 20 or so participating companies, the major nanotech players in the chemical manufacturing field are well represented” (Richardson, 2009). Even in 2015, the ACC remarked that “the program (NMSP) was quite successful” (ACC, 2015).

The second aspect of the first hypothesis is the stability of coalitions over time in the nanotechnology policy subsystem. I identified organizations that are involved in 2007 NMSP and Nano Reporting Rule by investigating news articles, reports, and documented comments to the EPA. I found out that most of the organizations were

involved in both policies. One of the interviewees briefly mentioned about this issue and said that “only the personnel has changed” (ENGO-01). When being asked about the changes in positions about nanotechnology policies, an EPA official said, “I continue to believe that the agency needs more information in order to effectively regulate nanomaterials, which is why the proposed rule went out as it did. My position hasn't really changed” (EPA-03). In terms of changes in the relationships among the organizations, a member of ENGO denied significant changes over time and further stated as follows:

We work together on our goals and then we achieve them at times differently and separately. Sometimes we come together and I guess we all are a smaller amount of groups, but this issue segues into other issues that are related to food and toxics. In that sense, we do have a much larger, broader movement that works together to revamp our current regulations when it comes to chemicals. (ENGO-02)

Recent legal actions of the ENGOs also demonstrated the stability of coalitions. In December 2014, the ENGOs filed a lawsuit under the Administrative Procedure Act seeking declaratory and injunctive relief for the EPA's failure to respond to the 2008 petition. Likewise, the first aspect (existence of coalitions) and the second aspect of the hypothesis were confirmed: in nanotechnology policy subsystem, there are two opposing coalitions with conflicting policy core beliefs and the coalitions are stable over the last decade.

One issue that can be raised about the stability of coalitions is the possible selection bias. At the interviewee selection stage, I excluded those who no longer worked in the field or those who no longer lived in the U.S. after the establishment of NMSP.

This exclusion may affect the selection bias of the research. In other words, the stability of the coalition could be associated with the exclusion of the individuals who might show instability because the chances for these people to change their positions are necessarily higher than those who are still in the field. To minimize the influence of the selection bias to the results of the research, I asked questions not only about interviewees' individual perspectives but also their organizations' positions about each issue (Table 4.2: Summary of interview questions). However, this selection bias is one of the limitations of the study.

The 'Principles for the Oversight of Nanotechnologies and Nanomaterials' (ETC Group, 2007) interpreted nanomaterials as new substances and argued in favor of mandatory regulations that were specific to nanotechnology. The organizations who proposed the principles also demanded the life cycle assessment of nanomaterials. The Natural Resources Defense Council (NRDC) also issued a report supporting mandatory assessment of nanomaterials as new substances, asking a temporary suspension until new materials were tested (Sass, 2007). EDF (2007) announced a statement that supported mandatory government regulations, but it argued that the NMSP was 'intended to provide useful guidance to companies that adopt it on how to address nanomaterials until government regulations are adopted.' However, EDF later criticized the voluntary framework as a failure to "provide both EPA and the public with critical data on the full range of nanomaterials in production and use in the United States."²⁵

²⁵ EPA's Voluntary Reporting Program Fails to Deliver Data Needed to Determine Safety of Nanomaterials, Report Shows (2009) Retrieved from <https://www.edf.org/news/epas-voluntary-reporting-program-fails-deliver-data-needed-determine-safety-nanomaterials-repor>

These documents show that even though there were some minor differences, there was consensus among ENGOs that greater mandatory regulation was needed (Hess, 2010).

On the other hand, Industry groups, such as the Synthetic Organic Chemical Manufacturers Association's (SOCMA) Nanotechnology SME Coalition, American Chemistry Council's (ACC) Nanotechnology Panel, the NanoBusiness Alliance, announced a joint statement in "full" support of the EPA's NMSP.²⁶ The interviewees also expressed the consensus among members of each coalition. They said ENGOs did not support voluntary program and wanted more "participation and engagement from the public and broader group of stakeholders beyond just companies and government" (ENGO-02), while industry welcomed voluntary policy. An EPA official even stated, "Industry loves volunteerism. Industry thinks volunteerism is the way everything should be. Seriously" (EPA-04). Table 4.3 describes the members of the two coalitions and their opposing beliefs.

