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Agenda Setting in Emergent R&D Policy Subsystems: Examining Discourse Effects of the 21st Century Nanotechnology Research and Development Act

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Abstract

The literature on government responsiveness to societal issues is extensive but provides a mixed assessment of effectiveness. We examine this issue in the case of policy addressing effective and safe management of research and development in the emerging field of nanotechnology. Specifically, we examine the agenda setting effects of the 21st Century Nanotechnology Research and Development Act (the Act), a piece of legislation designed to be implemented by a network of actors in the nanotechnology research and development policy subsystem. We adopt a public values lens in our examination of discourse related to societal concerns. Policy documents from Congress, an agency, and federal funding recipients are examined. Findings suggest a narrowing of public values discourse around more specific societal concerns in the documents crafted after the Act was passed.

KEY WORDS: research and development policy, nanotechnology, governance of emerging technology, innovation, public policy agenda setting

Introduction

The literature on government responsiveness to societal issues is extensive. While no more complex in relative terms than prior periods of democratic government development, the policy challenges facing modern governments are increasingly complicated by global insecurity, domestic economic downturns, and rapidly advancing technological developments that offer uncertain rewards and risks. How democratic governments respond is the subject of historical and contemporary inquiry, including, for example, Howlett's (2000) discussion of "wicked problems" for policy development and Potoski's (2002) observations on the problematic transition of policy from federal lawmakers to government regulators to produce meaningful and positive impact on citizens and other stakeholder groups.

Are traditional approaches to governance adequately responsive to modern societal problems? Baumgartner and Jones (1993) suggest that much of the literature, both scholarly and popular, offers discouraging assessments of the ability of government institutions to deal with change (p. 235). Similarly, Mintzberg (1978), in his classic assessment argued that it is a characteristic of certain organizations, including government organizations, to be slow in responding to environmental stimulations. Conversely, March and Olsen (1983) described impressive growth and change in government responsiveness to changes in cultural norms, beliefs, and values. The more current scholarly literature on government responsiveness to societal issues is also mixed. Olsen (2008) identified several instances of adequate government responsiveness to modern issues, but still called for research to explore government's capacity to respond to new situations. Robinson (2006) was also optimistic when he described examples of transition away from top-down styles of governance to those that respond to the needs and concerns of citizens. In contrast, Hall (1999) argued in a case study of Australian government that response to change in mental health-care organizations was slow and avoided major changes even given instability in their health-care system. Howlett (2000) described changes in government responsiveness to societal issues but also saw these adaptations as a threat to democratic processes and legitimacy because they may have worked too quickly or steered outcomes to preferred policy outcomes. Bozeman (2000) contributed to the discussion with his theory of "red tape" or public dissatisfaction with the rigidity of bureaucracy that impacts effective government decision making and action in the face of societal concerns.

Given the mixed findings in the literature, both classic and contemporary, the question of government responsiveness to current societal issues and concerns still remains. Like others in the field (see e.g., Sabatier, 1991), we contend that the issue is not the effectiveness of government in a broad sense but rather in policy subsystems. For example, policy researchers have found that the complexity of public policy can be simplified with the use of theoretically grounded frameworks. Such is the approach of Weible, Sabatier, and McQueen (2009) to study the question of policy change through the Advocacy Coalition Framework. We propose a similar narrowing of the analytical lens by focusing on a framework addressing the theories of agenda setting (Kingdon, 2002) and policy image setting (Baumgartner & Jones, 1993). We view the process of using legislation to establish a policy agenda as an example of a traditional approach to governance. The effective and safe management of research and development in the emerging field of nanotechnology is an example of a modern societal problem (Cobb & MaCoubrie, 2004; Guston, 2008). We examine the agenda setting effects of the 21st Century Nanotechnology Research and Development Act (the Act), a piece of legislation designed to be implemented by a network of policy actors in the nanotechnology research and development subsystem. Potential evidence for government responsiveness to nanotechnology promise and challenge is two-fold. First, the Act established a legislative foundation for a new institutional arrangement, the National Nanotechnology Initiative (NNI, 2011), to respond to the challenge of coordinating federal investments in nanotechnology research and development activities. Second, the Act provided a focus for the public values discourse surrounding nanotechnology research and development policy in the United States with input from nanotechnology stakeholders from a wide variety of government and academic institutions and industry (Boardman, Bozeman, & Slade, 2012). This second area is the chief focus of the empirical portion of this study.

Throughout this paper our primary objective is to examine the effects of the Act. In so doing we adopt a "public values" framework as outlined by Bozeman (2007). This nascent framework was developed as a lens for examining the extent to which public policies and especially research agendas achieve societal goals for science and technology (Bozeman & Sarewitz, 2011). Public value thinking places an emphasis on a broad spectrum of benefits and challenges facing science and technology programs. According to Bozeman and Sarewitz (2011), "research evaluation has made great strides in addressing questions of scientific and economic impacts. It has largely avoided, however, a more important challenge: assessing (prospectively or retrospectively) the impacts of a given research endeavor on the non-scientific, noneconomic goals [termed public values] that often are the core public rationale for the [research endeavor]" (p. 491). Thus, through a public values framework we seek to examine a broad spectrum of values associated with nanotechnology research and development.

This study's contributions to the overall public value mapping (PVM) research agenda constitute a secondary set of objectives. PVM has been proposed as an analytical tool for examining the public value dynamics of a given program. However, there is no consensus with regard to best practices of PVM. As such, this study stands to contribute to public value theory by improving—albeit incrementally—our understanding of how PVM may be used to examine the effects of policy events in multilevel, multiactor systems. Moreover, previous examples of PVM have relied heavily on qualitative approaches to examine chains of public values through policy implementation (see, e.g., Meyer, 2011; Slade, 2011a, 2011b; and Valdivia, 2011) while this study adopts a quantitative approach driven by data-reduction methods seen in other fields. Finally, this study stands to contribute to the overall PVM research through its attempt to integrate PVM thinking with a more established realm of public policy theory: agenda setting.

