GOVERNING NEW TECHNOLOGY: A COMPARATIVE ANALYSIS OF

GOVERNMENT SUPPORT FOR NANOTECHNOLOGY IN THE

NETHERLANDS AND THE UNITED STATES

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ABSTRACT OF DISSERTATION
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ABSTRACT

Since the 1990s, the potential of nanotechnology has captured the attention of scientists, industry, and governments. Nanotechnology, a ‘general purpose’ technology, is seen as supporting possibly revolutionary breakthroughs in many different sectors, with ample economic and social rewards. Governments, confronted with a new technology that offers great potential benefits while posing as yet uncertain risks, have responded in diverse ways.

This study examines this variance in national government support for nanotechnology – its shape, size, and policy priorities – by comparing the United States and the Netherlands. Our operating hypothesis is that national government support for nanotechnology development is driven not by the intrinsic nature of the technology but by longstanding structural and institutional arrangements. That is, in the U.S., pluralist political traditions and reliance on classical liberal market economics would suggest a detached national government approach, leaving any initiative to market actors. At the same time, legacies of corporatism in the Dutch political system and a tradition of greater direct government involvement in the national economy would suggest a government-led policy on nanotechnology development.

The findings show otherwise. Early on, the U.S. government established the National Nanotechnology Initiative, an overarching federal mechanism to promote and coordinate nanotechnology development. Yet, despite its appearance of central
direction and coordination, the NNI reflected pluralist arrangements by leaving ample autonomy for participating federal departments and agencies. More of note, creation of the NNI was driven particularly by concerns of about foreign challenges to American global leadership in science and technology, leading its proponents to seek to better coordinate an expanding range of federally funded nanotechnology research activities and, ultimately, to spur greater federal funding for nanoscale research.

In the Netherlands, by contrast, the path taken shows the legacy of Dutch corporatist practice – slow, incremental, and embedded in pre-existing institutional arrangements. The Dutch government initially took no directive role, relying instead on established links among universities, public research funding organizations, and industries to advance nanotechnology development in the Netherlands. However, over time, Dutch government involvement in nanotechnology grew to be more supportive, sizeable, comprehensive, and directive – in particular by requiring substantial investments in risk-related research as a condition for public funding and, notably, by stated preference to embed Dutch efforts within in broader European policy frameworks.

Analysis of government support for nanotechnology in the United States and the Netherlands underscores the potency of longstanding structural and institutional arrangements. The findings also speak to the increasing importance of international and supranational institutions in shaping national policy directions. Overall, the findings broaden our insights into factors shaping government support for promising fields of
science and technology, opportunities for multi-level governance of their effects, and the extent to which convergence in national approaches is a realistic possibility. Given the greater complexity of emerging fields of science and technology, the ever-increasing global competitiveness of applying and commercializing scientific insights and technological advancements, and the rising costs of supporting science and technology development, how governments organize themselves to promote research and development – while also protecting public health and the environment – is an increasingly important question.
This research was supported in part by a National Science Foundation Nanotechnology Interdisciplinary Research Team award, “Nanotechnology in the Public Interest: Regulatory Challenges, Capacity, and Policy Recommendations” (SES #0609078), Christopher Bosso, principal investigator. The views expressed are those of the author.

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I gladly and greatly thank Jacqueline Mout – Leurs at the Dutch Ministry of Education, Culture, and Science, Tom van Teunenbroek at the Dutch Ministry of Infrastructure and the Environment, and Leon Gielgens at NanoNextNL. Their willingness to help me with this study during the last few years and their input was vital for the result.

At this point I need to evoke memories of my mother, whose resolute dislike of whining continues to counter my, at times, wavering work ethics, and I want to thank my father, whose gentle and caring disposition is an example for me. Last but never least, I want to thank Wiebe for his casual confidence in me. Our love is the foundation of my life.
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ABBREVIATIONS

AEC  Atomic Energy Commission
ANSI  American National Standards Institute
ARRA  2009 American Recovery and Reinvestment Act
AWT  *Raad van Advies voor het Wetenschaps- en Technologiebeleid*
  - Advisory Council for Science and Technology Policy
BNC  *Beoordeling Nieuwe Commissie Voorstellen -*
  - Intradepartmental Working Group to Assess New Commission Proposals
CASG oN  EU REACH Subgroup on Nanomaterials
CDA  Christian Democratic People’s Party
CEN  European Committee for Standardization
CERN  European Organization for Nuclear Research
CieMDN  *Commissie Maatschappelijke Dialoog Nanotechnologie*
  - Commission National Dialogue Nanotechnology
CIP  Competitiveness and Innovation Programs
CPSC  Consumer Product Safety Commission
DARPA  Defense Advanced Research Project Agency
DG  European Union Directorate General
DG Enterprise  Directorate General for Enterprise
DG ENV  Directorate General Environment
DG RTD  Directorate General Research and Innovation
DG SANCO  Directorate General for Health and Consumers
DHS  Department of Homeland Security
DOC  Department of Commerce
DOD  Department of Defense
DOE  Department of Energy
DOEd  Department of Education
DOI  Department of the Interior
DOJ  Department of Justice
DOL  Department of Labor
DOS  Department of State
DOT  Department of Transportation
DOTreas  Department of the Treasury
ECHA  European Chemicals Agency
EFSA  European Food Safety Authority
EHS  Environmental Health & Safety
ELI  Ministry of Economic Affairs, Agriculture, and Innovation
ELSI  Ethical, Legal & Social Issues
<table>
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<th>Abbreviation</th>
<th>Full Form</th>
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<tr>
<td>EPA</td>
<td>Environmental Protection Agency</td>
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<td>ERA</td>
<td>European Research Area</td>
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<td>ERC</td>
<td>European Research Council</td>
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<td>ETIPC</td>
<td>White House Emerging Technologies Interagency Policy Coordination Committee (under OSTP)</td>
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<tr>
<td>EU</td>
<td>European Union</td>
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<tr>
<td>FAO</td>
<td>United Nations Food and Agriculture Organization</td>
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<td>FDA</td>
<td>Food &amp; Drug Administration</td>
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<td>FES</td>
<td><em>Fonds Economische Structuurversterking</em> - Economic Reinforcement Fund</td>
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<td>FHWA</td>
<td>Federal Highway Administration (under DOT)</td>
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<td>FOM</td>
<td><em>Stichting voor Fundamenteel Onderzoek der Materie</em> - Foundation for Fundamental Research on Matter</td>
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<tr>
<td>FP</td>
<td>Framework Programme for Research and Technological Development</td>
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<td>FP7</td>
<td>7th Framework Programme for Research and Technological Development</td>
</tr>
<tr>
<td>FS</td>
<td>Forest Service (under USDA)</td>
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<tr>
<td>GIN</td>
<td>Global Issues in Nanotechnology Working Group (NNI)</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<tr>
<td>HTSM</td>
<td>High Tech Systems &amp; Materials cluster <em>Top Sectoren</em> Program</td>
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<td>IC</td>
<td>Intelligence Community</td>
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<td>ICON</td>
<td>International Council of Nanotechnology at Rice University</td>
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<td>ICT</td>
<td>Information and Communication Technology</td>
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<tr>
<td>ION</td>
<td><em>Interdepartementale werkgroep nanotechnologie</em> - Interdepartmental working group on nanotechnology</td>
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<tr>
<td>IM</td>
<td>Ministry of Infrastructure and the Environment</td>
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<td>IRGC</td>
<td>International Risk Governance Council</td>
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<tr>
<td>ISO</td>
<td>International Organization for Standardization</td>
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<tr>
<td>IWGN</td>
<td>Interagency Working Group on Nanoscale Science, Engineering, and Technology</td>
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<tr>
<td>KNAW</td>
<td><em>Koninklijke Nationale Academie van Wetenschappen</em> - Royal National Academy of Sciences</td>
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<td>LTI</td>
<td>Leading Technology Institute</td>
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<td>NACA</td>
<td>National Advisory Committee for Aeronautics</td>
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<td>NASA</td>
<td>National Aeronautics &amp; Space Administration</td>
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<tr>
<td>NATO</td>
<td>North Atlantic Treaty Organization</td>
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<tr>
<td>NBIC</td>
<td>Nano-, Bio-, Information-technology and Cognitive Sciences</td>
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<td>NEC</td>
<td>National Economic Council</td>
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<tr>
<td>NEHI</td>
<td>Nanotechnology Environmental &amp; Health Implications Working Group (NNI)</td>
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<td>NEN</td>
<td><em>Nederlands Normalisatie Instituut</em> - Netherlands Normalisation Institute</td>
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<td>Acronym</td>
<td>Full Form</td>
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<tr>
<td>SRA</td>
<td>Strategic Research Agenda Nanotechnology</td>
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<td>STTR</td>
<td>Small Business Technology Transfer</td>
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<tr>
<td>STW</td>
<td><em>Technologie Stichting STW</em> - Technology Foundation STW</td>
</tr>
<tr>
<td>TC</td>
<td>Technical Committee (ISO)</td>
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<tr>
<td>TNO</td>
<td>Netherlands Organization for Applied Research</td>
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<td>TSCA</td>
<td>Toxic Substance Control Act</td>
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<tr>
<td>UARC</td>
<td>University Affiliated Research Centers (under DOD)</td>
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<tr>
<td>USDA</td>
<td>Department of Agriculture</td>
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<tr>
<td>USGS</td>
<td>US Geological Survey (under DOI)</td>
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<tr>
<td>USITC</td>
<td>US International Trade Commission</td>
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<tr>
<td>USPTO</td>
<td>US Patent and Trademark Office</td>
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<tr>
<td>VVD</td>
<td>People's Party for Freedom and Democracy</td>
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<tr>
<td>WECF</td>
<td>Women of Europe for a Common Future</td>
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<tr>
<td>WETC</td>
<td>World Technology Evaluation Center</td>
</tr>
<tr>
<td>WHO</td>
<td>United Nations World Health Organization</td>
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<tr>
<td>WPN</td>
<td>Working Party on Nanotechnology (OECD)</td>
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<td>WPNM</td>
<td>Working Party on Manufactured Nanomaterials (OECD)</td>
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<tr>
<td>WRR</td>
<td><em>Wetenschappelijke Raad voor het Regeringsadvies</em> - Netherlands Scientific Council for Government Policy</td>
</tr>
<tr>
<td>WTO</td>
<td>World Trade Organization</td>
</tr>
<tr>
<td>ZWO</td>
<td><em>Nederlandse Organisatie voor Zuiver-Wetenschappelijk Onderzoek</em> - Netherlands Organization for Pure Scientific Research</td>
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Chapter 1 Contrasting Government Support for Nanotechnology: Comparing the Dutch and the United States Government Approach of Nanotechnology

1.1 How to Capture the Promise of Nanotechnology?

Since the 1990s research at the scale of 0.1 to 100 nanometers - a nanometer is $10^{-9}$ meter - has captured the attention of scientists, industry, and governments. The emerging broad and multi-disciplinary field of nanosciences and nanotechnologies, loosely defined as the capability to control, manipulate, and manufacture matter at the nanoscale, promises to transform many aspects of contemporary life. Nanotechnology\(^1\) is an enabling or a ‘general purpose’ technology, which scientists expect to support rapid radical and possibly revolutionary breakthroughs in numerous scientific directions (Youtie, 2008) (Palmberg, 2009). A study sponsored by the United States National Science Foundation foresaw as early as in 2001 the potential of global nanotechnology-related economic activity to reach $1$ trillion U.S. by 2015 (Roco & Bainbridge, 2001). Applications of nanotechnology, though still limited today, might bring huge societal and environmental returns, offering sustainable solutions for pressing global issues such as climate change, clean water, and a continuous energy supply, even as uncertainty remains about any possible long-term side effects of nanoscale engineering.

\(^1\) For practical reasons, this study uses the name ‘nanotechnology’ to identify the broad field of nanosciences and nanotechnologies, which includes both engineering at the nanoscale and the production and use of engineered nanomaterials or particles, such as suggested by the International Organisation for Standardisation (ISO): “Nanotechnology is the understanding and control of matter and processes at the nanoscale, typically, but not exclusively, below 100 nanometers in one or more dimensions where the onset of size-dependent phenomena usually enables novel applications” (International Organization for Standardization, 2011).
Given such great expectations, it is hardly remarkable that in the last fifteen years governments in highly industrialized countries and in developing countries alike recognized the possibilities of emerging nanotechnology as a potential catalyst of innovation and economic growth and as a possible solution for national and global challenges. Though the promises and the concerns of nanotechnology are the same to all and despite the relatively early stage of development of this broad field, even a bird’s eye view shows notable differences between programs initiated or sponsored by governments around the world.

Such various responses trigger the research questions that this study aims to address: What explains the variance of government responses when confronted with a new form of science and technology that offers great potential rewards combined with risks and remaining uncertainty such as nanotechnology? More specifically, why did the government of the United States establish a new federal initiative for the development of nanotechnology, proclaiming it the ‘Next Industrial Revolution’ (White House, 2000), while the government of the Netherlands, another highly developed country with a strong tradition of research and development in science and technology, chose to embed the support of nanotechnology research in existing institutional arrangements? How did the early establishment of the United States National Nanotechnology Initiative influence other governments to support nanotechnology research? As we notice these various government approaches to promote nanotechnology research, is one more
effective than the other? And what does this mean for other situations, other countries, or other promising fields of science and technology? Finally, especially given Dutch membership in the European Union, which international factors affect government’s decision-making?

This study addresses these questions in an aim to advance our understanding of how structural factors, such as pre-existing institutional arrangements for policymaking and a country’s relative position in the international system, help to explain the variety in the forms of government support for science and technology in societies that share a high level of political, economic, and social similarity. In addition, this study contributes to our knowledge of why and how national governments use international and in particular European multi-level governance of science and technology to compliment or substitute national policymaking. A comparison of government approaches to support nanotechnology gives us insights in the possible shape of future government action pertaining to other emerging scientific fields of great and far-ranging promise.

1.2 The Puzzle

Based on its long traditions of political pluralism and liberal market based economic system, one might expect that the government of the United States would tend to leave research and development of emerging multi-purpose technologies such as the broad field of nanotechnology to the dynamics of the market. One could suggest that the
Netherlands, relying on a more centralized coordinated market economic system and with political traditions of corporatism (Hall & Soskice, An Introduction to Varieties of Capitalism, 2001), would see a more coordinated government-led effort to support nanotechnology research and development.

We notice another outcome however. The federal government of the United States established a new centralized government-led program in 2001, the so-called National Nanotechnology Initiative (NNI), to coordinate efforts of federal departments and agencies in nanotechnology (National Science and Technology Council, 2000).

Conversely, the Dutch government started funding of nanoscale research projects through its regular research funding organizations in 2001 and left, to a great extend, the initiative to development Dutch nanotechnology knowledge and expertise to non-government actors. In more recent years the government undertook a more comprehensive and directive approach that responds to yet relies on industry – universities – research institutes collaborations: A more decentralized, bottom up path to promote nanotechnology development.

1.3 The Argument

This study seeks to understand the factors that drive government involvement in nanoscale research and development as a way to understand broader questions of national approaches to science and technology. To do so, this study compares the Dutch government support emerging nanotechnology with the coordinated
government-led program of the United States, the National Nanotechnology Initiative.