My recollection is that the environmental groups, generally speaking, did not support the voluntary program, because they didn't think that it would elicit all of the information about all of the nanomaterials that were in commerce at the time. The NGOs definitely didn't like it. Industry generally supported it, because we already have lots of mandatory requests for information that we have to respond to, and so industry favored the voluntary approach. (IND-08)

²⁶ Joint statement on EPA's Nanoscale Materials Stewardship Program (2008) Retrieved from <http://www.nanowerk.com/news/newsid=6378.php>

To a very large extent, the NGOs really wanted the EPA to treat nanomaterials very much like the Europeans where it was suggested that before any nanomaterials are put into commerce that a full array of safety testing needs to be done so that we can then have a better understanding of the hazards, what were the exposures associated with it and then make a determination of the risk before any of the nanomaterials are put into commerce. (IND-02)

I think there's some basics that we agree on. We agree that when it comes to nanotechnology, it should be regulated. There should be meaningful participation and engagement from the public and broader group of stakeholders beyond just companies and government and that we should make sure that what is entering the market is safe and that's proven beyond just the company's representation of the product. I think that's where we all meet together and say on that we can work on. The way that we achieve that strategy, and the ways that we communicate publicly, and the tones we take can be very different. (ENGO-02)

Table 4.3: Advocacy Coalitions in Nanotechnology Policy Subsystem: Actors and Policy Core beliefs

“Pro-Mandatory Policy” Advocacy Coalition A	
Actors:	Environmental non-governmental organizations
Policy beliefs:	<ul style="list-style-type: none"> • Precautionary principle for nanotechnology policy • Mandatory regulation for nanotechnology (Nano Reporting Rule) • Treat nanomaterials as new material (Nano-specific regulations) • Increase public participation • NMSP was unsuccessful
“Pro-Voluntary Policy” Advocacy Coalition B	
Actors:	Industry representatives
Policy beliefs:	<ul style="list-style-type: none"> • Fully support EPA’s voluntary initiative (NMSP) • NMSP was successful and generated useful data

-
- EPA should withdraw, revise and re-propose the new rule (new rule shifts the burden of determining what is reportable onto companies)
-

Although the two coalitions maintained opposing views over time, there was a collaborative effort to reach agreements about the risk framework for nanoscale materials between the two for a short time. In 2006, DuPont Company and EDF formed a partnership for three years to develop a framework governing the responsible development, production, use and disposal of nanoscale materials.²⁷ DuPont planned to develop a robust program for examining the risks during the development of products that incorporate nanomaterials. Similarly, the EDF wanted to promote a sound approach to identifying and mitigating risks of nanomaterials.²⁸ The partnership was particularly interesting because normally developers of new technologies and the CSOs operate rather separately concerning the development of a new technology (Krabbenborg, 2013).

However, the partnership was criticized and rejected by many other ENGOs. For example, an international coalition of more than twenty CSOs (e.g. Friends of the Earth, Greenpeace, ETC group) developed a position paper in response to the launch of the risk framework. In the position paper, the coalition condemned the partnership and the risk framework as ‘fundamentally flawed’.²⁹ They perceived soft governance proposals such

²⁷ Environmental Defense. (2007). Environmental Defense and DuPont Jointly Launch Nano Risk Framework to Evaluate and Address Potential Risks of Nanoscale Materials. Retrieved from <https://www.edf.org/news/environmental-defense-and-dupont-jointly-launch-nano-risk-framework-evaluate-and-address-potent>

²⁸ The Nano Risk Framework. Retrieved from <http://www.nanoriskframework.org/>

²⁹ Civil Society-Labor Coalition. (2007). Civil society-labor coalition rejects fundamentally flawed DuPont-EDF framework (An open letter to the International Nanotechnology Community at Large). Retrieved from

as the risk framework as weak regulations that are often used as a strategy to delay or weaken rigorous regulation (Krabbenborg, 2013). Despite the criticism, the partnership between DuPont Corporation and EDF can be an example when the two advocacy coalitions worked together and shows that leading science companies and respected environmental advocate can reach an agreement.