Exploring Policy Change: Nanotechnology

The literature supports the notion that policy change is less likely to occur when economic and societal pressures are low (Jones, Baumgartner, & True, 1998; Jones, Sulkin, & Larsen, 2003). Under high societal pressure, policy change may be less predictable. The challenges of new and emerging technologies, such as nanotechnology, represent high pressure, atypical circumstances for policy makers and government. Guston and Sarewitz (2002) note that in the early days of nanotechnology research and development, scientific uncertainty as well as ethical, legal, and social implications represented significant challenges to policy makers. They are not alone in their assessment given that nanotechnology has been characterized by many as the next industrial revolution (Fisher & Mahajan, 2006; Roco, 2001, 2004). The literature also supports that this topic has high valence for society in general. In a large-N national survey, Cobb and MaCoubrie (2004) found that in the United States, citizen expectations for nanotechnology development to address societal problems like widespread diseases are high.

The Act represents government response to demands for greater federal attention to and investment in nanotechnology research. The Act institutionalized the National Nanotechnology Initiative (NNI), which organized nearly $4 billon toward nanotechnology programs within the first few years following its passage. Since then funding levels have continued to increase steadily; 2012 allocations alone totaled $1.7 billion. Table 1 shows actual, estimated, and requested NNI funding from 2001 to 2011 by agency. Of note for further discussion here is the proportion of funding to agencies like Department of Energy, the National Institutes of Health, and the Department of Defense (Congressional Research Service, 2012).

The NNI was charged with implementing the Act pursuant to the following primary directives:

Table 1. NNI Funding 2001 to 2011 (Millions of Current Dollars)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
DOE	88	89	134	202	208	231	236	245	333	374	346
NSF	150	204	221	256	335	360	389	409	409	429	485
NIH	40	59	78	106	165	192	215	305	343	457	409
DOD	125	224	220	291	352	424	450	460	459	440	425
NIST	33	77	64	77	79	78	88	86	93	115	96
NASA	22	35	36	47	45	50	20	17	14	20	17
EPA	5	6	5	5	7	5	8	12	12	18	17
Other*	1	3	3	4	9	14	19	22	40	61	61
Total	**464**	**697**	**761**	**988**	**1,200**	**1,354**	**1,425**	**1,556**	**1,703**	**1,914**	**1,856**

DOE = Department of Energy; NSF = National Science Foundation; NIH = National Institutes of Health; DOD = Department of Defense; NIST = National Institute of Standards and Technology; NASA = National Aeronautics and Space Administration; EPA = Environmental Protection Agency.
*Other includes the Food and Drug Administration, National Institute for Occupational Safety (HHS), National Institute of Food and Agriculture (USDA), Department of Homeland Security, Forest Service, Agriculture Research Service, Federal Highway Administration, Consumer Product Safety Commission, Deppartment of Justice.
Source: Congressional Research Service, 2012.

1 Steer development of a fundamental understanding of nanomaterials.

2 Establish a network of nanotechnology user facilities.

3 Establish and promote interdisciplinary research centers and collaborations.

4 Incorporate minority researchers into activities.

5 Advance U.S. economic competitiveness.

6 Accelerate the development and commercialization of nanotechnology products.

7 Ensure consideration and of ethical, legal, environmental, and general social concerns about nanotechnology.

We contend that the Act represents a significant government response to societal issues. Through the Act a policy agenda was set and a policy image constructed by virtue of the artifacts noted above. A policy agenda is described by Kingdon (2002) as "the list of subjects or problems to which governmental officials, and people outside of government closely associated with those officials, are paying some serious attention at any given time" (p. 3). Baumgartner and Jones (1993) describe agenda setting as a means for stabilizing policy systems. This agenda-setting standard is met by growing literature on the issues of nanotechnology and nanoscience public policy (Guston, 2008; Guston, Parsi, & Tosi, 2007; Roco & Bainbridge, 2005).

We find the discussion of "policy image" to be especially relevant for our research. A policy image is the way a policy is "understood and discussed" (Baumgartner & Jones, 1993, p. 25). Changes to or establishments of policy images typically occur in response to societal instability. Nanotechnology meets this definition as it is clearly being developed during uncertain economic times for federal funding and with due concern over rapid advance of technological developments. Redefining or establishing a policy image not only changes the way policy issues are discussed, but it also provides stability for government action and policy images result in new institutional arrangements (Baumgartner & Jones, 1993). Thus, our

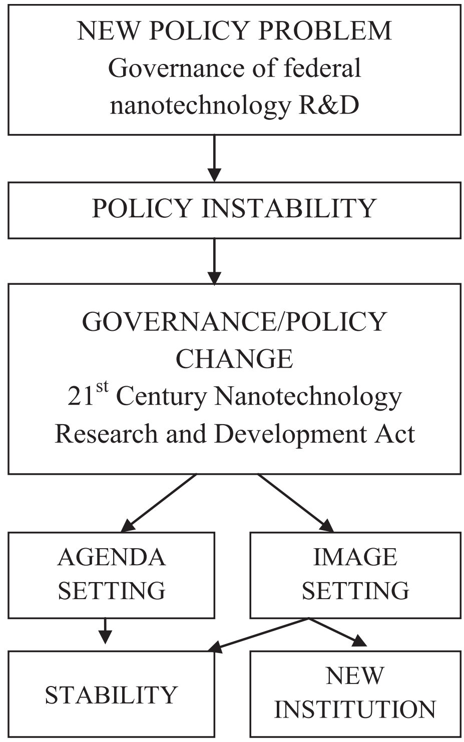

Figure 1. A Framework for the Nanotechnology Act as Government Responsiveness to Societal Issues

nanotechnology case study is a prime example of a policy image high on the policy agenda. The Act addressed the modern policy agenda. We predict that the results of this effort produced greater public policy stability and new institutional arrangements for nanotechnology research and development to address societal issues.