Such a comparison is designed to improve our understanding of the factors that explain varied forms of government involvement in science and technology in societies with many similar political, economic, and social characteristics.

The dependent variable in this study is government support for nanotechnology research in the United States and the Netherlands since the late 1990s, more specifically, the size and shape of the government efforts and the policy priorities and preferences set by these governments to promote nanotechnology development.

This study understands public policies and government involvement as all actions that a government takes in order to deal with a problem of public concern (Anderson, 1984). This interpretation of government support for nanotechnology goes beyond actual legislation and regulation. This study assesses policymaking in its totality: it includes for instance public deliberations or hearings and solicited or spontaneous advice by experts or advocacy networks such as a government science council or a trade organization. The definition of government involvement and public policy as used in this study also includes government decisions such as deferring action to other levels of government, like inter- or transnational regimes as well as the deliberations within such regimes. It also allows for deliberate non-action by governments on specific issues (Kraft, 2006).
This study poses several explanatory factors – or independent variables - to assess which have been most prominent in molding the United States and Dutch government approach to nanotechnology. In comparative studies of political economic outcomes, independent variables often are divided according to a theoretical trichotomy: explanations based on ideologies and cultural values, explanations based on institutional arrangements and structures, and explanations based on the direct interest and rewards for actors involved in the events that are the subject of study (Hall, 1997). The independent variables that appear to have shaped government involvement in the United States and the Netherlands most appear to be structural or institutional in nature: Traditions of governance and the institutional set up of policymaking; national challenges and national strengths – including the country’s position in the global system; overarching policy frameworks; and international collaboration and transnational governance. This study argues that alternative explanations of the variance in government support for nanotechnology, such as the intrinsic nature of nanotechnology or the vested interests of the actors involved in shaping government support for nanotechnology appear less instrumental in determining the outcome. The next chapter will elaborate on the different independent variables.

The operating hypothesis guiding this study is that national government promotion of nanotechnology development is driven not by the intrinsic nature of the technology but by longstanding structural and institutional arrangements.
This study argues that the wish to coordinate a range of federally funded research activities in the promising broad field of nanosciences and nanotechnology and the concern of being outpaced by government supported nanotechnology development in other countries threatening the United States’ global hegemony in science and technology, triggered the establishment of the National Nanotechnology Initiative (NNI) in the United States. The set up of the NNI, in which twenty-seven federal agencies and departments participate, is a variation on the practice of pluralist policymaking in the United States: it establishes a form of federal coordination, while allowing great autonomy to the participants. In the Netherlands, in a different position than the United States as a smaller country under the umbrella of the European Union and broader international cooperation treaties, such national government-led program to advance the Dutch global position did not emerge. Pre-existing relations between universities, public research funding organizations, and industry were able to promote nanotechnology development in the early years of the 2000s supported by government funding through traditional channels. Broader European governance early on established a framework for Dutch government support for nanotechnology development. However, in more recent years the Dutch government involvement in nanotechnology grew to become more sizeable, involved, and directive to support government’s policy principles and preferences in nanotechnology development: embedding of any policies and regulations in existing legislative frameworks and in harmonized European and broader international governance; attention for the risks, uncertainties, and consequences of nanotechnology; and a requirement of contribution
to publicly funded nanotechnology by Dutch industry. The government allocated additional new funds to nanoscale research.

1.4 The Cases

The global prominence of the United States is undisputed. Its position as the only remaining super power after the end of the Cold War, its premier position in the world economy, and its established frontrunner status in scientific inquiry and technological development, including nanotechnology, make the United States the ‘benchmark’ for the comparison of various government approaches to emerging nanotechnology. The choice of the Netherlands as a case for comparison needs more explanation.

As required in comparative research, the Netherlands and its benchmark in this research, the United States, have many characteristics in common: Both are highly developed, industrialized democracies, with successful and internationally oriented industrial sectors and established science and technology systems, including well-regarded universities and research institutes. Both countries enjoy high levels of gross domestic production (GDP) and individual (per capita) incomes. In either society education is important and a large percentage of the population has access to tertiary education (college) and advanced vocational and professional training. For multiple reasons, among them to ensure national security, to protect against natural disasters, and to spur economic growth, the governments in both the United States and the Netherlands have a long-standing tradition of involvement in science and technology.
Both governments have helped to build a significant institutional network to support scientific and technological progress, including nanotechnology. Scientists and engineers in both the United States and in the Netherlands pioneered in the field of nanosciences and –technologies, earning early recognition of the potential of their work. Industry in both countries has build up substantial positions in nanotechnology-related business.

Table 1.1 Bird’s eye comparison the Netherlands and the United States

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Netherlands</th>
<th>United States</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Political model</strong></td>
<td>Democracy</td>
<td>Democracy</td>
</tr>
<tr>
<td></td>
<td>Constitutional monarchy</td>
<td>Federal republic</td>
</tr>
<tr>
<td></td>
<td>Member of European Union</td>
<td></td>
</tr>
<tr>
<td><strong>Tradition of governance</strong></td>
<td>(neo)-Corporatism</td>
<td>Pluralism</td>
</tr>
<tr>
<td><strong>Economic model</strong></td>
<td>Coordinated market economy</td>
<td>Liberal market economy</td>
</tr>
<tr>
<td><strong>Globalization index</strong></td>
<td>Ranked 3rd most globalized</td>
<td>Ranked 27th most globalized</td>
</tr>
<tr>
<td>KOF globalization index 2010</td>
<td>(Swiss Institute of Technology Zurich, 2010)</td>
<td></td>
</tr>
<tr>
<td><strong>Public Spending on Science &amp; Technology (as % of GDP)</strong></td>
<td>0.76%</td>
<td>0.77%</td>
</tr>
<tr>
<td><strong>Population (2012)</strong></td>
<td>17 million</td>
<td>314 million</td>
</tr>
</tbody>
</table>

2 Economically the United States leads the world in the use of nanotechnology in applications and materials. Given the size of the economy, the Netherlands has a relatively strong position. Both societies continue to grow in this field (NanoNed, 2008) (Roco, 2007) (Lux Capital, 2003).
Compared to the United States, of course, the Netherlands is a small country with a small population. And though the Dutch economy is relatively large, it is modest in absolute size in comparison to the world’s largest players\(^3\).

As traditionally the United States and the Netherlands occupy very different positions in the global political and economic system, the Netherlands is a less obvious choice as a case in political or public policy research than, for instance, Germany or the United Kingdom. If ever, the German or British political and economic position in the world come closer to that of the United States than the position of the Dutch. However, the opportunity to examine the influence of the international positions of the United States, as a world leader in many ways, and the Netherlands, as a smaller yet very internationally oriented country embedded in the European Union, makes that this comparison gives a compelling new perspective on the research questions at hand.

1.5 This Study.

The events and outcomes that are the subjects of studies in political science often seem to be intangible and non-reproducible, so the generally accepted ‘scientific method’ of research\(^4\) is difficult to apply. In political science no case is exactly similar to another. However, when analyzing a single case, issues of generalizability of the findings arise.

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\(^3\) Reliable sources as the World Bank, the United Nations, and the OECD rank economies differently. The Dutch economy is approximately the world’s 20\(^{th}\) largest economy.

\(^4\) Science is the systematic gathering of knowledge, based on theoretical generalizations and tested through empirical observations. A systematic approach of research requires that any scientific findings are measurable, reproducible, and testable by other scientists (Pollock, 2005).
Thus comparing and analyzing multiple cases proves useful when trying to find answers as to why certain outcomes emerge. A comparison allows drawing conclusions on political outcomes by considering and contrasting, for instance, specific traditions of governance, political culture, and government authority. A comparative study may scrutinize different ways of policymaking and various manners of the institutional set up of policymaking and policy implementation, in order to conclude, for instance, whether different policy approaches lead to different policy outcomes, or whether outcomes in different cases are similar, regardless of the approach. Making comparisons and drawing analogies has proven to be an effective tool in studying social and political outcomes (Sandler, 2006).

This study uses a research design of most-similar systems (Przeworski & Teune, 1970) to compare the shape of government support for nanotechnology in the Netherlands with that of the U.S. government. In a most-similar system design one evaluates the variance of the value of a dependent variable - here the shape and size of government to promote nanotechnology - in cases that share a large number of common features. A comparison of different explanatory factors, or independent variables analyzes the variance in the dependent variable.

Ultimately, this research regards the national government – or, in case of the European Union, the European Commission - as the main actor when it comes to defining and implementing policies to support nanotechnology development. Yet this study also takes into account the role of other non-government actors like the emerging
nanotechnology industry, the scientific community, interest- and advocacy groups, and the general public.

The data on which the conclusions of this research are based come from extensive research of secondary and primary sources publicly available with regard to nanotechnology policies in the United States, the Netherlands, and the European Union. Where more clarification was needed, additional information was gathered through personal conversations and email exchanges with relevant civil servants and representatives of organized interest groups to elucidate the process of decision-making and the explicit and implicit motives behind the shape and format of the government approach of nanotechnology in the Netherlands. While the research focuses on a qualitative comparison of the government approach employed in the two countries, the comparison is, where relevant, supported by the analysis of available quantitative data, for instance, figures on government nanotechnology funding as a part of the total government R&D budget or compared to the national gross domestic product (GDP), and the size and growth of the nanotechnology industry since nanotechnology policies have been implemented.

Chapter 2 elaborates on factors that might explain variance in the shape and extend of government involvement in nanotechnology in the United States and the Netherlands.
Chapter 3 sets the comparative dimension of the study and provides an overview of the United States National Nanotechnology Initiative (NNI), its drivers, history, and results so far. It includes an overview of the current ‘nanotechnology’ landscape in the United States. As an overarching government initiative, the NNI covers almost all federal government involvement in the field of nanosciences and nanotechnologies. The chapter situates the NNI within broader traditions of governance in the United States. The main question to be addressed is whether the NNI as a government program can be considered a break with past practice and if so, why and how.

Chapters 4 and 5 present the case of the Netherlands. Chapter 4 gives an overview of traditions of governance and the institutional set up of policymaking in the Netherlands, looking especially at the historical legacy of Dutch support for science and technology. Chapter 5 moves on to describe the evolution of Dutch government involvement in nanosciences and -technologies starting from the late 1990s through the 2000s. Since a government-coordinated program for nanotechnology does not exist in the Netherlands, this chapter presents specific government actions – and reactions – to promote nanotechnology development. The chapter’s focus is on subsequent publicly funded collaborations between academia and industry supported by increasingly engaged government involvement in the emerging field of nanoscale research. A section of this chapter focuses specifically on the international dimensions of Dutch nanotechnology developments, including Dutch participation in and contributions to efforts made in this field within the European Union, the Organization for Economic
Cooperation and Development (OECD), and the International Organization for Standardization (ISO).

Chapter 6 concludes this study. It assesses the influence of each of the indicated explanatory factors on the shape of government support for nanotechnology research and development in the United States and the Netherlands. It contrasts the shape, weight, and influence of each of these factors on both cases to explain the variance observed, and elaborates on why possible alternative explanations seem less viable. The chapter also returns to the research questions that triggered this study, and tentatively reflects on additional questions: Was there a need for specific government action geared to nanotechnology? If so, does either the Dutch or American approach set an example for other emerging technologies? The preliminary answers to these questions present areas for further research.
Chapter 2 Explaining Government Support for Nanotechnology: Drivers of Science and Technology Policies

2.1 Overview

This study tests the hypothesis that government support for nanotechnology is driven not by the intrinsic nature of the technology but by longstanding structural and institutional arrangements. It does so by assessing a selection of explanatory factors to assess which have been most prominent in molding government support for nanotechnology in the U.S. and the Netherlands.

Figure 2.1 shows the conceptual framework of this study. It presents the independent variables of this study that help to explain the size and shape of government support for nanotechnology in the United States and the Netherlands thus far. In the case of the Netherlands, it adds the influence of its membership of the European Union.
This chapter clarifies in which way these explanatory factors are linked or related. One might argue that certain drivers are intermediate factors rather than direct causes. For example, we might evaluate national challenges as a catalyst for or driver of national strengths. Or we might see political culture as influencing the shape of the institutional set up of policymaking, resulting in certain policy formats.

2.2 Traditions of Governance and the Institutional Set Up of Policymaking

A range of established theoretical frameworks in comparative politics helps to explain political outcomes. Assessing how much cultural influences explain variance of political decisions, how the structural set up of the political process leads to specific results, or how direct interest of specific actors in the policymaking process determine
consequences may explain political outcomes (Lichbach, 1997) (Hall, The Role of Interests, Institutions, and Ideas in the Comparative Political Economy of Industrialized Nations, 1997). These frameworks might be conflicting or complementary, and are often used in combination, as a rigid application of a single framework often only allows for partial conclusions.

The subject of this research is the government support for nanotechnology - its size, shape, policy priorities, and governance preferences -, occurring over time in highly developed democratic societies in which many stakeholders are involved in established political procedures. Pre-existing political culture and established political institutional arrangements for policymaking are likely to have influenced why and how government support for nanotechnology took its shape.

**Political Cultural Explanations**

Culture is a ‘system of meaning’ which people use to assess their surroundings and society (Ross, 1997, p. 42). Culture evolves and is not static, yet it changes slowly, as values and traditions by definition are deeply rooted in society and in personal convictions. Culture frames the context in which politics occur, it sets priorities, and how things are done, (Ross, 1997) Political culture then is the common set of attitudes and assumptions that shape the political process (Almond, 1989) (Morone, 1996).
Defining a specific culture and pinpointing the influence of culture on political or societal outcomes and events is not a simple task. Scholars in political science often dismiss cultural explanations as subjective and unsatisfactory. For instance, aiming to explain German industriousness by referring to a common acceptance of values such as the merit of hard work and austerity based on principles put forward by Martin Luther, the German reformer who started the Protestant Reformation in the 16th century, falls short as the world has plenty of other examples of high productivity that take place in regions which lack a shared Protestant tradition (Shapin, 1988). As such, cultural references by themselves hardly ever have sufficient explanatory value to assess political outcomes. Yet, cultural traditions help to describe the context of the political process and policymaking, because the political culture in a society, in particular in democracies where people have direct influence in the political system, helps to shape the institutional set up of policymaking (Katznelson, 1997) (Almond, 1989).

The policymaking process consists of rules on how to make policies. For example, which stakeholders are involved, which are the subsequent steps of decision-making, and which actors will execute certain policies? These rules are the result of a larger political arrangement within which the different actors involved have accepted which rules will apply in the future and even how these rules might be changed. Such agreement is shaped by some kind of common understanding and common values, which define a political culture, or a tradition of governance, that represents ‘how things are done’ (Rothstein, 1996) (Skocpol, 1985) (Irwin, 2008).
Liberalism and pluralism define the political culture of the United States. Presumed shared values of American citizens such as individual freedom, equal opportunity, and political rights – such as the right to vote - are ingrained in the American political culture (Morone, 1996). Scholars often assume that the focus on individual rights weights less in, for instance, European or Asian societies and that, instead, in such societies political culture is presumed to attach more weight to collective rights and opportunities (Inglehart R., 1988). Traditions of consociationalism and corporatism, which encourage structured consultation of larger interest groups such as labor unions or trade associations in the political system, have a strong legacy in the Netherlands. Political culture influences political outcomes. Differences in political culture help to explain variance in government approaches of similar topics.