Position of the administrative agency: EPA

Based on the literature, I expected that the EPA acts as a member of coalition in the nanotechnology policy subsystem and it occupies more moderate position than their allies in the coalitions. First, many interviewees confirmed that the EPA is a leading authority in the policy making processes. An EPA official made clear that the agency initiated the two nanotechnology policies:

We did the right thing by trying the voluntary approach first because, in some instances, voluntary approaches work and they give you what you need without having to go to regulation. If we had just gone directly to regulation, then I think industry would have a legitimate complaint, “Well, why didn't you just ask us first instead of going this way?” [...] We were in a better, stronger position to make the case for a rule because we had tried the voluntary. (EPA-01)

However, interviewees also stated that the agency kept moderate, middle-ground positions. Interestingly, both an EPA official and an industry member pointed out the importance of balance of the agency among different parties. One EPA official even said,

<http://www.etcgroup.org/content/civil-societylabor-coalition-rejects-fundamentally-flawed-dupont-ed-proposed-nanotechnology>

“I don't think it's our job to resolve the conflicts because I don't think the conflicts will ever be resolved. The parties come from very different places” (EPA-01).

Usually if one side or the other's too happy, I'm suspicious that maybe we didn't balance this the best we could. Maybe we did, maybe we didn't. I think that's where the organizations like EPA need you. They need the balance because there's always an economic component. (EPA-02)

I just feel that organizations like EPA need to maintain a balance, a neutrality that is difficult for them to do in the policy arena. If they become too restrictive, there's the risk the technologies won't develop. If they are too promotional, there's a risk that we'll have environmental or safety and health concerns. (IND-04)

About ENGOs' criticism on the NMSP, one of the EPA officials stated how the agency responded to the accusations which shows the EPA's relationships with policy stakeholders in the nanotechnology subsystem.

I think our response to the environmental NGOs was and still would be, in a general sense, is that it's fine to say that regulation will give you better information but the reality is, and certainly was back then [year 2007], that it would take years, if ever, to get any information through regulation, whereas it was our hope we would get some information through the voluntary program. We did, but we would be the first to agree that it wasn't successful in giving us a complete picture. (EPA-01)

Also, for the EPA, public confidence was one of the important factors when taking positions or making decisions on nanotechnology policy issues. Since public confidence is critical in the government (Johnson, 1983), it seems inevitable for EPA officials to take it into account when making decisions. Aside from the influence of the two rival coalitions, two EPA officials showed concerns over public confidence in terms of decision making:

I think the administration and EPA's position is technology has been good for the economy, good for people, but if you don't keep your eye on that responsible development, then public's confidence can change. (EPA-01)

As policymakers, we decided that the only way the public could have confidence in nanotechnology was to do reporting rule. This is the argument that we made to the administration. The administration back in, let's say, 2011, 2012, put out a Statement of Principles for innovation and said that it should be science-based. (EPA-02)

The EPA established the voluntary NMSP in 2008 and finalized the new mandatory reporting rule in January 2017. Although there were no official statements on this specific policy, this seems that the agency switched sides, shifted from voluntary policy to mandatory policy over the course of the policy debate. This situation, where the administrative agency taking a more moderate or less consistent positions than other coalition members, confirms the third hypothesis of the study.

Apart from the coalition activities over time, there is another possible explanation about why the EPA switched its position from supporting a voluntary approach to the mandatory approach. The voluntary NMSP started under the Bush administration. For

example, in 2006, President Bush listed nanotechnology as a top technological opportunity for national competitiveness. Then, in January 2008, the EPA announced the NMSP. The NMSP formally ended at the end of 2009 and mandatory Nano Reporting Rule was proposed under the Obama administration in early 2015. Finally, only a few weeks before the beginning of the Trump administration, the EPA issued a final Nano Reporting Rule. Even though the Trump administration took office after the new rule, the development of the rule occurred under the former administration and therefore the rule is likely to reflect Obama administration's policy values. Although it is premature to conclude that the administrative changes are directly associated with the EPA's switch from voluntary to mandatory approach, it is possible to interpret the changes reflect the trend of science turning into partisan issue seems. In fact, even after the new reporting rule has been finalized in January 2017, nanomaterial users and producers has been urging the EPA under Trump administration to delay and overhaul the Obama administration nano reporting rule until recently.³⁰

Role of science in the nanotechnology policy subsystem

The last hypothesis to be examined concerns the role of science or scientists in the nanotechnology policy subsystem. As described, many stakeholders or advocacy coalitions are involved in the policy process of NMSP and the new reporting rule. Interestingly, these groups with conflicting views contend that their arguments are based on sound scientific evidence. In some cases, scientific experts appear to be come to the

³⁰ Risk Policy Report. (June 2017). Nanotech Sector Urges Trump EPA To Delay, Revise TSCA Reporting Rule. Retrieved from <https://environmentalnewsstand.com/newsletters/risk-policy-report>

front, while others cite scientific findings to support their arguments or scientists seem to be indirectly involved.