Figure 1 shows our model for integrating policy agenda and image setting theories into a flow diagram of the transition of societal issues to policy changes through the ACT to better policy stability and new associated public institutions.

Important to this discussion is the work of nanotechnology institutional leaders and policy entrepreneurs (Mintrom, 1997). Mihail Roco, a key player in the federal nanotechnology policy community and member of the National Science and Technology Council, has participated in nanotechnology policy making from the earliest days of policy engagement (McCray, 2005). Before the Act was implemented, Roco observed that, "for the first time, nanotechnology will be institutionalized in the federal government" (Fisher & Mahajan, 2006, p. 10). In 2005, after the Act had been implemented, Roco noted that with federal support for over 4,000 programs and 60 centers, the "vision of a decade ago has taken place" (Roco, 2007, p. 15).

Public Values Mapping: An Analytical Strategy for Science Policy Evaluation

Government action and policy development concerning nanotechnology suggest the presence of public values for the impacts of nanoscience on societal outcomes. Public values include, but are not limited to, economic competitiveness and represent such societal concerns as human dignity and conservation of resources and other noneconomic aspects of science policy (Bozeman & Sarewitz, 2011). The United States has a long history of supporting and investing in science and technology research and development. Vannevar Bush, the de facto first presidential science advisor, in his decisive report to President Franklin Delano Roosevelt articulated some of the public rationales for federal investments in science and technology research and development. According to Bush, "science, by itself, provides no panacea for individual, social, and economic ills. It can be effective in the national welfare only as a member of a team, whether the conditions be peace or war. But without scientific progress no amount of achievement in other directions can insure our health, prosperity, and security as a nation in the modern world" (Bush, 1960, p. 1).

The fundamental elements of Bush's claims—specifically that science can improve prosperity, security, and health, and should be directed to do so—have endured through the years and are adopted by many. As such, the federal government has established a number of robust programs, agencies, and partnerships to support science and technology research and development since Bush's 1945 report. Examples of these are seen in the Department of Energy, National Science Foundation, and the Defense Advanced Research Projects Agency, to name a few. As one might expect, expansions in federal support for research and development occurred side by side with advancements in science and technology. In turn, advances in science and technology have had grand impacts—for better or worse—on American society.

Thus, federally funded scientific programs have a rich history of being justified by a wide range of public values, but only recently have frameworks been developed to observe impacts of scientific research and development through the "web of institutions, networks and groups that give rise to social impacts" (Bozeman & Sarewitz, 2011, p. 1). Scientific research and development have traditionally been evaluated in terms of their economic benefits and outcomes (Bozeman, 2007; Bozeman & Sarewitz, 2011; Fisher, Slade, Anderson, & Bozeman, 2010). However, economic values fall short of representing the full spectrum of public interests. The tendency to rely on economically oriented evaluation schemes is both unfortunate and misleading for science policy analysis in particular. Examples of economically viable policies that fail to meet societal needs or expectations are myriad and include benefit hoarding with respect to agricultural research and development and genetically modified plant seeds (Lambrecht, 1998) and scarcity in the 2004–2005 flu vaccine (Feeney & Bozeman, 2007) to name a few.

PVM according to Bozeman's public value theory (Bozeman, 2007) has been offered as a tool for examining the multitude of values used as rationales for and products of public investments in science and technology. As discussed, PVM is a framework for assessing how public policies and especially research agendas achieve societal goals for science and technology (Bozeman & Sarewitz, 2011). As an evaluation tool, PVM has been developed with active recognition that market-based assessments of goods and services offer a way of thinking that is salient to many (Bozeman, 2002). Specifically, the notion of market failure is a concept that receives considerable attention. Even when used inappropriately or cast toward the uninitiated, claims of market failure—irrespective of whether it is a result of information asymmetry, noncompetition, externalities, or some other source—may be powerful for inciting action or concern. Hoping to operate in much the same way, PVM seeks to highlight instances of public values failure. Public values failure occurs "when neither the market nor the public sector provides goods and services required to achieve our public values" (Bozeman, 2002, p. 150). Examples of public values failure include, but are not limited to: poor mechanisms for articulating and aggregating values, imperfect monopolies, benefit hoarding, scarcity of providers, short time horizon, substitutability versus conservation of resources, and threats to subsistence and human dignity (Bozeman, 2002, p. 151).

PVM has been applied to policies for climate science and federal climate change programs (Meyer, 2011), nanomedicine and cancer (Slade, 2011a, 2011b), intellectual property laws and university technology transfer (Valdivia, 2011), natural disaster research (Maricle, 2011), and nanotechnology (Fisher et al., 2010).

We believe this to be the first attempt to apply PVM thinking to examine policy change and government responsiveness to societal issues associated with a particular technology and a particular policy image, in this case the Act.

Accordingly, our hypotheses are as follows:

> Hypothesis 1: Because the Act serves to address the science and technology *policy agenda* at the time, we will observe differences in the public value principle components structure pre- and postlegislation.
>
> Hypothesis 2: Because the Act serves as a *policy image*, we will observe a less ambiguous public values discourse postlegislation.