Institutional Arrangements

The concept of political culture supplies us with generic information about traditions of governance in certain societies, such as the cases at hand in this research, in which the policymaking process is embedded. The content of this common understanding such as political culture might differ between cases, leading to different traditions of governance, and a different institutional set up of the policymaking process and outcomes (Katznelson, 1997).

The public policymaking process includes what stakeholders chose to do and what not to do, when dealing with an issue of public concern (Kraft, 2006). The process covers
determining which issues should be on the policy agenda that any actors in the process want to address and which alternative approaches and solutions are available. It might include formal decisions on proposed policies and if so, it includes the implementation of such policies (Kingdon, 1995).

In any political system the policymaking process involves institutions. An institution is a set of “humanly devised constraints that shape human interaction” (North, 1990, p. 3) and comprises of “the rules of the game” (Rothstein, 1996, p. 145). Institutions have an important task in reducing uncertainty: after an institution takes shape, people become familiar with the rules and will know what to expect. An institution will reinforce its power through the force of repetition. Institutional arrangements such as the policymaking process itself are built according to governing traditions and often the result of a compromise between different actors involved (Campbell, 2010). Its function to create clarity, to reduce uncertainty, and to set the rules, makes it difficult to change an institution, unless all parties involved agree. For instance, in democracies the electoral system is an institution: there are, often written, rules and conventions to which participants in the process are bound and committed. Occasionally, a need may arise, at least with some participants, to change these rules and conventions. However, changing an electoral system appears to be complex; the winners of the last election, who were able to win under the existing rules, may feel little incentive to change the rules, as it may hurt their chances the next time.
In particular when dealing with rapidly evolving issues such as science and technology, resistance to change may lead to institutions appearing out-of-touch with their surroundings and not well equipped to deal with new developments. As previous compromises and decisions determine the shape of institutions, at times a path dependent pattern is noticeable. The notion of path dependence analyzes how current decision-making is constrained by earlier choices. Path dependence assumes that once a certain decision it taken -- for instance how an organization is set up or how a policy process is structured -- later decisions and actions will built on the previous ones. The costs and uncertainties of switching to an alternative or changing an already existing set up might be prohibitive for such a choice. A pattern of path dependence may lead to a situation of ‘lock-in’, in which reversal of direction or adaptation of institutions to new circumstances seems almost impossible. Such a situation may make institutional arrangements inefficient and ineffective (Arthur, 1994) (Campbell, 2010) (Cowan, 1991) (Hacker, 2002) (Pierson, 2000) (Pierson, 2004).

The structural or institutional approach to explain political outcomes looks at how the institutional configuration of the political process and policymaking shapes political outcomes (Thelen, 1992). Originally mainly limited to the legal and formal aspects of policymaking, ‘new’ institutionalism allows for a broader view of the policymaking process, including less formal actors such as advocacy groups, and the interactions between different actors in the process (Katznelson, 1997). There is quite a range of actors that participate in science and technology policies. Many are in formal roles in
the executive, legislative, and judicial branches of governments, while others reside in
publicly funded research organizations and advisory councils (Hamlett, 1991). Then
there is, increasingly, a role for social movements, industry and trade-organizations,
universities, research institutes, individual scientists etc. (Slaughter, 1996). It depends
on the organizational configuration whether and how such interests groups are allowed
to participate in the political process of policymaking (Skocpol, 1985).

It appears that differences in political culture and the institutionalization of how science
and technology policies are determined, implemented, and executed explain various
outcomes in science and technology policies (Elzinga, 1995). A recent comparative study
by Lepori and others (2007) for instance, presents variance between national research
policies of different countries even within the European Union. Lepori argues that
differences in historical and cultural institutional set up explain the shape of the
research policies and argues that sometimes a pattern of path dependence molds the
format of new policies and their implementation (Lepori, 2007). Hall (2001) argues that
different traditions of governance might lead to different outcomes even within similar
economic systems (Hall & Soskice, An Introduction to Varieties of Capitalism, 2001).
2.3 National Challenges and National Strengths

2.3.1 Challenges

A national challenge is a broad task or an issue that requires a comprehensive response from government, often in the form of a wider policy program. Such a national challenge might be specific for a country, for instance triggered by its specific geographical location, but might be a challenge that other countries face as well, such as poverty, illiteracy, improving public health, or economic underdevelopment. It may be events that are threats to national autonomy and security. Some challenges, such as climate change, are more international or global in nature. Others, such as geographical circumstances that lead to a scarcity of water, might be more localized. In case of global challenges, the consequences of the issue might be vary for different societies, thus requiring a more specific, national response. Sometimes acute national challenges trigger an immediate government response by means of science or technology: the Sputnik launch in 1957 by the Soviet Union threatened the U.S. supremacy in science and technology, or even its national security, and it accelerated the American space program (Audretsch, 1995), while widespread flooding in 1953 led to rapid, government funded, engineering breakthroughs for controlling water in the Netherlands (Bijker W. E., 2007). Yet, in general national challenges are more permanent and better foreseen than such sudden disasters or surprises. Governments are in a position to define the
challenges of the societies they govern and may be able to anticipate an adequate response.

As national challenges and the various possible responses to them often have large impact and wide consequences, these issues tend to shape the order of priorities of the public policy agenda, explaining why national and international priorities might differ (Hall & Soskice, An Introduction to Varieties of Capitalism, 2001). Three contemporary challenges in particular appear to have had impact on why and how governments support nanotechnology development: worldwide economic competition and international standing, public health, and environmental protection.

*Globalization and Economic Competition*

In particular since the end of the Cold War in the 1980s the United States emerged as the world’s sole superpower (Huntington, 1999). It’s military might, economic power, and prominence in science and technology are unrivaled. Maintaining such prominence remains an important challenge for the United States, however, with military tensions in the world subsiding after the collapse of the Soviet Union, new international challenges emerged: the quest to build up and maintain continuous economic development and growth has become a major challenge for most countries around the world, the United States included (Slaughter, 1996).
The accelerating effect of globalization - the ongoing increasing political, economic, and cultural interconnectedness of global society (Eriksen, 2007)- over the last couple of decades has lead to an increasing global competition, in particular from Asian countries (Branscomb L. M., 1998). The rise of China and other low-wage countries has changed the way the global economy produces and manufactures goods and services (Memedovic, 2009). Though economic competition always has been part of international relations, the ongoing shift poses a great challenge of established industrialized societies and emerging or underdeveloped countries as well. This explains why science and technology are increasingly prominent in international political economy: So-called ‘New Growth’ theory assumes that deliberate investment in an innovative science and technology environment - and an educational system to support that - creates knowledge and technology as a competitive tool for economic growth in particular in highly developed and industrialized societies such as the United States and most western European countries (Cozzens, 2008) (Bimber, 1995) (Rosenberg N. R., 1992) (Rosenberg N., 1982). Brought forward in the 1980s, this line of reasoning forms the basis of the idea that investing in knowledge and innovation is a successful response to challenging international economic competition.

As attention shifted from military challenges, and public financial allocations towards such challenges, at least relatively, have decreased, new questions arose on whether and how public money should be invested in more broadly described national
challenges, of which economic development is one (Branscomb L. M., 1998) and public health is another.

Public Health

Maintaining and improving public health has been a common challenge for societies around the world. Medical breakthroughs and advancing insights in particular since the late 19th century have only increased demand for better health care during the decades since. Rapid advancements in medical sciences and technology offer great opportunities to improve and lengthen human life, yet such progress comes at a cost, which makes state-of-the-art health services sometimes prohibitive for parts of society. Today access to and levels of health care are major challenges for societies around the world.

Access to health care links to another increasingly prominent challenge in high-developed societies: social inequality. Though apparently difficult to achieve and often the subject of an ideological debate\(^5\), in post-material societies - societies that have established a certain level of economic standing that allows for broad access to food, housing, and other goods and services deemed minimal necessities of life in most developed industrialized democracies (Inglehart & Abramson, 1994) -, citizens might be inclined to require higher levels of social equality: benefits progress and development should be accessible to as many as possible, while burdens should be limited and shared

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\(^5\) The public debate reflects on individual freedom: when, where, and how are constraints of individual freedom deemed acceptable by society?
by all. In a traditional utilitarian approach\(^6\), an important goal of government is to find the balance between the benefits and the potentials of scientific and technological progress with the risks and uncertainty that come along with ongoing scientific inquiry. It is in the realm of social equality that new challenges come with emerging sciences and technologies: ethical issues arise when scientific insights an technological might help only a few privileged individuals and/or have grave negative consequences for many. Such ethical consequences pose great challenges for societies today.

**Environmental Protection**

A last challenge that needs to be addressed in this chapter is environmental protection, as it is a common challenge to all countries in the world, though its form and implications might be very different for various societies. All human activity has consequences for the natural environment of mankind (Dasgupta et al, 2002). Increased economic development in recent decades clearly shows the environmental consequences of human behavior. As earth is mankind’s natural habitat, it is evident that it is a common interest, and thus a common challenge, to make sure that the natural environment is protected in such a way that continuity is safeguarded. Scientific and technological progress might help to diminish harmful effects of production and manufacturing (Branscomb & Young - Hwan, 1996).

\(^6\) The Principle of Utility: Maximizing an action’s utility or value (benefits), while minimizing its negative consequences – based on the argument of John Stuart Mill “Utilitarianism” (1863) (Mill, 2004) (Parsons, 1995).
Variable Responses to Challenges

Many challenges mentioned before, such as national security affairs and environmental issues, appear to be too large to be solved by single nations alone or require international collaboration for a more effective response (Keller, 1990) (Branscomb L. M., 1993). Differences between specific countries’ positions may influence how a country can and wants to respond to challenges it faces.

Because of its military and economic dominance the United States historically has been large and powerful enough to go its own way, often setting the direction of scientific, technological, industrial, and economic development for the world, and taking leadership roles in those international regimes it deems functional to its national interests, such as the North Atlantic Treaty Organization (NATO). And despite ongoing and increasing international engagement in the 20th century, the American political culture continues to display isolationist elements (Morone, 1996). Even in these times of globalization and accelerating international interconnectedness, one still finds calls to disengage the American political and economic system from the rest of the world (Tanenhaus, 2011).

By contrast, the small size of the Netherlands and its geographical location in the middle of Europe and on the North Sea shores historically forced international engagement. The Netherlands actively seeks international collaboration in numerous international organizations. It is protected under the broader shield of NATO and it is a founding
member of what has become the European Union (EU). NATO and EU, though very
different and each unique in institutional set up, scope and level of cooperation, and
pace of accomplishment, are illustrations of how single smaller states such as the
Netherlands may look for responses to national challenges in international
collaboration.

2.3.2 National Strengths

A strength is what one can do well, a certain skill or expertise one possesses. A strength
is sometimes a given advantage, such a population size or access to natural resources,
but is most often the result of effort, investment, and training. Building strength in
general is an incremental process, which requires time and patience. Such process might
be predetermined and directed, for instance by specific government action, or more or
less spontaneous, as a result of industrial competition and academic inquiry. A national
strength is an ability, which makes one superior to its competitors: an activity, an
opportunity, a quality, capacity, or capability in which a country excels⁷.

A national strength may lie in different realms of society, for instance within a certain
industry, within certain directions of academic research, or with certain individual
talents in a country. Yet, most likely, a perceived national strength is a form of co-

⁷ One can define national weaknesses as skills or expertise that a society lacks or shows
underperformance in comparison to its peers. If a perceived national weakness appears to be a driver of
science and technology policies in general, and nanotechnology government involvement specific, this
study sees such national weakness as a national challenge.
production between multiple partners and stakeholders. A national strength reflects a configuration of many activities, inputs, and conditions. For example, South Korea is widely credited for having built an exceptionally strong position in high tech manufacturing. This national strength builds on a combination of efforts and input from the technology industry, the educational system, and government involvement in the form of subsidies, tax-incentives, and research funding (Branscomb & Young - Hwan, 1996).

However, a national strength can also be a resource that is based on certain advantageous circumstances. A favorable geographical location, for instance in a temperate climate, with access to sea routes, or with plenty of fertile grounds for agriculture, often offers countries opportunities that other might lack. The presence of valued natural resources such as oil, natural gas, ore, or minerals, may put a country in good position. Such conditions, hardly a national strength but rather a form of national ‘luck’, help the shape the development of a society, its government, and its relative position among other countries.

A strong position in a certain field of expertise might be the result of a more autonomous process, in which random seemingly small inventions or scientific insights picked up by an innovative industry or an inquisitive academic environment might accelerate activity in a certain field of science or technology, often geographically concentrated in clusters of companies and research institutions, which build upon the
shared foundation (Shapira J. Y., 2008). Differences in intellectual traditions between societies might lead to different outcomes, establishing an ongoing growing tradition of a specific expertise and skills (Elzinga, 1995). An example of such development is the clustering of expertise in high tech firms and research institutes in the vicinity of Silicon Valley in California (Arthur, 1994). Scholars argue whether such clusters are still necessary in times of increasing interconnectedness, where geographical distances are easily overcome by real time and instant communication, yet, such agglomeration of expertise continues to promote competition, cooperation, and productivity, despite ongoing globalization (Porter, 1998). Technological or scientific clusters build on existing companies and academic specialization. Emerging technologies or scientific insights, such as nanotechnology, often get picked up within existing agglomerations, because science and technology is increasingly multi-disciplinary (Robinson, 2007). In this regard, established centers of scientific and technologies expertise, such as Boston or northern California in the United States or Twente and Delft in the Netherlands, have a large and deep concentration of academic institutions and knowledge intensive industries.

As observed earlier, the notion of path dependence offers insights into how policy-directions may be shaped by previous compromises and decisions, which re-enforce and continue a specific format or shape, in which reversal of direction or adaptation to new circumstances is difficult and costly (Pierson, 2000). The same might apply to the creation of specific strengths: once a certain cluster of expertise is established, it is efficient to use such concentration as a foundation for new endeavors. In such a case a
pattern of path dependence, often seen as constraining and limiting, might actually be helpful and productive. Technological and scientific clusters often reflect certain patterns of path dependence between new knowledge and institutions, which reinforce the build up of specific strengths. (Kuhlmann, Shapira, & Smits, 2010) (Ziman, 2003).

Specific pre-existing capabilities, abilities, and opportunities are the strengths of a society. Do such existing strengths help to shape the government approach of emerging nanotechnology? If so, why, and in which way, were such strengths influential?

2.4 Umbrella Policy Frameworks.

Public policies are actions governments take in order to deal with a problem of public concern (Anderson, 1984). As such, matters of public concern that deal with, among others, national security, economic development, social issues, ethical questions, and environmental protection have increasingly led governments to seek and implement policies that are either supported by scientific findings and technological means or are triggered by the (possible) side effects of science and technology. In the past fifty years in particular, growing government engagement in promoting science and technology has in turn driven the acceleration of developments in science and technology.