In policy networks, scientific actors are important providers of objective and technical knowledge (Leifeld & Schneider, 2012). Reports and comments from EPA, ENGOs, and industry commonly argue that EPA's regulatory decisions on nanomaterials should be science based. One of the interviewees, a consultant who worked for EPA when it held meetings when introducing NMSP mentioned that there were significant number of scientists in the meetings: "The panels, depending on the topic of the meeting, we would typical have a third of the panelists would be academics, the research scientists" (OTHER-01).

For NMSP, one EPA official stated the role of scientists were not significant because the purpose of the program was to collect initial data on nanomaterials: "Scientists didn't play a big role because they agreed we needed more information" (EPA-02). However, another interviewee from EPA stated that scientists played important roles in the process: "All of the TSCA Program, and NMSP assessments, all went through the TSCA new chemical process, which is a multi-disciplinary team of scientists" (EPA-03). Also, an EPA official described some of the details about the role of scientific community as follows:

The scientific community played an important early role in pointing out the linking new nanomaterials, particularly carbon nanotubes, as to older environmental health problems that had existed like mesothelioma from asbestos exposure. (EPA-01)

For the Nano Reporting Rule, on the other hand, interviewees generally agreed the importance and involvement of scientists in the policy process. One of the EPA

officials explicitly stated that “Science helps us make not just better decisions, but decisions you can justify” (EPA-02). The EPA utilized scientific information not only from its own scientists but from other agencies such as National Institute of Standard (NIST) and Office of Pollution Prevention and Toxic (OPPT). On the other hand, some of the industry representative organizations have their own scientists as their staff and used the scientific information on possible health and environmental effects of nanomaterials when making decisions.

The scientific community was very involved, and it was involved across the various agencies. We had the EPA scientists and other scientists who'd done research on the particles and they could be toxic. You would have people from the National Institute of Standards and Technology or NIST. They have a program for measuring nanomaterials and looking at how changes in properties affect behavior. (EPA-01)

Scientists tell us what the material is. How it is classified for regulatory purposes. How it might migrate in the environment, in the workspace. Help the affluent, up the stack. How it might become in bedded and encapsulated in the finished product. Do you need scientists at every step of the way? To guide your judgement about each of those steps of the value chain. We have now; I think 10 PhDs on staff here that are Chemists. Organic and Inorganic Chemist, exposure experts, Toxicologists. They can tell us what the health effects are. What the environmental effects are. Is something bad for aquatic organisms? Is it bad for releases to water? Any practice like ours, needs a very, very discipline team of scientists to help our understanding. (IND-01)

I think that where we haven't yet succeeded is getting support for providing the information that's needed for the public to be confident. [...] We still don't have enough information on these substances to understand whether all of them are safe even after now 15 years of looking at some of them. (EPA-01)

The entire regulatory process, often times, you have a program manager from EPA talking to a program manager at a company, but we bring in the technical, the scientists, as needed. I think it's sort of a back and forth and a dynamic process, in terms of evaluating the different substances. (EPA-03)

In Office of Pollution Prevention and Toxic, you have people who read scientific literature, who just follow what studies are being done around the world. They're reading the summaries and they're trying to target which chemicals should be chemicals of concern. (EPA-03)

We have chemists and toxicologists, and we use them to understand the materials and to understand the testing and the test protocols and the status of the testing. Whether you're going to get reproducible results. We have them evaluate those parts of the rule and provide comments from their perspective. On whether EPA is proposing is science based. Whether it's sound, whether there's gaps, whether it's arbitrary. That's how we use our folks. (IND-06)

However, some members of industry and industry representatives stated they do not explicitly work with scientists. These members relied on peer-reviewed scientific literature and used them as evidence to support their arguments.