Given the timing and design features of the Act, we expect that policy will produce a before and after change in public value priorities and articulation. Consistent with our hypotheses, we anticipate that the analysis will show that the Act rests high on the public's policy agenda, evidenced by the sheer number of related value statements in the multiinstitutional discourse. Further, we anticipate that the Act does serve as a policy image or focal point for multi-institutional discourse as evidenced by less ambiguity and variation in the discussion of core public values for nanotechnology research and development. A PVM interpretation of a manifestation of these occurrences constitutes a public values success. The Act's failure to establish an agenda or image may be considered a public values failure.

Data Source and Methods

Public values may represent themselves as statements in written or spoken communication. For our analysis we use a subset of data from the nanotechnology discourse of policy actors and subgroups in the United States (Fisher & Mahajan, 2006; Fisher et al., 2010).[1] This data set is the result of an analysis of value-laden statements in several different types of policy documents generated by actors in the U.S. nanotechnology research enterprise. Of concern for this study are value statements in the documents of the nanotechnology policy subsystem before and after the Act was signed into law on December 3, 2003. The data set is a count of the frequency of occurrence of 82 public value-laden terms in 1,020 policy documents including U.S. Congress committee reports, National Science Foundation (NSF) program solicitations related to nanotechnology, and the abstracts from NSF research projects and laboratories funded through these programs. Congressional committee reports were collected electronically from the Library of Congress; NSF program solicitations were collected from the NSF website; and abstracts from funded laboratory proposals were collected from the NSF Award Search database. In selecting these documents we consulted science and innovation policy scholars and practitioners (including a now former staff member of the U.S. House of Representatives science and technology committee), senior NSF advisors, program officers and staff members, and scientists and laboratory directors presently or recently funded through these NSF nanotechnology programs.

For congressional level documents we reviewed all committee reports from 2000 to 2008 containing the word "nano*" (n = 189). Our focus on committee reports rather than legislation was intentional. Committee reports include greater opportunity to express normative views relative to laws in question. For example, such reports often include sections such as "Background and Need for Legislation," "Purpose of Legislation," or "Additional Views" of committee members. The normative views expressed in these sections are assumed to be rich with public value language. By way of example, consider the following statement in reference to the need for enhanced funding of nanotechnology taken from the "Additional Views of [New Mexico] Senator Jeff Bingaman" section of the National Defense Authorization Act of 2001:

> I believe significantly more funding is needed now in order to ensure that we have that capability in the future so that we will be more confident of the reliability of our nuclear stockpile in the absence of testing nuclear weapons. The bill contains no additional funding beyond the requested level for this high priority effort needed to support the nation's non-proliferation goals while meeting nuclear stockpile reliability requirements (U.S. Senate, 2000, p. 468).

Another example relative to an expressed need for enhanced nanotechnology investments in support of national manufacturing competitiveness is seen in a committee report from the House of Representatives: "The world is getting much tougher in terms of our ability to compete, to develop the kinds of products people want to buy and to develop them at high quality and low cost" (U.S. House, 2001, p. 34). Each of these statements illustrates our view of how public values are referenced in policy documents (and also provide a qualitative context for this quantitative assessment).

Our choice of documents used to represent subordinate actors in this nanotechnology policy subgroup is deliberate. The original specifications of NNI support for NSF nanotechnology research occurred along three main program lines: Nanoscale Exploratory Research (NER), Nanoscale Interdisciplinary Research Teams (NIRT), and Nanoscale Science and Engineering Centers (NSEC). We analyze all NSF program solicitations related to these three programs as well as the solicitations from programs that co-funded research projects with these programs (n = 96) between 2000 and 2008. Finally, we analyze the abstracts of all research projects funded through NER, NIRT, or NSEC (n = 735).

We analyze the incidence of 82 value-laden key terms across all documents (Lacey, 1999). There are many sources from which to consider referencing when generating a list of public values related to nanotechnology research and development. Such sources may be external to this policy subsystem (i.e., speech made by

Table 2. Public Value Key Words for Content Analysis and Frequency Counts (n = 82)

Access	Developing	Homeland	Rural
Advanced Science	Discovery	Infection	Security
Afford	Disease	Integrate	Servicemen
African American	Disseminate	Justice	Smallpox
Armed Forces	DOD	Knowledge	Social
Atmosphere	Domestic	Leadership	Socioeconomic
Attack	Durable	Legal	Soldier
Basic Research	Economic Competition	Low-cost	Supply and/or Demand
Basic Science	Education	Market	Surveillance
Brain	Efficiency	Medical	Technology Transfer
Business	Emergency	MEMS	Terror
Cancer	EPA	Military	Toxic
Clean Air	Equal	Minority	Training
Climate Change	Ethics	Modeling	Under Represented
Commerce	Flu	Native American	Understand
Community	Forefront	Oversight	Virus
Company	Gender	Product	Waste
Consumer	Global Warming	Progressive	Weapon
Decentralized	Greenhouse Gas	Reliable	Wound
Defense	High Performance	Renewable	
Demand	Hispanic	Renewable Energy	

Table 3. Policy Documents Analyzed for Value Statements (n = 1020)

Institution	Policy Document	Source	n (Pre-Act)	n (Post-Act)	n (Total)
Congress	Committee report	Library of Congress	80	109	189
NSF	Program solicitation	NSF website (http://www.nsf.gov)	61	35	96
Laboratories	Proposal abstract	Awardsearch database (http://www.nsf.gov/awardsearch)	180	555	735

a high-profile political official or a position statement by an interest group) or internal. For this study we turn to internal sources as outlined here. These search terms were created through a vetting process that involved a "review of sample annotated records and reports, comparison and analysis of sample value statements, and grouping and selection of indicators" (Fisher et al., 2010). More specifically, a random selection of policy documents described above was examined wherein example value statements were isolated. Value statements were defined as those that either (1) offered opinions or insight as to why investment in nanotechnology is justified or (2) offered opinions or insight into what the benefits of nanotechnology research and development may include. An aggregate list of these individual sentences was generated whereupon key words were extracted to form the list of search terms. We used a computer-aided content analysis software program, NVivo (NVivo, 2009), to assess the incidence of each search term across all documents. Table 2 provides a list of these search terms.