For technology, here loosely defined as a means to an end, government engagement is usually little controversial. A government sets itself goals and it might use technological
means to achieve those. It buys, for instance, security systems, weaponry, and means of transportation to support law enforcement. Government policies routinely rely on technological solutions or on combinations of ‘technological fixes’ and social steering of human behavior (Fisher, 1990).

Governments support science in the expectation that social and economic returns of research will advance the overall wellbeing of society (Slaughter, 1996). In a capitalist economic system market dynamics might lead to social inequities: some people can afford and thus benefit from better access to health care, education, or technology than others. Within certain ideological and political boundaries, governments tend to seek a proportional, more utilitarian approach to address societal concerns (Woodhouse, 2007). When social returns, such as health benefits or environmental protection exceed financial returns of research and development, or when results are uncertain, private industry might not invest in research. In such an event, governments may step in to support specific research. (Mowery, 1989) (Lepori, 2007).

Another aspect of policymaking with regard to science and technology pertains to governments’ need to mitigate the potentially harmful side effects that come with ongoing progress in science and technology. This sets a double mandate for governments: enable society to reap the benefits of scientific insights and technological inventions yet mitigate the drawbacks and risks associated with such breakthroughs. To prevent or at least minimize negative consequences that are deemed unacceptable, the
government might be forced, after new fields of science or applications of technology emerge, to respond to and, at times, constrain or regulate scientific advancements and technological inventions. This requires the careful balancing act of government, which defines what science and technology policies are about.

Taking into account national challenges, national strengths, and the role of government, this study looks at four overarching policy frameworks in which government involvement in nanotechnology is embedded: (1) Economic Development & Innovation Policy; (2) Education, Science, & Technology Policy; (3) Defense & National Security Policy; and (4) Risk Policy. This study understands a policy framework as a comprehensive set of policy recommendations, guidelines, procedures, rules, and laws on a certain topic such as national security or economic development. Such a set of policies is geared towards a common goal, for instance environmental protection.

As policymaking increasingly takes place in an international setting, this research addresses the dynamics of international policymaking for these policy frameworks and the consequences for domestic policymaking, which are discussed in following sections. These policy frameworks group policies together for argument’s sake. In reality policies often are linked or formulated in such a way that it is more difficult to categorize them. Depending on the institutional set up of a government, sets of policies such as economic policies may fall under a single department or ministry, yet other policies, for instance regulations regarding risks and dangers of certain activities, may be implemented by a
range of departments and government agencies. The fact that lawmakers sometimes
resort to formulate ‘comprehensive’ laws or regulations, which combine a range of
measures to achieve the goal of the policy, may create some confusion, when one aims
to categorize them under a single label or cluster. Thus, the four policy frameworks
presented here are mere representations of clustered policies, rather than
institutionalized and accepted formal categories.

2.4.1 Economic Development & Innovation Policy

Already in 1965 Shonfield argued that government intervention in capitalist economies
to spur and manage economic development, grow employment, and build a welfare
state had become commonplace in industrialized societies. (Shonfield, 1965). However,
arguably, governments in particular in highly developed countries have retrenched in
their control over the economic system somewhat since the 1980s and moved towards
a more neoliberal approach of support for market-based economic activity rather than
such more government-directed coordination of national economic systems.

Nevertheless stimulating economic development and creating financial security remains
an important task of governments (Levy, 2006). Citizens require their governments to
facilitate economic development as employment and subsequent income allow people
to afford the necessities of life like food and shelter, and, as societies continue to develop, many more products and services (Elzinga, 1995) (Lepori, 2007)\(^8\).

As mentioned, ‘New Growth’ economic theory assumes that deliberate government investment in science, technology, education, and innovation grows a knowledge-based economy, which uses innovation, information, and scientific and technological expertise as a competitive tool for economic growth (Rosenberg N., 1982) (Rosenberg N. R., 1992) (Bimber, 1995) (Cozzens, 2008). This theoretical frame forms the basis of the idea that investing in knowledge and innovation is a successful response to challenging international economic competition. Concern about international competitiveness has made innovation, developing and implementing new and improved ways – or finding new combinations of goods, services, and markets - to respond to social or economic demand (Schumpeter, 1961) (Mowery, 1989) (Arthur, 2009) (Kuhlmann, Shapira, & Smits, 2010) a priority in economic policies, with a focus on the continuation, renewal, and sustainable development of national economies (Arentsen, 2010). Innovation policies actually includes multiple policy areas which combine the development of human capital (education and training programs), the promotion and public funding of research and development, and the support for public - private collaboration to grow productivity and innovative capacity for increased competitiveness and accelerated

\(^8\) One may argue that economic development has also become a matter of national security (Inman, 1990), as national economies in our globalized system compete in the worldwide market for consumers and resources. High economic development and strong economic growth gives a country a position of power in the world. Economic weakness can threaten a country’s sovereignty and independence.
economic growth (Rammer, 2006). Economic and innovation policies often - quite controversially given the doctrine of free markets in the theory of capitalism - include government involvement in specific ‘desirable’ industries to create an environment for productivity, which influences the dynamics of supposedly free market competition.

This study compares two highly developed capitalist democracies. However, variations of capitalism occur: the United States, despite numerous examples of government intervention in the market dynamics of the American economic system, is generally considered a liberal market economy, in which the government aims to play a limited role. The Dutch economic system, with a tradition of structured consultations between the government and economic partners, is considered a coordinated market economy, in which the government plays a more active role in planning and directing the course of economic development (Esping-Andersen, 1990) (Hall & Soskice, 2001) (Ahlquist & Breunig, 2009). Such different government approaches of a market based economic system helps to explain differences in government support for science and technology that triggered the research questions of this study.

2.4.2 Education, Science, and Technology Policy

Science and technology policies create the climate for scientific and technological progress. Governments rely on an array of policy instruments, including offering grants and public funding to promising research funding, offering tax incentives for research &
development investments, facilitate education and skills – training, and creating a legal framework that fosters science and innovation, for instance by securing intellectual property rights and patents (Hamlett, 1991) (Kline, 1992) (Branscomb L. M., 1993). In addition, governments have developed a range of public research facilities and institutes to advance science and technology.

To overcome short-term return-on-investment goals of industry or high financial barriers, which seems unlikely to be paid back by future financial returns, governments around the world routinely invest in basic research, which may offer a wide range of applications (Branscomb & Parker, 1993). In addition, governments fund basic science reasoning that progress builds on small steps: common knowledge is the basis for specific use - for instance, we would have no electrical applications without general knowledge of electricity (Rosenberg N., 1994). Public support of technology, viewed as more applied than science - discussed in the next section - goes beyond the support of basic or fundamental science. Technology policy allocates public means to develop and support technological capabilities, which may have broad financial and societal returns.

The questions when, why, and how science or technology should be publicly supported are political: who decides which research received support, how much, for how long, and under which conditions. Such questions refers back to previous parts of this chapter: a multitude of challenges and goals, in the cultural, economic, political, environmental, national security, or public health realm of society, trigger public
involvement in science and technology. In recent decades saw science and technology policies increasingly becoming more thematic, less focused on supporting basic science, but more directing support to address specific targets deemed worthy of public backing (Rammer, 2006).

Government policies and public facilities help to cluster knowledge and expertise, (Hall & Soskice, 2001). Yet building particular strengths or capabilities is almost always a combination of government facilities, ambitious research institutions – public or private, independent, or linked to universities -, and innovative industry, supported by a strong educational system.

A society’s educational system educates and trains the country’s future scientists and workers. Societies seeking a competitive edge in today’s global economy increasingly rely on highly educated and skilled employees to spur the innovation needed to be maintain or grow a country’s economic position. Education policies form the basis of the educational system: They set the priorities, determine - at least in part - the curricula of school programs, arrange access for students, and proscribe levels of minimum achievements for students. Of course, as science advances, new information and requirements need to be included in the curricula (Roco M. C., 2001) (Roco M. C., 2005).

This study looks into whether and how pre-existing institutional arrangements for science, technology, and innovation policies in the United States and the Netherlands
have shaped the government support for nanotechnology and its policy preferences and priorities, and whether innovation in policymaking in this field has molded the way the government approached emerging nanotechnology.

2.4.3 Defense & National Security Policy

National Positions in the International Structure

Realist theory of international relations argues that states and their governments will use their power to expand and protect their national interests (Morgenthau, 2006) and that a state’s relative place in the world’s international structure defines a country’s opportunities to advance its national interests (Waltz, 1988).

Obviously the United States and the Netherlands occupy very different positions in the international structure of countries in the world. As argued before, since the end of the Cold War and the collapse of the Soviet Union, the United States is the world’s only remaining superpower. It is in its national interest to maintain and confirm its power and international influence, in particular times when other countries emerge as powerful competitors, which might challenge the American hegemony, either in military might, economic force, or science and technology leadership. One of its means is its dominant role in the North Atlantic Treaty Organization (NATO), which it established in 1949 together with Canada and western European countries, among them the Netherlands, was set up to provide security against threats of the Soviet Union.
(U.S. Department of State, 2013).

On the contrary, the Netherlands, as a much smaller country, takes a very different position in the world’s international structure. It aligned itself under the shelter of the NATO security umbrella bolstered by American military power in 1949 to ensure its national security and it joined in European integration early on to profit from further economic and political collaboration on the European continent, as it acknowledged that such collaborations offer better opportunity to advance Dutch interests than trying to push national interests on its own.

/Public Investment in Science and Technology for National Security/

Traditionally the most prominent policy framework that links to government support for science and technology, in particular in the United States, is matters of defense and national security. One of the most awesome examples of government involvement in science and technology is the concentrated effort made under the direction of governments during World War II to develop an atomic bomb. The U.S. endeavor, which came to be known under the name the Manhattan Project, succeeded in its task, supported by a public investment of some $2 billion – a current equivalent would be around $30 billion – by hiring the most prominent scientists, building some thirty research facilities, and employing up to 130,000 people to help develop the weapon (Mazuzan, 1984).

Despite relatively speaking declining armed conflict in the world since World War II
(Center for Systemic Peace, 2012), governments around the world continue to invest in scientific and technological solutions to address issues of defense and national security. Today the science and technology component of national security policies and defense-related public budgets remains substantive. This is most tellingly so in the United States, which allocates more than half of its annual science and technology budget to defense-related research (Office of Science and Technology Policies, 2012).

Maintaining national security remains very important. New threats to national security seem to emerge continuously. Think for instance about the possibility and occurrence of new phenomena like cyber attacks, where computers undermine the confidentiality, integrity, or availability of other computers or information on those computers, which, given today’s reliance on information technology, can cause major economic and societal disruptions (o'Shea, 2003).

An additional argument used to promote continuous public investment in defense and national security-related science and technology is the idea that investments in military research are not exclusive to defense and national security applications. There are many examples of spill-overs of information and expertise that flow from military use to civilian applications (Smit, 1995), for instance in the way that the findings of the Manhattan Project have led to civilian nuclear power plants that help to guarantee our energy supply or satellite navigation originally developed for military use that today is made available to civilians around the world, to name a few.
This study assesses whether and how pre-existing forms and arrangements for defense and national-security related public investments in science and technology have had an influence on the shape, size, and priorities of government support for nanotechnology in the United States and the Netherlands.

2.4.4 Risk Policy

All human activity, in particular economic activity, has consequences. For decades governments developed policies that address the environmental, health, and safety (EHS) consequences of such activity. In recent years governments, stimulated by an ever better-informed general public, include ethical, legal, and social issues (ELSI), when addressing the results and consequences of human activity.

Risk is the possibility of a harmful effect of human activity (RIVM, 2003). It includes notion of the probability of occurrence, the level of uncertainty about the risk, gravity of harm, and the size of harm. Increasingly it takes in more social aspects like the level of controversy associated with the risk, the effort needed to respond to risks, and the fact that certain activities may have different and higher risks for certain groups of people than for others (RIVM, 2003) (Aven, 2010). Conducting scientific research and developing and using technology, in particular new forms of science and technology, of which uncertainty remains about the long term effects and consequences, such as nanotechnology, come with risks and unknowns that require oversight and foresight.
Government policies or regulations that deal with risks include a notion of prevention, trying to limit any known dangers of activity, and a notion of precaution, trying to limit any uncertainty about the possible harmful effects of any human activity.

Regulation consists of a set of rules set by government to constrain certain activities and influence how actors behave with the aim to secure the well being of as many as possible (Blind, 2010). Contemporary government involvement in public matters often integrates a societal, health, and environmental risk component. Such components may be linked to all kinds of policies, not limited to a specific risk policy framework.

To avoid stifling innovation or constraining industrial entrepreneurship, government risk approaches tend to apply a principle of utility or proportionality that aims to balance potential benefits of certain activities with the costs of limiting their risks and reducing remaining uncertainty. Sometimes, certain activities come with such potential dangers that industry will not find sufficient incentive to engage in further research. Civilian nuclear power, for example, is a potentially abundant and cheap form of energy, yet safety concerns and the issue of managing radioactive waste made commercial exploitation of civilian nuclear power almost non viable and, as a result, heavily reliant on public funding.

However, balancing benefits and harms of science and technology may also create a paradox of innovation policy: some see regulations of any kinds as a hindrance of
innovation, as it constrains scientists and entrepreneurs. Yet, these same constraints may be a stimulus to innovate, as they create a necessity to work around them. The example of renewable energy comes to mind: regulations and limitations of relying on fossil fuels create an incentive to develop new forms of energy production, such as solar, wind, hydro, or geothermal electricity plants (Blind, 2010).

Traditions of governance and varieties of economic systems may have led to different government approaches on how to approach the risks and uncertainties to come with any human endeavor. There are noticeable differences in the regulatory approach of risks between the United States and the European Union. Vogel (2012) argues that those differences can be explained the cultural differences – the United States being more an individualist society, while the European Union might be more collectivist -, the influence of business interests on policymaking, and whether political actors unite behind a cause - as for instance environmental protection, as many political parties in the European Union do - or divide over an issue, such as is common in the two-party system in the United States.

This research addresses why and how governments priorities with regard to dealing with risks and uncertainties associated with nanotechnology have shaped the government support for nanotechnology development.
Public Health

Obviously the policy frameworks that are most likely to encompass government involvement in nanotechnology are closely related to challenges and tasks or goals that governments see themselves confronted with. Maintaining and improving public health is a constant challenge for governments, reinforced by strong public demand and expectation. Nanotechnology offers great promises in the medical field. A healthy population tends to be productive and prosperous. At the same time, such an emerging scientific field may bring unforeseen side effects that have negative consequences for human health. Mitigating these effects links to risk regulations. In the field of public health both benefits and harms are addressed. As such science and technology in the medical field attract attention from policy makers, scientists and experts, health care suppliers, pharmaceutical and medical appliances industry, patients, and the general public alike.

2.4.5 International Embedding of Policymaking

As member of the European Union (EU), Dutch policymaking and implementation is increasingly influenced by and framed within European laws and programs. As such, representatives of Dutch government agencies, as well as staff of Dutch companies, research institutions, interest groups, and universities participate in a wide range of European collaborations in science, technology, and policymaking in general, including activities in field of nanosciences and -technologies. Interactions between the EU and
the Dutch levels of governance are thus taken into account given the embedding of Dutch domestic policies within the larger frame of the European Union.