We tend to favor peer reviewed scientific literature that is well established. We don't like to have things based on one study or two studies. We like a preponderance of evidence for certain things, especially when it comes in regard to human health type issues. We, at times, have supported things we don't like because there's scientific evidence behind it. (IND-11)

Typically we would not get in touch with scientists. We'd have a professional scientist evaluate the literature and offer an opinion on weight of evidence in the whole body of literature, what's the implication of the outcome? Does this cause cancer or does it not cause cancer? There may be some evidence, but maybe not an overwhelming amount of evidence. That usually serves as the basis for any comments that we make to a regulatory agency. (IND-04)

Also, interviewers from ENGOs pointed out potential limitations about the role of scientists in the nanotechnology policy process. While they agree that science is an important factor in regulatory decision making, they worried that scientists might not be able to fully understand the interdisciplinary nature of public policy. They also showed concern about the possible manipulation of science by industry in the decision-making process.

Many scientists are funneled into narrow scopes of work usually kept focused on their one smaller area of science when in fact nanotechnology combines. But it's a very interdisciplinary area. It combines from biology to physics, to chemistry. (ENGO-02)

I think the EPA wants to make sure that things are science-based. It's just, at the end of the day, our agencies are often more guided towards the opinions of industry and the science. [...] There is something also called corporate science where science can be manipulated. There are many ways that you can take a scientific study and make it say several things. That's something we have to watch out for from all stakeholders is making sure that we're looking at science that is the highest quality and really best that we can do that's not just attached to making a profit. (ENGO-03)

Table 4.4: Summary of results

Themes	Hypotheses	Results
Nature of advocacy coalitions	H1: In the nanotechnology policy subsystem where the policy core beliefs are in dispute, the lineup of allies and opponents (i.e. coalitions) tends to be rather stable over time.	In the nanotechnology policy subsystem, there are two opposing coalitions with conflicting core beliefs and the lineup of the coalitions have been relatively stable over the past ten years.
	H2: Actors within each advocacy coalition in the nanotechnology policy subsystem show substantial consensus on issues pertaining to the policy core beliefs	Actors within each two advocacy coalitions in the nanotechnology policy subsystem showed substantial consensus on issues related to policy core beliefs including regulatory approaches to the technology.
Position of the administrative agency	H3: Within nanotechnology policy subsystem, the administrative agency (EPA) will advocate more moderate or less consistent positions than its interest group allies.	Within nanotechnology policy subsystem, the EPA has advocated less consistent positions than other members of coalitions and the agency, shifting from a voluntary to a mandatory approach to regulating and collecting information on the potential risks from nanomaterials.
Role of science in the policy subsystem	H4: In the nanotechnology policy subsystem, scientific actors play a central role within the subsystem.	Scientists and scientific information have played significant roles in the nanotechnology policy subsystem. Interviewees from two opposing coalitions both agree the importance and involvement of scientists in the policy process.

Discussion/Conclusion

Analyzing complex public policy-making processes is a challenging task (Sotirov & Memmler, 2012). Using Advocacy Coalition Framework (ACF) as a theoretical framework, this study explored the actions and motivations of policy actors involved in two of the EPA's nanotechnology regulation policies: Nanomaterial Stewardship Program (NMSP) and Nano Reporting Rule.

The first contribution of this study is that it showed various levels of interactions among policy actors in nanotechnology policy subsystem over the last ten years. I first identified two advocacy coalitions projected by their policy core beliefs within nanotechnology policy subsystem. The two coalitions, "Pro-Mandatory Policy" advocacy coalition and a "Pro-Voluntary Policy" advocacy coalition were formed based on shared core beliefs and there were evidences of coordination among coalition members. The findings of the study indicate that each advocacy coalition remained stable over the last ten years and during that time, coalition members showed substantial consensus on the issues related to the core beliefs. One of the purposes of the study is to test the applicability of ACF to the nanotechnology policy environment. The findings supported two existing ACF hypotheses on advocacy coalitions: most members of a coalition maintain agreement on policy core issues and these core beliefs remain stable over time (Jenkins-Smith & Sabatier, 1994; Sabatier, 1988; Weible, 2007).

The second contribution of this study is that it showed the EPA maintained more moderate and less consistent positions over time. Although nanotechnology policy subsystem can be characterized by intense conflict between industry and ENGO coalition, I found that the dispute between the two seemed arbitrated by the administrative agency, EPA. Rather than direct interactions, the opposing coalitions communicated through the EPA such as providing comments to the agency and making

lawsuits against it. This study confirmed the ACF hypothesis that the administrative agencies advocates more moderate positions than its interest group allies within policy subsystem than other allies (Jenkins-Smith & Sabatier, 1994). Specifically, I found that the agency switched sides from voluntary policy to mandatory policy over the course of the policy debates. This study adds literature to the topic of administrative agencies' positions in policy subsystems, which ACF scholars have called for more renewed testing and development (Jenkins-Smith, 2014).