As mentioned previously, the time frame for these documents is January 2000 to mid-2008, thus providing four years of pre-Act data and approximately four and a half years of post-Act data. The frequency statistics of the documents according to their status as pre- and post-Act are shown in Table 3.

The differences in documentation before and after the Act—fewer NSF nanotechnology solicitations and greater numbers of laboratory abstracts and congressional reports—offer *prima facie* evidence that the Act may have served as a policy image and affected the nanotechnology research and development policy agenda. A greater number of abstracts coming from a smaller number of NSF solicitations may indicate the emergence of a more efficient, consolidated spectrum of programs funding nanotechnology. Similarly, a slightly greater number of congressional committee reports are consistent with our expectations as the Act created new appropriations requirements and thus a need for more legislation and committee reports.

The results of the document search for the 82 key public value-related words related to nanotechnology research and development were analyzed using a principle components method (Hotelling, 1933). In this case, a principle components extraction method was used because of its capacity to reduce a large number of related variables to a smaller number of components that we, in turn, use to explore the existence of theoretical constructs, or in our case categories of public values related to nanotechnology research and development policy (Costello & Osborne, 2005; Fabrigar, Wegener, MacCallum, & Strahan, 1999; Rummel, 1967). The principle components extraction method is preferred given the number of public value terms (n = 82) and our application of data-reduction techniques for the related documents (n = 1,020) (Costello & Osborne, 2005). We adhere to recommendations in the methods literature by applying an orthogonal rotation, specifically promax with a kappa (4), because we anticipate some correlation between factors (Costello & Osborne, 2005).

Previous analysis of the data set suggested three principle components of the nanotechnology public value discourse including "society and the economy," "security and defense," and "energy and the environment" (Fisher et al., 2010). However, this analysis was without consideration to any specific time dimension or policy change that would trigger a shift in public values. Building on this preliminary analysis of the data set, our current investigation studies the effect of agenda and image setting policy on the public value discourse in nanotechnology policy.

Our approach is to perform two principal component analyses, including one on the 82 public value key words in pre-Act Congressional documents and one on the same public value key words in post-Act documents. The results are compared and interpreted in terms of propositions concerning PVM, policy images and agenda-setting, and the evidence from our factor analytic methods.

Results and Discussion

Table 4 shows the results of the pre-Act factor analysis. A total of four factors are retained, each explaining over 5 percent variance with eigenvalues greater than 1.0. Collectively, these four factors explain approximately 59 percent of the variance.

As is the case with Fisher et al. (2010), each factor references multiple categories of public values in terms of societal concerns. This is especially true in the case of the first factor which we find difficult to characterize or name. A total of 39 terms with loadings greater than 0.5 appear in this factor and it accounts for the most variance explained by a single factor; we infer that it represents the wide variety of nanotechnology-related sentiments and concerns represented in these policy documents for the time period leading up to the passage of the Act. The second factor seems to focus on issues of national security and the third factor addresses energy and the environment. Finally, a fourth factor includes no clear set of salient public values as only one term loads at a level higher than 0.5. Unlike the first factor, the

Table 4. Pre-Act Factor Analysis (82 Key Words, 1020 Documents)