In addition to its European engagements, Dutch actors in nanotechnology policies take part in different international organizations that address the consequences and possibilities of nanotechnology. In today’s internationally interconnected world, an exclusive focus on the arrangements of domestic policymaking would yield insufficient explanatory value. Any assessment needs to take into account the international context and the extent to which domestic policy is shaped by national government participation in wider international policy settings. In this regard, there are multiple international organizations that in one way or another deal with the consequences of emerging nanosciences and technologies, including the World Trade Organization (WTO) and United Nations Educational, Scientific, and Cultural Organization (UNESCO). However, the most prominent and influential international collaborative platforms are the two working parties established by the Organization for Economic Cooperation and Development (OECD) - the Working Party on Nanotechnology (WPN) and the Working Party on Manufactured Nanomaterials (WPMN) (Organisation for Economic Co-operation and Development, 2011) - and the International Organization for Standardization (ISO). Both the United States and the Netherlands contribute to the nanotechnology-related activities of these organizations. This research therefore focuses on the OECD and ISO when assessing the influence of international regimes on
the shape of domestic policies on the development of nanotechnology in the United States and the Netherlands.

These international regimes work based on an internationally set agenda of issues (Elzinga, 1995). The main focus of international collaboration appears to be how to address the risks and remaining uncertainties associated with nanotechnology. Closing the gaps of information requires a large investment of time and money, too large for some smaller countries to carry by themselves. Identifying and assessing the risks of nanotechnology is in the interest of the international community, as it will create a common foundation for commercial application around the globe.

Like in the United States, risk-related research in the European Union is only a part of the whole public investment in research and development. The European Commission strongly supports scientific research through its successive framework programs (FPs), which supply financial support for research and foster European cooperation. The so-called European Research Area (ERA) aims to be a single market for research and education in Europe. In addition, the European Union increasingly supports innovation by European industry through grants and by offering facilities to consortia of industry and research institutes. The EU’s ambitious Horizon 2020 program, which includes the next installment of the framework program, envisions the European Union as a so-called ‘innovation union’, leveraging the national efforts of the member states with the
strength of the combined European capacity in research and development (European Commission, 2011) (European Commission, 2012).

*Multi-level Governance*

It is important to note that the influence of international organizations on the involvement and domestic public policies of national governments is not limited to top down directives. Finding agreement between the different members and representatives is a political process in itself, in which the different members, representatives, and other stakeholders participate (Hooghe & Marks, 2001) (Buthe, 2010). It includes defining the problem, getting it on the agenda, weighing different opinions, choosing the most appropriate alternative, and communicating such outcomes (Prakesh, 2010). Representatives of the member countries of the European Union and European policymakers co-produce the European legal and regulatory framework. This study understands co-production as a deliberate act of cooperation between those impacted by proposed matters of governance (here the members states) and the governing institution (in this case the European Union) to shape certain policies (Brandsen & Pestoff, 2006). This gives member countries opportunities to influence European policymaking and –implementation from the bottom up.

Such multi-level policymaking is not unique to the European Union. Within the OECD and the International Organization for Standardization such forms of co-production are even stronger, as, unlike the European Union, which is backed up by formal treaties,
these organizations works on a voluntary basis of consensus. It is the dynamics between the different members or representatives, and of course which views they bring to the negotiation table, and which conclusions they draw, which are highly influential in shaping the outcomes and the success of such trans- and international deliberations (Prakesh, 2010).

As members of the European Union such as the Netherlands, actively contribute to decision-making in the OECD and ISO, increasingly harmonization of policies and recommendations takes place between the different regimes. The case studies presented in the following chapters will reflect on the participation of both the United States and the Netherlands in these international regimes and how it shapes the overall government support of emerging nanotechnology.

2.5 The Intrinsic Nature of Nanotechnology

Regardless who instigates advances of science or the accelerating progression of technology, such progress always demands a government response, as science and technology take place in society and thus have economic, social, and political consequences (Kitcher, 2007). As such, the specific nature of nanotechnology might mold the format of nanotechnology policies.
Nanotechnology is the ability to control and manipulate matter at the nanoscale. Such ability makes it possible to take advantage of specific, often new and sometimes unknown, properties of well known materials like silver or carbon: nanomaterials might be stronger, have higher conductive qualities, or resist bacteria better than the same materials in a larger form. Already nanomaterials are used to improve existing materials, for instance mixing certain ceramics used for the electricity-insulating properties with graphene (nanoscale carbon) to strengthen the material (Economist, 2011) or adding nano-titanium oxide to sunscreens to more effectively block harmful ultraviolet sunrays.

Working at this small a scale, traditional boundaries between sciences as chemistry, physics, and biology merge (Lux Capital, 2003). The identification ‘nanosciences and nanotechnologies’ implies a catch all label of a wide range of activities: conducting research in several previously more or less separated sciences and developing and using different technologies. The broad field of nanosciences and nanotechnologies, which this study labels nanotechnology, increasingly appears to be an enabling or a ‘general purpose’ technology, which might support rapid, radical, and possibly revolutionary breakthroughs in numerous scientific directions (Youtie, 2008) (Palmberg, 2009). For instance, major impact is expected in medicine, where, as far back as in 1960, the physicist Richard Feynman foresaw possibility to “swallow the surgeon” in the form of very small machines able to look around in the hearts and blood vessels of patients (Feynman, 1960 p. 30). Other examples of nanoscale applications include nano-sized transistors that allow for continuously powered-up computers which are smaller and
work faster and longer (Economist, 2011) and a micro-chip sized device that splits salts and viruses from water through a polymer membrane and directs them to different nano-channels in order to desalinate sea water (Chandler, 2010).

However, these promises might have side effects and consequences yet unknown. At this point much uncertainty remains about the environmental, health, and safety (EHS) risks of nanotechnology. While nanotechnology offers plenty of opportunities, risk-related research is seen by many as a necessary condition for the responsible development of nanotechnology.

**Determinism**

Scholars hold different opinions on the nature of science and technology, and its advance. The notion of scientific or technological determinism assumes that such developments take place independently of society in an autonomous process. Such a strict (or hard) interpretation of determinism sees scientific and technological development as an autonomous force independent of social constraints. Proponents of hard determinism take a pessimistic view arguing that moral human progress is overtaken by material power: Technology goes beyond human control and might lead to an increasingly totalitarian regime of technocrats (Winner, 1977) (Smith, 1994).

Such a view is not widely accepted in today’s discourse, but it remains fascinating:

Sometimes certain politicians and even scientists use hard deterministic views to draw a
doom scenario of a society ruled by machines rather than people. In his influential work *Engines of Creation*, Eric Drexler introduces the notion of ‘grey goo’, self-replicating nanoscale robots might destroy earth (Drexler E. K., 1990). Building on such fears of out-of-control nanotechnology, scientist and captain of industry Bill Joy (in)famously pleaded for a moratorium of nanotechnology in 2000 (Joy, 2000). This argument was rebutted by more techno-optimistic scientist Ray Kurzweil, arguing that while emerging science and technologies come with uncertainties, proposing a moratorium was ignorant, as these insights already exists and the knowledge is spread (Kurzweil, 2001). Yet, Kurzweil argued, people are in a position to influence the course and the pace of development of science and technology and such would be the opportunity with nanotechnology as well.

Kurzweil’s argument is a soft-determinist approach: The notion of soft determinism sees scientific progress and technological development as a driver of societal change, but it allows for human intervention in order to be able to respond to social pressures and social requests (Smith, 1994) (Wyatt, 2008). Consider the following examples: The industrial revolution or the transformation caused by information technology are powerful events, following a seemingly path-dependent autonomous course, yet society has been able to influence such advancements to its benefit (Mokyr, 1990). The soft approach is a more optimistic take of scientific and technological determinism: Soft determinism sees science and technology as means to achieve higher social, economic,
and political ends: growing prosperity leads to a stable economy, which helps to stabilize society and the political systems.

The general notion that technological trajectories are predetermined and inevitable is often contradicted by examples that show that science and technology are part of a broader social, economic, political context, which influences the trajectory of development (Bijker W. E., 1992). That leaves a more soft approach of scientific and technological determinism or a lens of social constructivism to assess the relation between science and technology with society as more viable.

This leads to questions on how the specific nature of nanotechnology shapes the government support for nanoscale research. Are their specific factors about nanotechnology that mold the government response? Does progress in the field seem inevitable, irreversible, unethical, or dangerous? How do the risks and remaining uncertainties of nanotechnology influence policy priority setting? Are such risks and uncertainty unique for nanotechnology? How does the enabling aspect of nanotechnology shape government support? And is such notion of general purpose specific for nanotechnology?
2.6 Conclusion

This chapter provides a conceptual overview of the factors that help to explain the variance of government support for nanotechnology in the United States and the Netherlands since the late 1990s. The next several chapters describe such government support, its size and shape, national policy preferences and priorities, and forms of international engagement and embedding.
Chapter 3   The U.S. Case: Traditions of Pluralism – Federal Initiative for Nanotechnology

3.1 Introduction

This study aims to explain the observed variance of government support for nanotechnology in the United States and the Netherlands and draw broader insights about how policies for emerging fields of science and technology are shaped. The hypothesis of this study assumes that not the intrinsic nature of the technology but longstanding structural and institutional arrangements shape the national government support for nanotechnology.

In the United States, pluralist political traditions and reliance on classical liberal market economics would suggest a detached national government approach, leaving initiative to market actors. However, early on, the U.S. government established the National Nanotechnology Initiative (NNI), a centralized overarching federal mechanism to promote nanotechnology research in the United States. Creation of the NNI was driven particularly by the desire to find some coordination of a widening range of federally funded research activities in promising nanotechnology, combined with concerns of being outpaced by government supported nanotechnology development in other countries, which would threaten the strong American position on the forefront of science and technology.
The main reason to choose the United States as such a benchmark is the global prominence of American science. Its scope and scale is unparalleled in the world (Greenberg, 2001). And, as in many other fields of science and technology, the U.S. is the world’s leader in nanotechnology.

Different indicators stress the strong American position in nanotechnology in comparison with other countries, such as the timing and the size of government support, the number of citations and references of American academic work, the number of patents filed by U.S. companies and scientists, and the size and number of companies involved in nanotechnology (Hwang, 2010) (Palmberg, 2009). Research by Hwang (2010) ranks countries on these different indicators, clearly putting the United States on top, but indicates, as other researchers do, that other countries are catching up (Motoyama, 2011) (Palmberg, 2009).

The number of citations is an indicator of the strength and diffusion of original research. Based in the continuous Science Citation Index⁹, the number of citations of American research was strong in the earlier phases of nanotechnology development in the 1990s, over 40% of the total number of citations. Today the U.S still leads in an absolute sense, yet relatively declines as other countries, notably China, pick up the pace by adding

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⁹ As referred in the Nanotechnology Policy Primer (Sargent Jr., 2011): See http://thomsonreuters.com/products_services/science/science_products/a-z/science_citation_index/
higher number of scientists and by participating at higher levels in peer-reviewed (and thus citation-generating) research (National Science Board, 2010) (Sargent Jr., 2011).

Patents show the strength and diffusion of inventions and applications. A filed (and accepted) patent assigns the property right of an invention to the filer (United States Patent and Trademark Office, 2012). American inventors (being individuals, but mostly on behalf of universities and companies) have filed by far the most nanotechnology-related patents. The United States is closely followed by Japan (Eloshway, 2007) (Sargent Jr., 2011).

The U.S. National Nanotechnology Initiative (NNI) is the first and largest program of its kind in the world (Roco M. C., 2007). This major early commitment by the American government to support nanotechnology accelerated the general interest in this field of science and technology. It spurred activity in academic circles, drew the attention of relevant industry for nanotechnology, and established a precedent and example for governments around the world to create programs to stimulate nanotechnology (Lane, 2005). Since the start of the NNI, nanotechnology development is increasingly ‘globalized’ with strong positions for countries such as Japan, China, Russia, South Korea, and Taiwan (Roco M. C., 2001). Today at least sixty governments have created some kind of nanotechnology program but no government has established a program similar in set up, scope, and governmental embedding such as the NNI (Roco M. C.,
2007). The U.S. is still in the lead, but distance gets smaller because of other countries’ investments and efforts (Cientifica, 2011)

As the role of nanotechnology as part of commercial industry is still relatively young, comprehensive economic data are hard to find. Statistics gathered by commercial research and consulting companies such as Lux Research\textsuperscript{10} and Cientifica\textsuperscript{11} tend to be based on estimates. For example, Lux Research estimated in 2008 that the United States accounted for approximately 36% of total worldwide public and private investment in nanotechnology R&D (Sargent Jr., 2011). Private investment in nanotechnology is also the largest in the United States, followed, by Japan (Sargent Jr., 2011). Moreover, it is estimated that up to 60% of all companies involved in nanotechnology are located in the United States, accounting for 80% of the total value of products that contain a manufactured nanoscale component. The overall market value of the global nanotechnology sector is estimated to be around $1 trillion in 2015 (Roco M. C., 2011)

This study compares the Dutch government approach to nanotechnology research and development with that of the United States. As such, it maintains its main focus on U.S. national government involvement in nanotechnology, where most, but definitely not all, government action takes place, and mainly under the umbrella of the National Nanotechnology Initiative. Later in this chapter we will examine examples of state and

\textsuperscript{10} See www.luxresearchinc.com
\textsuperscript{11} See www.cientifica.com
local government involvement in nanotechnology development, the primary unit of analysis is at the national government level.

3.2 Traditions of U.S. government Involvement in Science and Technology

In Chapter 2 we noted that America’s political culture is commonly understood to be rooted in classical liberalism, based on shared values of individual rights and equal opportunity (Morone, 1996). Kraemer argues that the American political and economic system is comparatively ‘open,’ and enables participation based on individual interests and abilities (Kraemer, 2006). The dominant U.S. political – economic ideology, with its origins in Enlightenment period notions of human nature, is founded to a degree on Adam Smith’s ideas of the centrality of private property, free markets, minimal government involvement, and a decentralized, pragmatic ‘laissez-faire’ approach where market demand and supply drive economic growth (Smith A., 1991) (Kraemer, 2006). This approach requires a political culture that embraces transparency and accountability, allowing a pluralist approach of decision-making in which different competing and contrasting views are included (Kraemer, 2006).

By definition, all forms of democracy are pluralist in nature, enabling different voices to play a role in deciding matters of policy (Dahl, 1967). Even so, from its foundation, the American political system, more than counterparts in Europe, is based on pluralist principles in which many more or less independent organized ‘interests’ exist within the
state, with none able to dominate the political system easily, or for very long (Dahl, 1982). These groups all seek access to government and aim to influence policymaking for their own self-interests (Baskin, 1970). How successful interests groups, for instance industry or the scientific community, are in influencing government policies depends on their access to decision-makers and by their relative resources, skills, time, and capacity to support their efforts to shape policies to their advantage (Dahl, 1967). Americans have come to see the pluralist, at times contentious, nature of American politics as normal, even attractive, as it links to classical liberalism, individual freedom, and the ability to choose, as opposed to the tendency to focus on order and consensus seeking, which may characterize European politics (Baskin, 1970).