The third contribution of this study is that it showed role of scientific and technical information in the nanotechnology policy subsystem. Existing literature on ACF has explored the role of scientists in the policy process (Jenkins-Smith et al., 2014). However, there is a lack of literature in the field of emerging technology policy where risk and benefit of the technology remains uncertain. This study confirmed that scientific actors played a central role within policy subsystems (Weible et al., 2009). It showed that scientific experts played important roles in the nanotechnology policy process and other policy actors rely heavily on them. This finding supports the arguments that in a policy sector where scientific evidence is lacking, scientific information is a critical resource in policy making and policy actors seek new information and thus depend on scientific experts (Ingold et al., 2016). This study also found that EPA officials who propose and design nanotechnology policies are scientists in relevant fields. In other policy environments, public officials and scientists often form distinctive groups, therefore interaction between scientists and officials become an important issue (Anderson & MacLean, 2015). Although they still consult scientific information from other experts, the EPA officials already had expertise knowledge from the beginning of the policy process and this is a unique feature of the nanotechnology policy case.

However, there were concerns over manipulation of science from ENGOs. Politicization of science happens when decision makers selectively exploit the uncertainty in science to promote a particular agenda (Bolsen & Druckman). Since there are significant knowledge gaps and scientific uncertainty about nanomaterials risk (Falkner & Jaspers, 2012), the concerns over the use of science in policy making in the field seem legitimate. Also, while most policy actors acknowledge the significant roles of scientists, it was not clear at what stage of the policy process scientists could be involved. During the interview, one of the consultants expressed a concern about this issue: “My opinion, and I bet you most people agree with this opinion, scientists should be involved in the first day (of the policy process); often, they're involved in the last day” (OTHER-02). Given the concerns over the use of science in the nanotechnology decision making, EPA should clarify the exact role of scientific information including the stages at which scientists should be involved.

Another contribution of the study is that this study employed qualitative method to the policy process analysis. In this study, qualitative analysis provided in-depth information about specific actors' positions, relationships and interactions among the coalitions (Weishaar, Amos, & Collin, 2015). The interviews with individuals who participated in the policy process provided insights that were unattainable or unnoticeable from the quantitative analysis (Miles & Huberman, 1994). Also, qualitative social research focuses on reflexivity while quantitative research emphasizes on replicability (Hammersley, 2007). For example, quantitative data cannot provide EPA's dilemma in maintaining balance and neutrality between the two opposing sides or the role of scientists and scientific information in the original nanotechnology policy process. These cultural and institutional aspects are the uniqueness of nanotechnology policy subsystem and can only be observed from qualitative approach.

One of the important areas of further research for ACF is regarding external factors effecting policy subsystem (Sabatier, 1988). The ACF predicts that the broader institutional context in which a policy process takes place can affect policy change. Policy making in policy subsystem is constrained by variety of events of the society (Kiser & Ostrom, 2000) and it includes a change in government. Although this study did not explicitly focus on the topic, four interviewees mentioned the potential impact of administration change on EPA's regulatory policies during the conversation. They pointed out that even though the EPA finalizes the new reporting rule for nanotechnology regulation, there could be another change depending on the policy stance of the new, incoming government. Further study should be carried out to determine the effect of this significant external factor.

I explored one of the unanswered questions of the ACF literature: to what extent can ACF be used as a practical tool for policy makers (Sabatier & Weible, 2007). The ACF provided a great tool to examine the process of policy change through the interactions among coalitions in nanotechnology policy subsystem. By testing the applicability of the ACF, this study can contribute to the development of nanotechnology policy-making as well as an advance in the understanding of the theoretical framework. Also, this study helps expanding and improving the ACF, thus increasing the ability of the framework to explain and predict stakeholder behaviors and policy outcomes.

Chapter 5

DISCUSSION AND IMPLICATIONS

This research investigates the research question of (1) how nano-scientists' individual characteristics and values are associated with their perceptions of public engagement and political involvement, (2) how the Advocacy Coalition Framework (ACF) can be applied to nanotechnology policy subsystem, and (3) how the EPA utilizes science when making regulatory decisions about nanotechnology.