	Factors					Factors			
Terms (1–41)	1	2	3	4	Terms (42–end)	1	2	3	4
Access	**0.930**	0.101	−0.048	−0.061	DOD	0.204	**0.846**	0.107	0.035
Developing	**0.927**	0.129	0.133	−0.082	Attack	0.222	**0.842**	0.044	0.108
Education	**0.907**	−0.179	−0.225	−0.066	Low-cost	0.324	**0.788**	0.190	0.099
Community	**0.871**	−0.254	−0.181	−0.278	Soldier	0.115	**0.747**	0.048	0.091
Hispanic	**0.868**	−0.278	−0.014	0.011	Surveillance	0.483	**0.698**	−0.097	0.064
Minority	**0.855**	−0.248	−0.332	0.025	Armed Forces	0.273	**0.678**	0.078	−0.052
Medical	**0.853**	−0.013	−0.266	−0.036	Modeling	0.319	**0.669**	0.199	0.061
Leadership	**0.849**	−0.056	−0.300	0.101	Basic research	0.256	**0.558**	−0.069	0.491
Progressive	**0.819**	0.189	−0.064	0.336	Wound	0.144	**0.532**	−0.001	0.050
Training	**0.810**	0.250	−0.177	−0.052	Efficiency	0.352	−0.102	**0.804**	0.323
Social	**0.790**	−0.257	−0.318	0.023	Renewable	0.199	−0.311	**0.803**	0.276
Native American	**0.768**	−0.311	−0.196	−0.271	Renewable energy	0.146	−0.310	**0.767**	0.300
African American	**0.767**	−0.266	−0.281	−0.098	Supply and demand	0.315	−0.333	**0.715**	0.304
Legal	**0.766**	0.059	0.014	−0.464	Product	0.447	−0.003	**0.675**	0.184
Business	**0.763**	−0.160	0.332	−0.244	Demand	0.452	−0.105	**0.660**	0.375
Integrate	**0.751**	0.348	−0.106	0.173	Clean air	0.331	−0.213	**0.646**	0.097
Infection	**0.745**	−0.203	−0.449	0.327	Company	0.241	−0.231	**0.624**	0.228
Knowledge	**0.724**	−0.150	−0.229	0.504	Brain	0.485	−0.175	−0.513	**0.618**
Disseminate	**0.706**	−0.270	−0.220	0.250	Socio-economic	0.267	−0.038	−0.024	0.466
Cancer	**0.697**	−0.208	−0.488	0.391	Basic science	0.287	−0.229	−0.249	0.460
Security	**0.696**	0.354	0.103	−0.339	Underrepresented	0.181	−0.174	0.310	0.331
Domestic	**0.682**	0.033	0.279	−0.269	Reliable	0.421	0.495	0.487	0.311
Rural	**0.672**	−0.305	0.064	−0.111	Technology transfer	0.189	−0.241	0.456	0.148
Commerce	**0.662**	−0.258	0.315	−0.423	Global warming	0.030	−0.164	0.405	0.143
Equal	**0.657**	−0.123	0.403	−0.118	High performance	−0.035	0.220	0.057	0.135
Disease	**0.649**	−0.233	−0.466	0.479	Gender	0.498	0.070	−0.120	0.122
Understanding	**0.644**	0.464	−0.091	0.222	Advanced Science	0.105	0.025	0.207	.068
Market	**0.633**	−0.229	0.318	−0.093	Economic Competition	0.127	−0.003	0.117	0.020
Flu	**0.596**	−0.237	−0.309	0.233	Smallpox	0.044	−0.010	−0.112	0.018
Atmosphere	**0.580**	0.008	0.084	−0.493	MEMS	0.013	0.397	−0.032	0.017
Emergency	**0.551**	0.054	−0.076	−0.378	Forefront	0.137	0.035	−0.112	0.012
Oversight	**0.550**	0.467	0.067	−0.246	Greenhouse gas	0.246	−0.277	0.418	0.003
Discovery	**0.548**	−0.126	−0.385	0.286	Ethics	0.279	−0.168	−0.028	−0.045
Virus	**0.546**	−0.179	−0.287	0.226	Durable	0.403	−0.078	0.022	−0.125
Justice	**0.540**	−0.110	−0.055	−0.574	Waste	0.436	−0.075	0.360	−0.167
Decentralized	**0.532**	−0.068	−0.057	−0.459	Servicemen	0.219	0.076	−0.071	−0.170
Consumer	**0.528**	−0.409	0.484	−0.008	Toxic	0.401	−0.017	0.071	−0.219
Terror	**0.525**	0.433	−0.007	−0.385	EPA	0.172	−0.175	0.044	−0.229
Afford	**0.513**	0.302	0.187	−0.040	Homeland	0.354	0.282	−0.019	−0.311
Weapon	0.135	**0.908**	0.124	0.116	Climate Change	0.459	−0.289	0.210	−0.392
Military	0.237	**0.894**	0.112	0.048	**Eigenvalue**	**23.63**	**10.74**	**8.33**	**5.61**
Defense	0.192	**0.889**	0.116	0.051	**Variance explained**	**28.82**	**13.10**	**10.16**	**6.84**
Continued →					**Cum. variance explained**	**28.82**	**41.92**	**52.08**	**58.92**

Note: Boldfaced entries show which terms are associated with each factor (e.g., bolded entries in column 1 indicate terms associated with Factor 1).

fourth factor may represent an inefficient appeal to public sentiments or values in a policy system that does not benefit from the direction derived from an agenda affected by the Act.

These three supplemental factors are important, given that our rotation specification allows for some thematic overlap between individual factors. We are not surprised to find multiple interrelated sets of discourse that collectively characterize the nanotechnology research and development policy subsystem. Thus, our first factor can be seen as representing the varied primary public values invoked in this subsystem prior to the Act. At the same time, the second, third, and fourth factors highlight related sets of public values that may be invoked in support of the primary values or, equally likely, they represent secondary, tertiary, and quaternary sets of values. For example, issues of national security are invoked as a part of the primary factor. At the same time, they are the central feature of a secondary set of public values seen in the second factor. This factor focuses squarely on security. This could represent the dual role of national security pre-Act years in which it was both an independent policy issue as well as a major component of the growing nanotechnology discourse. It is important that we discuss this dynamic as it plays an important role in allowing us to compare the pre- and post-Act agenda setting dynamics.

The post-Act factor analysis results as shown in Table 5, conform to our expectations for highlighting a more refined policy agenda. This analysis contains three factors that each explain more than 5 percent of the variance and have eigenvalues greater than 1.0. Collectively, these factors explain about 47 percent of the total variance. This number is lower than that explained in the pre-Act analysis and can be attributed to the greater total number of policy documents in the post-Act data set. Like the pre-Act analysis, the first factor includes a variety of public values associated with the Act, including social justice and responsibility, advancement of fundamental knowledge, and economic competitiveness. This factor, termed the "primary value set," represents the most salient set of public values invoked within the context of this nanotechnology policy subsystem. Similarly, the second and third factors represent secondary (defense and security values) and tertiary (energy and commerce values) sets of related public values in the subsystem. These three factors together represent the agenda and policy image that is established by the Act.