However, as argued before, political culture may evolve over time. It is not static (Morone, 1996). When reviewing government involvement in science and technology in the United States since World War II, it is hard to conclude that principles relying solely on market forces and limited government are always honored, nor do different interests groups always entertain different opinions on matters of policy. In this regard, it should be noted that the American government has a long tradition of direct and indirect involvement in science, technology, and innovation. For example, the U.S. Constitution, written in 1787, explicitly gives Congress the power to grant patents to promote innovation in both science and the “useful arts” (Article 1, Section 8). In general, U.S. government promotion of science and technology has continuously expanded over time, often with bipartisan support, based on consensus views that advances in
scientific knowledge bring widespread societal benefits, chief among them economic growth (Greenberg, 2001). Despite such consensus, private industry is not always in a position to play a leading role, either because of the degree of risk involved or because of the private sector’s tendency to think in the short term (Teitelman, 1994). As a result, despite a broader political culture rooted in ‘laissez-faire’ principles (Feldman & Zaller, 1992) (Dobbin, 1994), the government of the United States has developed over time an expanding frame of science and technology policies, which balance promotion and support of science and technology with regulation of (negative) side effects (Smith L. R., 1990) (Peckerar, 2004).

Scholars generally agree on three phases on science and technology policies in the United States since World War II: The war period in the 1940s and the technological optimism of the 1950s; the more critical assessments of science and technology during the 1960s and the 1970s; and, since the 1980s, a general return to optimism, albeit less unquestioning than before, and focus on innovation as a key to economic growth (Smith L. R., 1990).

Since World War II

Prior to World War II, science and technology development in the U.S. generally fell in the realm of the laboratories of private industry and in the nation’s universities. In those years the government’s involvement was mainly limited to setting standards and protecting patents (Smith L. R., 1990) and investments in military technology. Then, with
the advent of World War II, the federal government clearly looked to science and technology as an answer to military challenges and public funding of military related research rapidly accelerated. By setting up the Manhattan Project, the deliberate government-led effort to develop an atomic bomb, a new phase of science and technology policies emerged, with the U.S. government taking over from private industry the role of main sponsor of basic research (Teitelman, 1994).

During the war years, science and technology policy was more or less industrial policy and contracts for the military were the main form of government involvement. The end of the war stimulated optimism about the possibilities of science and technology and the opportunities of accessible education, yet peace demanded a civilian application of science and technology (Smith L. R., 1990). Questions arose of what to do with the available military research and development expertise, the public research facilities, and the education of new scientists and engineers (Kraemer, 2006).

At President Roosevelt’s request, such a proposal was put forward by his science advisor Vannevar Bush, in the previously mentioned report ‘Science: The Endless Frontier’ (Bush, 1945). In the report Bush laid out the foundation of American science and technology policies and institutions we still know it today. However, the initial proposal was much more science oriented than the ultimate layout came out to be (Kraemer, 2006). After a long political struggle, which pitched proponents of a ‘closed’ scientist-led, basic research oriented organization against promoters of a less powerful, more
accessible institute that also funded research more applied towards societal needs (Kleinman, 1994) (Kraemer, 2006), Congress in 1950 established the National Science Foundation as an independent federal agency to promote science, public health, prosperity and national defense by funding basic science (National Science Foundation, 2012), yet with more political oversight and less exclusivity than Bush’s original proposal suggested.

The National Science Foundation (NSF) is the main research funding organization (RFO) in the United States. Even so, it only allocates approximately 20% of the total federally sponsored research. The larger administrative government system, steeped as it is pluralist principles of decentralization, allows many other government organizations to fund research and development within their field of activities (Kleinman, 1995) (National Science Foundation, 2012). This being said, NSF funding differed from funding through other agencies and departments as it reviews grants submitted by scientists and scholars directly and on a competitive basis, with peer review, whereas other agencies tended to rely on research assignments which were contracted out. Because of the delay of the establishment of the NSF after World War II, many other federal agencies and departments, as well as universities, had already increased their research funding, a situation which seemed irreversible once the NSF was established (Kleinman, 1994).

Given the circumstances, the government set up different other agencies to deal with the legacy of science and technology for military causes. Take the example of the
Atomic Energy Commission (AEC), the predecessor of today’s Nuclear Regulatory Commission. The wartime Manhattan project greatly advanced nuclear physics. Yet its focus on nuclear weaponry, while relevant given the growing Cold War tension with the Soviet Union and even today, seemed less appropriate in times of peace, in particular as nuclear physics was promising in other fields, for instance the idea of abundant energy. To balance this proprietary, and classified, knowledge about nuclear physics with civilian applications, Congress established the AEC in 1946 (Mazuzan, 1984) (Smith L. R., 1990).

Strong public support for science and technology after World War II (Greenberg, 2001) made possible dramatic growth in expenditures on research and development both in public funding and in private investments. To coordinate and facilitate such growing government involvement in science and technology, the existing institutional set up to support government engagement in science and technology deepened and expanded in the past World War II years (Smith L. R., 1990). The continued government efforts to facilitate research and development placed the United States in a top position worldwide in the field of science and technology, a position it maintains today (Smith L. R., 1990).

These years of postwar optimism about and large investments in scientific research and technological development created the establishment and anchoring of a national science and technology system of federal agencies, advisory councils, national laboratories and research facilities, and universities, which still is largely in place. What
followed were two decades of more critical reflection about the role of science and technology. The ‘techno-optimism’ of the postwar period gave way to the skepticism about elitism of any form and demands for more participation and democratic oversight of political and educational institutions during the broader wave of societal reorientation that took place during the late 1960s and early 1970s (Smith L. R., 1990) (Shapira & Kuhlmann, 2003). The same social forces that nurtured the civil rights movement, the anti-Vietnam movement, and the emerging feminist movement also underpinned the environmental movement, which contained within it elements of skepticism about techno-optimism. At the same time negative consequences of the use of science and technology in everyday life became more visible, such as increasing pollution of air and water. In the mid 1960s, public concern about environmental issues grew rapidly (Dunlap, 1991). Such developments led Congress to enact most of the major environmental laws that remain in force today: The Clean Air Act (1970) and the Clean Water Act (1972) are among the first comprehensive environmental protection policies enacted in the United States (Freeman III, 2000) (Portnoy, 2000).

Since the 1980s

Though the Cold War would last until the late 1980s, and the risks and negative side effects of scientific and technological progress would forever be part of the policy framework, the argument that the general public is opposed to public support of science and technology is belied by the continuous heavy public funding of science and technology in these decades (Ruscio, 1994). From the start of the 1980s science and
technology policies were refocused back to the linear model proposed by Vannevar Bush in 1945, according to which funding of basic research would lead to technological inventions that would accelerate economic development (Smith L. R., 1990).

Nevertheless the distinction between basic science and more applied and directed R&D is increasingly blurry (Greenberg, 2001).

Congress decided on a lingering subject regarding the ownership of publicly funded research by passing the so-called Bayh – Dole Act (Public Law 95-517) in 1980, concluding that despite public funding organizations or scientists or companies which did the research could hold the ownership of the invention. The government department or agency that paid for the research would no longer hold the patents. This act gave much more opportunity to the private or commercial use of publicly funded research, which was a boost for industry. It kick-started a development that has become almost the norm in today’s science and technology system: the links between industry and research institutes or universities, as well as multi-party cooperation between industry, universities, and government agencies (Shapira & Kuhlmann, 2003).

Since the 1980s investments in research and development show a continuous growth in public funding, in industry efforts, and in combined public – private partnership R&D projects (Greenberg, 2001). Over the last decades this set up has created a complex interplay between private companies, research institutes and universities, federal or public research facilities, and federal research funding organizations such as the NSF.
Government or industry is not the sole decision-maker. Shared funding and interests shape the outcome of scientific and technological endeavors (Teitelman, 1994). For instance, the cost-benefit ratio of projects becomes more important, as industry wants to see economic returns, and thus will seek more applied research, while government agencies focus on regulating any risks and uncertainties (Ruscio, 1994). Distinct cultures of academia, business, and government seem to merge in an establishment of a large national science and technology system (Greenberg, 2001),

Despite that changing dynamics in the relations and connections between government, academia, and industry, the institutional set up of science and technology policies since World War II is remarkably stable (Kleinman, 1995). The federal government relies on a wide set of instruments to use in implementing science and technology policies, such as:

- Congressional authorization and establishment of policies and agencies;
- Congressional annual appropriations of budgets and funding;
- Specific mission agencies, such as the Nuclear Regulatory Commission;
- Intramural laboratories and facilities, such as the Oak Ridge Laboratory, as run by the Department of Energy;
- Federally funded research and development centers, such as the National Defense Research Institute;
- Many agencies are mandated to fund research, of which the NSF is the most prominent, yet other large funding organizations are the Department of Energy, the Department of Defense, and the National Institutes of Health;
- Different regulatory agencies, such as the Environmental Protection Agency and the National Institute for Occupational Safety and Health;
- A legal framework, such as the U.S. Patent Law;
- Through procurement of goods and services;
- Through service providing to industry, academia, and the general public;
- And of course as the largest employer in the country (Kraemer, 2006).

Many of these institutional arrangements were established decades ago. Institutional change is often only incremental and the organizations in science and technology policies, with the exception of some mission oriented agencies such as the Nuclear Regulatory Commission and the National Aeronautics and Space Agency (NASA), evolve slowly and, to their critics, seem rather risk averse, aiming to secure continuity of the established status quo. Abrupt and sudden transformative change would impact the institutional set up and carry negative consequences might for the organizations involved and their staff (Kraemer, 2006) (Greenberg, 2001). Yet, in general, these institutions and organizations are open and accessible to all who have an interest, thus reflecting, at least in principle, a pluralist foundation. This being said, we see a constant debate between ‘centralized priority setting’ and a more pluralist ‘open agenda’ approach (Kleinman, 1995) (Kraemer, 2006). This debate shapes the outcomes of many different science and technology programs set up by the U.S. federal government in the decades since World War II.
**Big Science**

Perhaps the most notable trend in the post-WWII era is the emergence of federally funded and coordinated ‘Big Science’ projects. These massive projects had their origins in the Manhattan Project, which, while military in nature, became a template for large and highly complex projects dependent on public funds and public leadership. This is remarkable and actually a bit paradoxical given the American political-economic culture, which is supposedly based on individual merit, open access, limited government involvement, and free market dynamics.

One of the first of such programs was the Apollo Program, established in 1963 by the National Aeronautics and Space Administration (NASA). Congress established NASA as a specific mission oriented agency in 1958\(^{12}\) to respond to challenges posed by the Soviet Union after it launched the world’s first satellite in space in 1957 (Hansen, 1995). Like the Manhattan Project, the Apollo Program, whose stated goal was to land a man on the moon within ten years to counter the Soviet’s perceived lead in space flight, clearly linked government funding of science and technological development to national power and solidarity behind a common goal (Hansen, 1995).

The Manhattan Project and the Apollo Program came to be early examples of what was dubbed by Alvin Weinberg, a prominent scientist, who took an important part in the

\(^{12}\) Federal government had been engaged with the possibilities of flight and aeronautics since 1915 through the National Advisory Committee for Aeronautics (NACA), which preceded NASA (Bilstein, 1989).
execution of the Manhattan Project, as ‘Big Science’ (Weinberg, 1968). The notion of ‘Big Science’ represents large centrally orchestrated efforts by government agencies or by parties contracted by government to achieve specific scientific and technological goals, which are deemed to be too large in scale or scope, and often of too much national strategic importance, to be reached independently by innovative industries and inquisitive scientists. Such efforts have created major research and development agglomerations and facilities, paid for by large amounts of public funding, often bundling resources from different government agencies. Such efforts require extensive teamwork and coordinated management, bringing together government funding, academic and engineering expertise, and private industry execution. Given the aim of rapidly advancing knowledge, such programs often include an educational program to train new scientists and engineers. As the programs are quite directive in nature, and work is done more or less in a factory style, little scientific autonomy remains (Galison, 1992).

Other examples of publicly funded and university-run non-defense programs include the establishment of the system of national laboratories (including Batavia, Argonne, and Lawrence Livermore) to advance physics, and, between 1988 and 2003, the Human Genome Project, biology’s first large scale research project which ran (Collins, 2003) (McCray, 2005). It is notable that Congress canceled a major project - the embryonic Superconducting Supercollider - in 1993 only after concerns about the project’s growing price tag and strong doubts about its practical utility. That decision posed direct
economic returns of federal spending on science and technology against ideas that such fundamental research has intrinsic value deserving public support. In this regard, physicists could not show that the expected costs could be linked to identifiable commercial or other products (McCray, 2005). The decision to cancel the project ultimately shifted primacy in high-energy physics research to the European Organization for Nuclear Research (CERN). The cancellation sent a larger message to the overall science community about the need to connect their work with larger national goals.

Opponents of ‘Big Science’ projects argue that such massive public investments make science and technology development dependent on these sources, and as a result complacent and less motivated (Kraemer, 2006). The struggle for control and direction allows for little scientific autonomy and a lot of top-down control, which compromises the idea of the inquisitive ‘scientific method’ (Smith L. R., 1990) (Kleinman, 1995). Also, such large government influence disturbs market dynamics as the government, and not market demand, may picking ‘winners’ and ‘losers’ – those scientific fields and technological directions that seem, to the government, most viable and feasible (Kraemer, 2006).

Thus, the idea that only large companies and substantive government investments can advance science and technology is subject of an ongoing discussion that shapes how the federal government is involved in science and technology. The at times successful approach of ‘Big Science’ compares to more traditional approaches of ‘Small Science’
that, better fitting in a free market ideology of entrepreneurial endeavor, allows for a decentralized, more autonomous process of science and technology development, of which there also many examples of success of successful inventions by small inventors (Teitelman, 1994).

Science and Technology Policies for Innovation and Economic Growth
Since the 1980s and in particular since the end of the Cold War, American science and technology policies have focused on innovation and economic growth. For instance, a 1998 U.S. House of Representatives Committee on Science report confirms that the focus of national science and technology policies should be on economic competitiveness rather than on defense (House of Representatives Committee on Science, 1998). Although public funding tends to stress basic research as its main goal, industry and non-government advocacy groups have had a larger role in setting priorities of public research funding, which has lead to more applied and directed research (Kleinman, 1995). Accountability of how public money is being used has increasingly become more important in evaluating the performance of government (Kraemer, 2006). It is in this context that this research understands U.S. government support of nanotechnology research and development.
3.3 The National Nanotechnology Initiative.

The establishment of a national program to address and coordinate responsible development of nanotechnology in the United States began with President Clinton’s establishment of the National Nanotechnology Initiative (NNI) in November 2000 (Roco M. C., 2001). Congress gave the NNI a more formal foundation by passing the 21st Century Nanotechnology Research and Development Act (108 S 189 / 108 HR 766) on December 3, 2003, assigning agency responsibilities and authorizing funding for the years fiscal years 2005 to 2008\(^\text{13}\). The preparation of the NNI started a decade before its actual establishment, and over time a series of strategic reassessments, evaluations and external reviews have changed the NNI’s goals and shape. The next sections will present the coming-into-being of the NNI, its set up, and the developments since its establishment. These sections show which motivations, which ideas and which constraints played important a role in shaping the NNI.