In the first essay, I look into scientists' perceptions in association with public engagement in the field of nanotechnology. Using quantitative data from a 2011 mail survey of elite U.S. nanoscientists, I find perceptions about nanotechnology among U.S. nano-scientists and examines the influence of scientists' individual perceptions on their perceptions about public engagement, including political involvement, public communications, and regulations. I find that that scientists are supportive of engaging with policy-makers and the public about their research outcomes. Findings also suggest that there is a diversity of opinions among nano-scientists. Therefore, policy makers in this field should understand that scientific judgment is made within a value-rich context and consider nano-scientists' diverse views depending on their fields, approaches, and subjective judgments.

My second essay examines actions and motivations of policy actors involved in two of the EPA's nanotechnology regulation policies: NMSP and Nano Reporting Rule using ACF as a theoretical framework. Qualitative interview analysis suggests that there are two opposing advocacy groups with shared beliefs in the nanotechnology policy subsystem. The lineup of coalition members is stable over the last 10 years but the administrative agency, EPA advocates less consistent positions. The interview data also show a significant role of scientific information in the subsystem.

Finally, in my third essay, I show how the EPA acquires and uses the scientific information when making decisions and sheds light on the understanding of the relationship between science and politics in the agency. I explore comprehensive document analysis of the use of science at EPA as well as existing barriers that constrain the use in decision-making process at the agency. Also, I provide internal perspectives of those who oversaw the establishment of the nanotechnology policies from an internal perspective using original interview data,

Nanotechnology provides a good case for new ideas about public engagement, science and democracy. Exploring the relationship between scientists' individual values and their perceptions about public engagement can shed light on how (and when) scientists should be brought into meaningful conversations with the public. By testing the applicability of the ACF, this study contributes to the nanotechnology policy-making as well as improve the understanding of the theoretical framework. I believe this research can be a guide for policy makers who want to induce science into government decision making. Also, it can be a useful tool for scientists' who want to more public engagement activities, bridging the gap between science and decision making.