Comparing the pre- and post-Act principal component analyses as shown in Table 6, we note several significant findings. First, the pre-Act analysis includes a fourth factor that has few, if any, salient public values. The post-Act analysis does not include this fourth factor. This is a welcome finding indicating the possible effectiveness of the Act in orienting the policy discourse toward a better defined set of public values. Second, the three factors in the post-Act analysis all have pre-Act counterparts. This finding confirms the expectation of a degree of public value continuity across time. Third, and perhaps most importantly, the content of the primary set of public values, those contained in the first factor, exhibits subtle changes in the post-Act discourse. These changes have important implications for our hypotheses. The number of terms loading at 0.5 or above in the first factor decreases from 39 to 26. This reduction in the number of terms loading in the first factor suggests a narrowing of the discourse around a specified set of value statements. Table 6 also shows the change in terms loading in the first factor in the pre- and post-Act analysis. It indicates which of the 15 pre-Act terms do not appear in the post-Act analysis. There are also two terms (i.e., "brain" and "smallpox") that are added to the post-Act analysis. The terms are clustered according to their broader sets of public values.

It is also important to note that the first factor in the pre-Act analysis includes terms related to national security and defense plus a secondary factor that contains essentially national security and defense terms. In the post-Act analysis, however, there are no national security or defense-related terms that load above 0.5 in the first factor. The second factor of the post-Act analysis, like the pre-Act analysis, is

Table 5. Post-Act Factor Analysis (82 key words, 1020 documents)

	Factors				Factors		
Terms (1–41)	1	2	3	Terms (42-end)	1	2	3
Progressive	**0.936**	−0.117	0.070	Renewable	0.054	0.266	**0.808**
Medical	**0.891**	−0.041	−0.201	Renewable energy	0.054	0.293	**0.804**
Access	**0.888**	0.097	−0.060	Greenhouse gas	0.075	0.251	**0.804**
Developing	**0.823**	0.221	0.205	Demand	0.333	0.274	**0.770**
Leadership	**0.815**	−0.470	−0.005	Technology transfer	0.050	0.103	**0.688**
Education	**0.777**	−0.429	0.034	Product	0.136	0.345	**0.639**
Training	**0.763**	0.004	−0.164	Market	0.330	0.317	**0.635**
Cancer	**0.754**	−0.571	−0.024	Supply and demand	0.073	0.107	**0.635**
Understanding	**0.754**	0.032	−0.117	Commerce	−0.022	0.162	**0.551**
Minority	**0.753**	−0.572	0.016	Company	0.033	0.141	0.466
Infection	**0.750**	−0.566	−0.024	Equal	0.435	0.436	0.463
Disease	**0.745**	−0.594	0.003	Waste	0.060	0.326	0.461
Community	**0.743**	−0.511	−0.004	Climate change	0.084	0.228	0.458
Disseminate	**0.735**	−0.186	0.230	Business	0.233	0.309	0.366
Hispanic	**0.705**	−0.397	0.235	Toxic	0.375	0.086	0.295
Brain	**0.696**	0.244	−0.206	Consumer	0.026	0.034	0.286
Knowledge	**0.684**	−0.325	0.161	Forefront	0.116	−0.140	0.187
Social	**0.671**	−0.549	−0.028	Global warming	−0.004	0.068	0.169
Gender	**0.655**	0.234	−0.149	Atmosphere	−0.008	0.031	0.158
Integrate	**0.618**	−0.047	0.002	Rural	0.241	−0.266	0.155
Native American	**0.609**	−0.521	0.068	High Performance	−0.043	0.083	0.139
African American	**0.607**	−0.548	−0.011	Underrepresented	0.049	−0.165	0.112
Domestic	**0.596**	0.434	0.181	EPA	−0.047	−0.015	0.082
Discovery	**0.558**	−0.469	0.122	Economic Competition	−0.077	−0.127	0.076
Smallpox	**0.530**	−0.385	−0.059	Durable	0.131	0.168	0.053
Legal	**0.517**	0.379	−0.121	Virus	0.408	−0.298	0.030
Defense	0.472	**0.748**	−0.348	Decentralized	0.201	−0.153	0.003
Military	0.480	**0.745**	−0.356	Socio-economic	0.118	−0.081	−0.007
DOD	0.474	**0.725**	−0.349	Advanced Science	−0.091	−0.028	−0.018
Wound	0.466	**0.702**	−0.334	Basic Research	0.411	−0.150	−0.054
Armed Forces	0.473	**0.659**	−0.284	Justice	0.045	0.075	−0.063
Reliable	0.465	**0.639**	0.119	Afford	0.270	0.414	−0.065
Modeling	0.249	**0.611**	−0.117	Flu	0.417	−0.281	−0.076
Security	0.413	**0.607**	−0.185	Basic Science	0.473	−0.171	−0.079
Terror	0.351	**0.602**	−0.351	Surveillance	0.108	0.050	−0.167
Attach	0.398	**0.593**	−0.331	MEMS	0.026	0.197	−0.178
Weapon	0.261	**0.578**	−0.179	Emergency	0.209	0.062	−0.187
Oversight	0.404	**0.572**	−0.254	Ethics	0.285	0.340	−0.197
Low-cost	0.240	**0.506**	0.078	Servicemen	0.169	0.354	−0.209
Soldier	0.223	**0.501**	−0.335	Homeland	0.198	0.330	−0.236
Efficiency	0.137	0.320	**0.836**	**Eigenvalue**	**17.61**	**11.86**	**8.97**
Clean air	0.104	0.265	**0.830**	**Variance explained**	**21.48**	**14.46**	**10.94**
Continued →				**Cum. variance explained**	**21.48**	**35.94**	**46.88**

Note: Boldfaced entries show which terms are associated with each factor (e.g., bolded entries in column 1 indicate terms associated with Factor 1).

laden with national security defense terms. This result could imply that the Act served to establish national security and defense-related nanotechnology public values as secondary to the varied and primary set of public values for nanotechnology research and development which include: social justice and responsibility, scientific progress and knowledge advancement, medicine and public health, and economic competitiveness and commerce. Alternatively, it can also be suggested that nanotechnology issues related to national defense were justified in civilian terms during this specific legislative time frame.