3.3.1 Establishing the National Nanotechnology Initiative

The invention of instruments such as the scanning tunneling microscope, which allowed for observation and manipulation of matter at the nanoscale, accelerated interest and activity in the field of nanotechnology in the late 1980s and early 1990s, and in turn

\(^{13}\text{As per U.S. federal government practice, the fiscal year starts on October 1st of the previous year: thus FY2005 starts on 1 October 2004.}\)
offered promising views for the future. Such growing enthusiasm also came with early calls for regulation of the use and production of nanomaterials given uncertainties and potential risks of working at the nanoscale (Forrest, 1989).

It took over a decade to create and establish a coordinated government response to the promises and potential drawbacks of nanotechnology. The steps towards the establishment of the National Nanotechnology Initiative are presented along a timeline in figure 3.1.
Fig. 3.1  Timeline of the NNI.

- **1989** First suggestion of regulating nanotechnology
- **1990** The NSF asks for nanotechnology proposals in her Emerging Technologies Competition
- **1991** The government of Japan allocates 225 million US dollar for nanotechnology research
- **1990s** Other US Government Agencies start funding nanotechnology R&D, for instance under the Department of Defense DARPA program on ULTRA Electronics
- **1997** NSF initiates a meeting of group of experts from academia and government to create a national vision on nanotechnology
- **1997** 1997 - 1998 The NSF creates a specific nanotechnology program
- **1998** The White House National Science and Technology Council creates the Interagency Working Group on Nanoscale Science, Engineering, and Technology (IWGN)
- **1999** The IWGN proposes to double the public R&D budget for nanotechnology to 422 million USD in 2001
- **1999** 1999 the IWGN prepares the NNI proposal
- **2000** Jan 2000 President Clinton announces the NNI
- **2000** 2000 the IWGN is replaced by the permanent Subcommittee on Nanoscale Science, Engineering, and Technology (NSET)
- **2000** Nov 2000 the NNI is enacted, and will be supported by the National Nanotechnology Coordination Office (NNCO)
- **2003** Dec 2003 Congress passes the 21st Century Nanotechnology R&D Act

During the 1990s, nanotechnology became one of the three trends in science and technology, together with information and communication technologies (ICT) and biotechnology (Schultz, 2000). Actually, nanotechnology, like biotechnology, became an example of the convergence of traditional and new fields of science and technology,
such as physics, chemistry, and biology, facilitated by advanced engineering and information, communication, and computation technologies (Roco M. C., 2007).

The dissolution of the Soviet Union in 1991 brought a definitive end to the Cold War, thus diminishing government attention to defense and national security until the attacks of September 11, 2001. At the same time, concern about international economic competition grew, bringing renewed interest in science and technology as engines of economic growth (McCray, 2005). In 1990, the NSF for the first time requested specific nanoscale research proposals as part of its Emerging Technologies Competition. This call began an era of continuous funding of nanoscience and nanotechnology, at first as single projects within established NSF programs, and later, in particular after the establishment of the NNI, as specific nanotechnology programs (Roco M. C., 2007).

Given their great autonomy in funding research projects, around the same time other federal departments and agencies such as the Department of Energy (DOE), NASA, the National Institutes of Health (NIH), and the Department of Defense (DOD) as one of the largest investors in science and technology started nanoscale research programs in the 1990s; For instance, the Defense Advanced Research Project Agency (DARPA), under the Department of Defense, included specific nanoscale oriented research in its ULTRA electronics program (Lane, 2005)
After having funded nanotechnology research since the start of the 1990s, the NSF initiated a first meeting of representatives of the science community and relevant government officials to prepare a more comprehensive vision for nanotechnology development in the United States (Roco M. C., 2007) (Shapira P. &., 2007). Given the international character of science and technology in general, and of emerging nanotechnology specifically, a consortium of federal research agencies established the World Technology Evaluation Center (WTEC)\textsuperscript{14}, to assess international developments of science and technology (World Technology Evaluation Center, 2012). The WTEC assessed a variety of studies on both domestic and international progress, discussed scientific, economic, and societal implications of advances in nanotechnology, and considered ways to fund nanotechnology research in the United States (Roco M. C., 2007)

Around the same time the NSF established a specific nanotechnology program, ‘Partnership in Nanotechnology: Functional Nanostructure’, which awarded approximately $10 million to research devoted to the discovery of novel phenomena and processes at the nanoscale (Roco M. C., 2007) (National Science Foundation, 1998). Overall federal funding for identifiable nanotechnology research grew to $116 million in 1997 and further to $260 million in 1999 (Interagency Working Group on Nanoscience, Engineering, and Technology, 1999)

\textsuperscript{14} Which in previous years went under the name “Japan Technology Evaluation Center”, indicating where technological progress was deemed most promising and most competitive.
In October 1998 the White House National Council of Science and Technology (NSTC) established an interdepartmental group to develop a proposal for the coordination of government involvement in the development of nanotechnology in the United States. The Interagency Working Group on Nanoscale Science, Engineering and Technology (IWGN) was comprised of representatives from the NSF, the White House Office of Science & Technology Policies (OSTP), the White House Office of Management and Budget (OMB), NASA, the National Health Institutes (NIH), and the departments of Defense, Energy, Treasury, and Commerce. Dr. Mihail C. Roco, an acclaimed engineer and advisor to the NSF, led the IWGN. Dr. Roco was, and has ever since been, one of the most prominent people in the development of the nanotechnology infrastructure and government response in the U.S. (National Science Foundation, 2008) (Roco M. C., 2007).

The goal for the IWGN was to envision and propose a national nanotechnology program that would orchestrate and coordinate the fragmented and decentralized cross-discipline and cross-agency research efforts (Roco M. C., 2007). The transformative possibilities which nanotechnology offered demanded a cross-agency coordination to leverage all federal investments in nanotechnology research (Lane, 2005) and better enable the U.S. to maintain its global leadership position as governments of other countries appeared to be ready to invest heavily in nanotechnology research and development (McCray, 2005) (Roco M. C., 2001). The IWGN also saw a combined program as an opportunity to strengthen the image of nanotechnology and to support
participating agencies in acquiring additional federal funding. The national program should be based on a transparent and inclusive coalition of stakeholders in nanotechnology: the scientific community, different industries, federal government departments and agencies, state and local governments – in particular of those locations which seemed to be the most likely ‘hubs’ of nanotechnology research – public interest organizations, and the general public (Roco M. C., 2007).

Given the emerging nature of nanotechnology at the end of the 1990s, much remained unknown. The IWGN considered the need to avoid any public skepticism about the possibilities promised by nanotechnology optimists. Such skepticism often appears in reaction to overly promising messages about the possibilities of new technologies. The claim that biotechnology would end world hunger comes to mind (Borlaus, 2000) (Nash, 2001). Public skepticism and concern, in the eyes of scientists at least, can become an obstacle in gaining public acceptance of new fields of science and technology, and for public funding of research in that field. When promised results fail to come or, even worse, when emerging sciences and technologies cause harm, the general public may turn away from such endeavors all together. The development and application of civilian nuclear power production has gone through such a phase (Walker, 1992). Also, lessons from other promising science and technologies, such as genetic modification of agricultural crops pointed to the need for any research and development program to also keep in mind any possible environmental, health, and safety consequences (EHS) of nanotechnology.
The nanotechnology program, as envisioned, was to be a long term integrated and multi-disciplinary vision about nanotechnology development concentrated around science and technology, as determined by leading scientists (McCray, 2005). The program was to be ‘expert-driven’: scientists and experts from within the participating agencies would decide which research projects where to be funded. In the view of the members of the IWGN, a main target of the nanotechnology program should be to identify core concepts and definitions of nanotechnology through scientific discovery, thus focusing on basic research. To achieve that goal investments in upgrading research facilities and developing new instruments to measure and observe phenomena at the nanoscale was necessary (Roco M. C., 2001) (Roco M. C., 2007).

However, as the program was to be embedded in the broader framework of science and technology policies, the program was to address opportunities and consequences for general social and economic goals such as public health and economic growth, as well as opportunities to maintain peace (Roco M. C., 2001).

As preparations progressed in the late 1990s, the following arguments came forward as why nanotechnology should be considered a strategic field of research for America, and why a federal government-coordinated centralized program would be justified:

- Addressing National Challenges: The broad field of nanotechnology showed tremendous promise to address a whole range of national challenges, such as
sustaining economic growth, securing energy supply, and advancing public
health (Roco M. C., 2001);

- Transformative Nature of Nanotechnology: Nanotechnology appeared to be a
potential general purpose technology, which could transform the world
economy and society: as President Clinton stated on January 21, 2000: “The Next
Industrial Revolution” (White House, 2000);

- Revive Certain Fields of Science and Technology: Nanotechnology had the
potential to revive fields of science and technology such as physics, chemistry,
and engineering, which seemed to have become of lesser interest to young
people, stimulating new fields of study in the educational system, thus creating a
new generation of scientists and engineers (Smalley, 2000) (McCray, 2005).

- Government as Early Investor: Nanotechnology was at such a early stage, that
research needed appeared to be too long term, too high risk, too expensive and
of too uncertain outcomes that industry needed public assistance in developing
nanotechnology applications for economic and societal benefit, similar to other
fields of sciences an technologies (Roco M. C., 2001)

- Maintain U.S. Leadership: Given the lead of the United States in nanotechnology
in the late 1990s, a coordinated development created the potential to ensure
and maintain global leadership, scientifically as well as economically – and more
coveted, in a military sense - (Lane, 2005).
In March 1999 the interagency working group presented its first proposal for the National Nanotechnology Initiative to White House Office of Science and Technology Policy (OSTP). The IWGN proposed to more or less double the amount spent on nanotechnology research in 1999 ($260 million) for the budget year 2001, of which almost half was reserved for public funding of nanotechnology research through the NSF (Lane, 2005) (Roco M. C., 2001) (Schultz, 2000) (McCray, 2005). The proposal for the NNI focused on creating greater coordination of research efforts to overcome traditional barriers between different federal departments and agencies, to establish a common research agenda, to avoid any unnecessary duplication of research efforts, and to foster information exchange between the different agencies and departments. The proposal focused on six key agencies: the NSF as a main research funding organization; the Department of Defense (DOD) as one of the largest investors in science and technology; the Department of Energy (DOE) as the manager of most of the federal research infrastructure, such as many national laboratories and research facilities; NASA as a specific mission-oriented research and development organization; NIH, operating a range of specific research centers; and the National Institute for Standards and Technology (NIST) as an organization appropriate to help create missing standards and definitions in nanotechnology. The IWGN spent much of 1999 in drawing up the form of cooperation for such a ‘grand coalition’ (Schultz, 2000) (Roco M. C., 2007).

The IWGN also focused on preparing Congress for the idea of a national nanotechnology program. Different committees and subcommittees in both the House of
Representatives and the Senate held hearings on the subject. These hearings addressed numerous topics, of which the most prominent were:

- A suspicion of costly ‘Big Science’: The proposal countered these concerns by stressing the goal to have a small coordination team working with a whole range of federal departments, agencies, and research facilities (McCray, 2005). Also the broad field of nanosciences and nanotechnologies hardly invited such an approach, as it lacked the singular goal that inspired most ‘Big Science’ projects;

- Fear of self-replicating and uncontrollable nanobots, as suggested by Eric Drexler (Drexler E. K., 1990): These concerns were countered by Nobel Laureate Richard E. Smalley\textsuperscript{15}, who argued before the Senate Subcommittee on May 12, 1999 that such ideas were unrealistic (Smalley, 1999) (Smalley, 2000);

- The debate on which direction of research to prioritize - bottom-up versus top-down: The direction issue was decided by Smalley’s argument that bottom-up molecular engineering seemed much more difficult to achieve as there were hardly any instruments to manipulate matter at that scale\textsuperscript{16}, while actual focus of the program on top down miniaturization seemed more feasible to bring results in the shorter term.

\textsuperscript{15} Richard E. Smalley was an influential and well-respected scientist, who won the 1996 Nobel Prize as part of the team that discovered carbon-60 molecules.

\textsuperscript{16} Smalley called this issue ‘thick fingers’: instruments too big to handle single atoms. (Smalley R. E., 2001)
In 1999 the IWGN produced three reports to inform stakeholders and members of Congress on the proposal of the National Nanotechnology Initiative:

- *Nanostructure Science and Technology*, which assessed the status and trends of nanotechnology in different parts of the world. The report concluded that while the United States was in a strong position, Japan and some European countries were not far behind -- and in some cases ahead -- of the U.S. (Interagency Working Group on Nanoscience, 1999);

- *Nanotechnology Research Directions*, which concluded on the following priorities to improve nanotechnology research in the U.S.:
  
  o Focus on fundamental research of novel properties and phenomena occurring at the nanoscale;

  o Encourage multi- and trans disciplinary research;

  o Improve research facilities and laboratories;

  o Create new educational opportunities;

  o Improve the institutional structure to support nanotechnology – looking at the interplay between industry, academia, and government

  (Interagency Working Group on Nanoscience, Engineering, and Technology, 1999);

- *National Nanotechnology Initiative: Leading to the Next Industrial Revolution*:
  
  the formal budget proposal for 2001, amounting to $495 million, based upon the specifically allocated budget proposals by the NSF, DOD, DOE, the Department of
Commerce (DOC) (representing NIST), and NIH. The proposal included various
categories for investment: basic research, research infrastructure, education &
training, and addressing ethical, legal, and societal issues. (Interagency Working

The IWGN also published a brochure, *Nanotechnology: Shaping the World Atom by
Atom*, to explain to the general public what nanotechnology was, what its applications
could mean for the future, and why it was imperative to invest in nanotechnology
research (Interagency Working Group on Nanoscience, Engineering, and Technology,
1999). As noted before, lessons drawn from previous experiences with emerging fields
of science and technology indicated that public acceptance of novel sciences and
technologies, and the willingness to support such research, is based on understanding
the opportunities of research, on comprehending remaining risks and uncertainties, and
on what can be done to mitigate any such risks. The inclusion of a specific working group
for public participation and communication in the set up of the program underscored
the importance the IWGN gave to informing the general public.

In January 2000 President Clinton announced his proposal for the National
Nanotechnology Initiative while visiting the California Institute of Technology, not
coincidentally where Richard Feynman made his famous speech forty years earlier
(White House, 2000) (Roco M. C., 2007), Clinton’s announcement also included the
creation of the 21st Century Research Fund, an almost $3 billion increase in science and
technology funding that would include biomedical research and information technology, and which doubled the annual budget for the NSF beyond the almost $500 million proposed for the NNI (Office of Science and Technology Policy, 2000) (Lane, 2005).

In July 2000 the National Science and Technology Council’s Committee on Technology replaced the IWGN with the Subcommittee on Nanoscale Science, Engineering, and Technology (NSET), under continued leadership of Mihail C. Roco. NSET went on to present the National Nanotechnology Initiative: The Initiative and its Implementation Plan, the formal proposal for the NNI to Congress (Roco M. C., 2007) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2000). The implementation plan suggested an organizational set up including a small National Nanotechnology Coordination Office (NNCO) to support NSET in the daily operations\(^ {17} \), the budget proposal of $495 million for fiscal year 2001, the six participating federal departments and agencies, and an ambitious agenda of collaboration over the next five years (Subcommittee on Nanoscale Science, Engineering, and Technology, 2000).