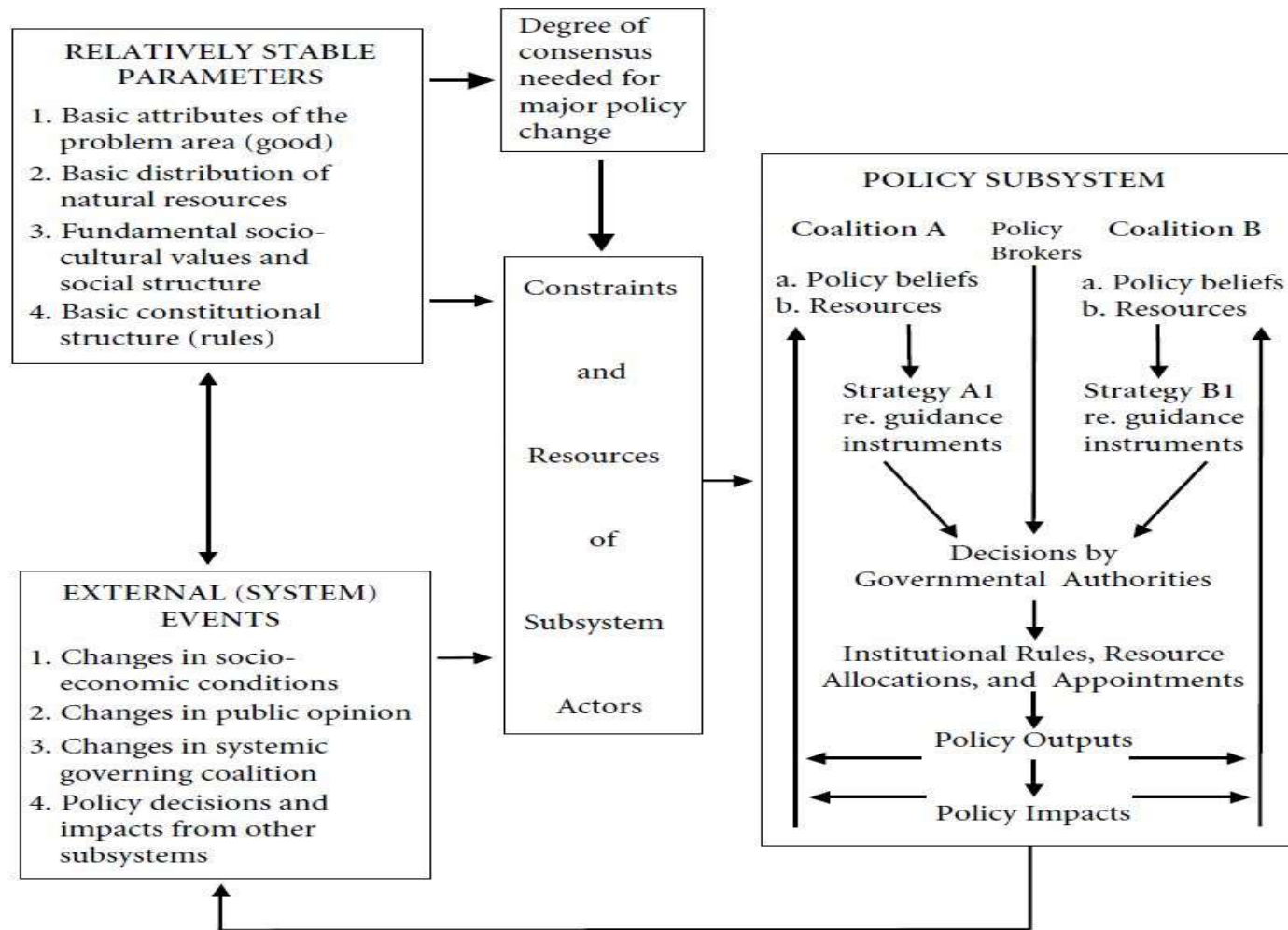


Figure 4.1: Diagram of the Advocacy Coalition Framework. Reprinted from *Theories of the Policy Process* (p. 191), by Paul A. Sabatier, 2007, Boulder, CO: Westview Press.

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APPENDIX A
REQUEST FOR INTERVIEW

I'm a Doctoral Student in the School of Public Affairs at Arizona State University and I'm contacting you to ask if you would have time to talk with me about my dissertation research. I'm currently working under the direction of Professor Elizabeth A. Corley in the School of Public Affairs at Arizona State University for this research. My dissertation is focused on the development of voluntary initiatives for nanotechnology, with a special emphasis on the EPA's Nanoscale Materials Stewardship Program (NMSP) and the 2015 proposed EPA rule.

I would be extremely grateful if you might have time to chat with me briefly in person over the next few weeks. I am planning to visit your area during the week of November 7 and the week of November 14, 2016. If you are available, I would like to meet with you and ask some questions about your experience with the voluntary approach to the regulation of nanotechnology (generally), as well as your experience with the 2008 EPA NMSP program (more specifically). The duration of the interview would be around 45 minutes and no more than an hour.

Would you be available to meet with me sometime during the week of November 7 or the week of November 14, 2016?

I'll look forward to hearing from you.

Best Wishes,

Youngjae Kim

APPENDIX B
CONSENT FORM

Dear [Participant],

Thank you for agreeing to meet with on [DATE] to talk about your experience with nanotechnology policy. Participating in the interview will serve as your consent to participate in this study. The purpose of the study is to explore the development of voluntary initiatives for nanotechnology, with a special focus on the EPA's Nanoscale Materials Stewardship Program (NMSP) and 2015 proposed rule. The study will also examine the role of scientists in these voluntary initiatives.

While there are no direct benefits to the participants, it is an opportunity to express your opinions to the regulation of nanotechnology and your opinions may contribute to the further development of nanotechnology regulations. And there are no risks involved in participating in this study.

As mentioned, the duration of the interview would be no more than an hour and your responses will be confidential. The interview will be audio recorded unless otherwise requested by you. The audio recording of the interview will be destroyed after it has been transcribed. There may be additional follow-up/clarification through email unless otherwise requested by you. Privacy will be ensured through confidentiality.

Participation is voluntary and you have the right to terminate the interview at any time.

If you wish to receive a copy of the results of this study, you may request a copy be sent to you when the report is complete. If you have any questions concerning the research, please contact the research team at: ykim128@asu.edu or corley.elizabeth@gmail.com. If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects

Institutional Review Board, through the ASU Office of Research Integrity and Assurance,
at (480) 965-6788.

Sincerely,

Youngjae Kim