We are careful not to infer from this finding that national security and defense-related issues play a lesser role in the policy agenda of the post-Act era than they did

Table 6. Comparison of Terms in Factor 1 Including Lab, NSF, and Congressional Documents (n = 1020)

	Social Justice and Responsibility		Scientific Progress and Knowledge Advancement		Medicine and Public Health		Economic Competitiveness and Commerce		National Security and Defense	
Pre-Act (2000–2003)	Access	0.930	Developing	0.927	Medical	0.853	Leadership	0.849	Security*	0.696
	Community	0.871	Education	0.907	Infection	0.745	Business*	.0763	Emergency*	0.551
	Hispanic	0.868	Progressive	0.819	Cancer	0.697	Commerce*	0.662	Decentralized*	0.532
	Minority	0.855	Training	0.810	Disease	0.649	Market*	0.633	Terror*	0.525
	Social	0.790	Integrate	0.751	Flu*	0.596	Domestic	0.682		
	Native American	0.768	Knowledge	0.724	Virus*	0.546	Consumer*	0.528		
	African American	0.767	Disseminate	0.706						
	Legal	0.766	Understanding	0.644						
	Rural*	0.672	Discovery	0.548						
	Equal*	0.657								
	Oversight*	0.550								
	Justice*	0.540								
	Afford*	0.513								
Post-Act (2004–2008)	Access	0.888	Progressive	0.936	Medical	0.891	Leadership	0.815		
	Minority	0.753	Developing	0.823	Cancer	0.754	Domestic	0.596		
	Community	0.743	Education	0.777	Infection	0.750				
	Hispanic	0.705	Training	0.763	Disease	0.745				
	Social	0.671	Understanding	0.754	Brain†	0.696				
	Gender†	0.655	Knowledge	0.684	Smallpox†	0.530				
	Native American	0.609	Integrate	0.618						
	African American	0.607	Discovery	0.558						
	Legal	0.517	Disseminate	0.735						

*Indicates that this term does not appear in the post-Act analysis.
†Indicates that this term does not appear in the pre-Act analysis.

in the pre-Act era. This logic discredits the important role that national security and defense initiatives play in driving innovation in emerging technologies. Rather, we suggest that the Act created an agenda for the subsystem that more effectively specifies a space for defense and security-related public values discourse. This space continues to play an important role in the policy agenda. It alone accounts for over 14 percent of the variance explained in the post-Act policy discourse; this percent variance explained is slightly higher than it was in the pre-Act analysis.

These findings and others that indicate narrowing of the public values discourse in post-Act legislation can be viewed as evidence of a public values success or at least the absence of a public values failure. We suggest that the Act binds the policy discussion and that this is evidenced by less ambiguity about societal concerns for nanotechnology. This evidence supports our hypotheses. Our first hypothesis states that because the Act punctuates the nanotechnology policy subsystem, there will be an observable difference in factor structure of public value key words in pre- and post-Act policy discourse. Our second hypothesis states that because the Act provides an agenda and an image for the nanotechnology policy subsystem, the public value discourse in post-Act policy will be less ambiguous.

Conclusion

As expected, using classical policy analysis theory was helpful in framing our analysis of the quantification of public values for nanotechnology research and development. In terms of agenda setting theory, Kingdon (2002) notes that "out of the set of all conceivable subjects or problems to which officials could be paying attention, they do in fact seriously attend to some rather than others. So the agenda-setting process narrows this set of conceivable subjects to the set that actually becomes the focus of attention" (p. 3). This dynamic is manifest in our results where certain terms cluster in different ways and more closely in the public value discourse after the Act. Thus, the stability in public discourse on nanotechnology provided by the Act is a key finding of our research. The Act appears to establish an agenda for the nanotechnology policy subsystem that incorporates three interrelated groups of public values. Similarly, the artifacts of the Act presented an image that may also help narrow and focus the discourse (Baumgartner & Jones, 1993).

Policy subsystems exist in part to respond to particular public challenges, in this case, the research and development activities in the emerging field of nanotechnology. We argue that the Act established an agenda and policy image for the U.S. nanotechnology subsystem. This subsystem, in turn, focused attention on the complex challenges of this emerging technology. Still, it is difficult to evaluate the extent to which this constitutes an adequate government response to a modern complex problem like science policy and emerging technology research and development. Despite the remaining questions of science policy development, implementation, and analysis, these findings reflect positively on the capacity of lawmakers and the political process to perform at least one important task relevant to government responsiveness to modern challenges: the articulation of a set of values to be preserved or promoted with regard to a public issue.

We contend that this is an important analysis for policy makers who seek understanding of ways to avoid public values failure and policy analysis for noneconomic considerations (Bozeman, 2007), especially with respect to high-profile science policy subsystems like nanotechnology research and development. There are limitations associated with all quantitative analyses of PVM and this study is no different. Specifically, this approach observes discourse and not actual nanotechnology development activities. At the same time, it is reasonable to assume that the focus on documents from the NSF may not reflect the full spectrum of federal nanotechnology research and development initiatives. We view these questions as opportunities and directions for further inquiry.

Note

1. These data come from NanoPVM project at the Center for Nanotechnology in Society at Arizona State University (CNS-ASU; http://www.cns.asu.edu).

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