Congress in November 2000 approved the NNI proposal with broad bipartisan support and appropriated an initial $465 million for nanotechnology research in 2001, a 72% increase compared to fiscal year 2000. The NSF was the largest participant in financial capacity and would be able to fund nanotechnology research for almost $200 million in

\(^ {17} \) The organizational set up will be presented in the next section of this chapter.

In December 2003, Congress passed the 21st Century Nanotechnology Research and Development Act (108 S 189 / 108 HR 766), formally creating the National Nanotechnology Program (NNP) and assigning the responsibilities to each of the agencies involved as outlined in the NNI plan. The Act also authorized increased direct funding for nanotechnology research for a total of $3.7 billion for the years fiscal years 2005 to 2007. Congress mandated in the enactment that research in environmental, health, safety, and broader societal issues should be funded as part of the act. In addition Congress required regular reviews of the program and its results (United States Congress, 2003) (McCray, 2005) (Sargent Jr., 2011).

The history of the creation of the National Nanotechnology Initiative shows a focus on the scientific endeavor to advance basic or fundamental knowledge about properties and phenomena taking place at the nanoscale level. From early on a clear notion of the possibilities of nanotechnology for both economic and societal returns appeared to be a main driver to spur development. Also, a strong sense of international competition and concerns about challenges of its global leadership position in science and technology, in particular compared to Japan and various European countries, drove support for government involvement in nanotechnology development in the United States. A third driver appears to be the idea that the United States in general was starting to lose its
edge in science and engineering compared to other countries and needed an impulse for its education and workforce training system to attract new students. Matters of defense and national security, though always prominently present through the participation of the traditionally strong research focused and funding Department of Defense in the NNI, are not explicitly mentioned as a driver of government support for nanoscale research in the late 1990s.

The institutional set up of the NNI is arguably a novel way of coordinating otherwise separate operations by a range of federal departments and agencies. The set up of the NNI fosters exchange of information, which avoids a duplication of research efforts by different departments or agencies. The set up brings a notion of efficiency and coordination. However, deliberately the NNI is not a centralized effort of government coordination like previous ‘Big Science’ programs. Lessons learned of such projects as well as the broadness of the multidisciplinary field of nanosciences and nanotechnologies shaped the more decentralized approach of government involvement in the development of nanotechnology, leaving ample room for autonomy for the participating departments and agencies and thus continues the pluralist approach of policymaking.
3.3.2 The National Nanotechnology Initiative in Action

*Set up of the National Nanotechnology Initiative*

The NNI is often presented as a new way to implement a national research priority and a unique model of governance and cross-agency coordination (Roco M. C., 2011). It was established as a coordinated collaboration of the six federal agencies that allocated funding for nanoscale research and development: the NSF, the Department of Defense, the Department of Energy, NASA, NIH, and the National Institute for Standards and Technology of the Department of Commerce (NIST/DOC). Over time those original six have expanded to twenty-seven federal agencies and departments (Sargent Jr., 2011) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2011). The expansion reflects both an increased awareness of the possibilities and consequences of nanotechnology as well as the desire of agencies and departments to share in the new insights of nanoscale research and the opportunities of Federal funding directed to nanotechnology.

The variety of participants reflects the breadth of nanotechnology applications as well as the concern about potentially harmful side effects. Over time, what started out as collaboration among agencies and departments traditionally involved in research and development grew into a broad coalition of departments and agencies with quite divergent mandates and fields of operation, including seemingly unlikely participants such as the Intelligence Community - a network of seventeen federal agencies and
organizations entrusted with collecting information to support U.S. security, and the
Forest Service. Of the participants in the NNI, fifteen agencies actually dedicate research
budgets to nanotechnology research and ten others participate in information exchange
and deliberations. Table 3.1 supplies an overview of the current participants in the NNI.

Table 3.1 Overview NNI Participants.

<table>
<thead>
<tr>
<th>Name</th>
<th>Acronym</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer Product Safety Commission</td>
<td>CPSC</td>
</tr>
<tr>
<td>Department of Defense</td>
<td>DOD</td>
</tr>
<tr>
<td>Department of Energy</td>
<td>DOE</td>
</tr>
<tr>
<td>Department of Homeland Security</td>
<td>DHS</td>
</tr>
<tr>
<td>Department of Justice</td>
<td>DOJ</td>
</tr>
<tr>
<td>Department of Transportation - Federal Highway</td>
<td>DOT / FHWA</td>
</tr>
<tr>
<td>Administration</td>
<td></td>
</tr>
<tr>
<td>Environmental Protection Agency</td>
<td>EPA</td>
</tr>
<tr>
<td>Food and Drug Administration</td>
<td>FDA</td>
</tr>
<tr>
<td>Forest Service</td>
<td>USDA / FS</td>
</tr>
<tr>
<td>National Aeronautics and Space Agency</td>
<td>NASA</td>
</tr>
<tr>
<td>National Institute for Occupational Safety and Health</td>
<td>NIOSH</td>
</tr>
<tr>
<td>National Institute of Food and Agriculture</td>
<td>USDA / NIFA</td>
</tr>
<tr>
<td>National Institutes of Health</td>
<td>NIH</td>
</tr>
<tr>
<td>National Institute of Standards and Technology</td>
<td>NIST</td>
</tr>
<tr>
<td>National Science Foundation</td>
<td>NSF</td>
</tr>
</tbody>
</table>

Other Participants

| Bureau of Industry and Security                      | DOC / BIS     |
| Department of Education                              | DOEd          |
| Department of Labor                                  | DOL           |
| Department of State                                  | DOS           |
| Department of Treasury                               | DOTreas       |
| Intelligence Community                              | IC            |
| Nuclear Regulatory Commission                        | NRC           |
| US Geological Survey                                 | DOI / USGS    |
| US International Trade Commission                    | USITC         |
| US Patent and Trademark Office                       | USPTO         |

Source: (Subcommittee on Nanoscale Science, Engineering, and Technology, 2011)
The Congressional authorization in 2003 confirmed the organizational set up of the NNI. The National Science and Technology Council (NSTC) is a cabinet-level council that coordinates interagency cooperation in science and technology. The President’s Senior Science Advisor, who leads the White House Office of Science and Technology Policy (OSTP), is a member of NSTC and in charge of implementing such coordination. The NSTC has created the Subcommittee on Nanoscale Science, Engineering and Technology (NSET) under its Committee on Technology to establish and lead the NNI, with the help of a small staff in the newly created National Nanotechnology Coordination Office (NNCO) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2000). All participants of the NNI are member of NSET.

The NSET is co-chaired by representatives of three executive office units, reflecting the interplay of motivations and goals behind the establishment of the NNI: promoting science, supporting economic growth, and a results-driven approach. These are the National Economic Council (NEC), which coordinates economic policy advise to the President (National Economic Council, 2012), the Office of Management and Budget (OMB) (Office of Management and Budget, 2012), which annually puts together the president’s budget proposal and oversees the performance of the federal agencies and departments, and the OSTP.

The creation of the NNI involved a range of actors both inside government and outside, including academic scientists and engineers, as well as representatives from industries.
and organizations that were already or wanted to become involved in nanotechnology research, development, and commercialization. Figure 3.2 shows the set up of the NNI in the executive branch. Obviously most of the organizations involved are part of government, yet the NNI is strongly embedded in the scientific community as well as in the business community through triennial external reviews mandated by Congress in the 21st Century Nanotechnology Research and Development Act (United States Congress, 2003), as well as through extensive academia and industry collaborations and partnerships in the actual implementation and execution of nanotechnology research.

Fig. 3.2. Organizational Embedding of the National Nanotechnology Foundation
The National Nanotechnology Advisory Panel (NNAP) conducts the triennial external reviews of the NNI as required by the 21st Century Nanotechnology Research and Development Act18. The NNAP is selected by the President’s Council of Advisors on Science and Technology (PCAST), an external advisory group to the President on matters of science and technology that is comprised of scientists and engineers from academic and industry backgrounds (National Nanotechnology Advisory Panel, 2005) (President’s Council of Advisors on Science and Technology, 2012).

The NSET has set up four working groups to coordinate the activities of the participants in the NNI, and which reflect the focus the NNI’s program:

- The Global Issues in Nanotechnology Working Group (GIN) coordinates international cooperation of NNI participants and prepares common viewpoints to be presented in international meetings, such as the Working Parties of the OECD;
- Nanotechnology Environmental & Health Implications Working Group (NEHI) focuses on the environmental, health, and safety (EHS) concerns that are

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18 This with the exception of the first review, which was conducted by the Committee for the Review of the National Nanotechnology Initiative of the National Research Council at the request of the NEC (Committee for the Review of the National Nanotechnology Initiative, 2002). The National Research Council is a one of the independent National Academies, chartered by Congress since the late 19th century to offer independent advice of matters of science and technology (National Research Council, 2012)
associated with nanotechnology. As many uncertainties remain about possible risks and negative consequences of nanotechnology for the environment, human health, and safety of manufacturing and using nano-materials and other nanotechnology applications, EHS issues are an important part of advancing nanotechnology. NEHI aims to coordinate the efforts of the various NNI participants in this field of nanotechnology research by facilitating knowledge exchange.

• The Nanomanufacturing, Industry Liaison & Innovation Working Group (NILI) aims to facilitate knowledge transfer and information exchange between the different NNI members and the larger scientific and industry community involved or interested in nanotechnology. Diffusion of new scientific insight and technological possibilities is the basis of rapid application and commercialization of nanotechnology, which fosters economic and societal returns. This is a main goal of the NNI.

• The Nanotechnology Public Engagement & Communications Working Group (NPEC) helps NNI participants in the crucial task to inform the general public, advocacy groups, and policymakers about nanotechnology, its achievements, possibilities, and possible side effects, and about what the different members of the NNI are doing and aiming to achieve in nanotechnology research and development.
Focus of the National Nanotechnology Initiative

The Subcommittee of Nanoscale Science, Engineering, and Technology (NSET), in which all NNI participants are represented, coordinates and combines the activities and programs of the different members along the overall goals and priorities of the NNI. Since its establishment, the NSET has published a range of documents, laying out its goals, its priorities, and the plans and the activities, which the NNI participants lined up to achieve their targets. These include the NNI strategic plans, which are updated almost every three years (in 2004, 2007, and 2011), as well as annual supplements to the President’s budget, submitted every February (fiscal years 2008 up to 2013). In addition, there are the reports of the triennial reviews by the National Research Commission, later by the NNAP (2002, 2005, 2006, 2008, 2010, and 2012).

This section offers an overview of the priorities and goals of the NNI, the main focus of which has remained constant over the years. It addresses shifts of NNI attention since its establishment in 2000, as certain goals have been achieved and much progress has been made in nanotechnology. The development of funding of the NNI over the years, as shown in the next section of this chapter, reflects the NNI’s priorities.

The original NNI implementation plan showed five themes for research funding:

1. Fundamental research -- ‘Grand Challenges’ -- establishing research centers and network, creating a research infrastructure, and addressing societal implications, which included setting up educational and training programs. The so-called
‘Grand Challenges’ were broadly defined fields of applications of nanotechnology that required priority: nanomaterials, electronics, processes & environment, spacecraft, energy, health care, and national security. It included a focus of research on both bottom up molecular engineering as top down miniaturization. This being quite a list of priorities and activities, in later strategy documents the NNI worked consistently to achieve four goals which show the focus of the NNI: support basic research, transfer of technology and knowledge, create a research infrastructure and education & training program, while addressing risks and concerns that are associated with nanotechnology (Roco M. C., 2003):

2. Advance a world-class nanotechnology research and development program to maintain American leadership in fundamental interdisciplinary research through and across multiple stakeholders (government, industry, and academia) via collaboration and partnerships;

3. Foster the transfer of new technologies into products for commercial and public benefit to grow the international competitive position of the U.S. and ensure national security by facilitating information exchange and knowledge diffusion through public – private partnerships;

4. Develop and sustain educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology to establish and maintain a network of research facilities, education centers, and networks to facilitate nanotechnology research, as well as a common set of standards, definitions, measures, and nomenclature to advance scientific progress;
5. Support responsible development of nanotechnology to address environmental, health, and safety aspects, through risk assessment and risk management of nanomaterials and processes, as well as ethical, legal, and societal implications, through research and public engagement and outreach.


To achieve these goals, the NNI works with a set of program component areas (PCAs), as shown in Table 3.2. The set of PCAs has not changed over the years, with one exception: In 2007 the NSET added the Environmental, Health, and Safety Aspects component in response to growing concerns about the EHS implications of nanotechnology development (Committee to Review the National Nanotechnology Initiative, 2006) (National Nanotechnology Advisory Panel, 2005) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2007).

Table 3.2  NNI Program Component Areas

<table>
<thead>
<tr>
<th>PCA</th>
<th>Goal</th>
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</thead>
<tbody>
<tr>
<td>Fundamental Nanoscale Phenomena &amp; Processes</td>
<td>1</td>
</tr>
<tr>
<td>Nanomaterials</td>
<td>1</td>
</tr>
<tr>
<td>Nanoscale Devices and Systems</td>
<td>1 and 2</td>
</tr>
<tr>
<td>Instrumentation &amp; Standards</td>
<td>1, 2 and 4</td>
</tr>
<tr>
<td>Nanomanufacturing</td>
<td>1 and 2</td>
</tr>
<tr>
<td>Research Facilities</td>
<td>3</td>
</tr>
<tr>
<td>Environmental, Health, and Safety Aspects</td>
<td>4</td>
</tr>
<tr>
<td>Societal Implications and Education</td>
<td>4</td>
</tr>
</tbody>
</table>

The wide range of the issues addressed by NNI program components shows why such a large group of government departments and agencies became engaged in the National nanotechnology Initiative. Some agencies, such as the NSF, are involved in almost all program components. Others, like the Department of Justice or the Department of State, have a more limited engagement. The EPA has a dual interest in the NNI: its mandate to regulate possible pollution of the environment requires EPA to address issues of possible toxicity of nanomaterials. At the same time, the agency is interested in creating new materials and processes at the nanoscale that may replace existing products and processes with more environmentally safe alternatives.

**Funding the NNI**

Despite outward appearances that the NNI coordinates federal spending on nanotechnology research, the NSET does not allocate any budget. To the contrary, NNI participants dedicate a part of their annual research budgets to nanotechnology, which are then authorized, or amended, by Congress. The NNI itself, with the exception of a small annual operating budget for the coordinating office (NNCO), has no centralized budget. As a result the NSET has little independent power over the budget itself and is limited to the coordination of the overall nanotechnology research budget process. It presents the aggregated results in the annual NNI budget supplement of the President’s overall budget proposal (Subcommittee on Nanoscale Science, Engineering, and

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19 See section 3.3.3 on related government involvement for more information.
Technology, 2000) (Sargent Jr., 2011). The NNI budgets for fiscal 2001 - 2004 were not proposed in aggregated form, but as separate parts of each participant’s budget. The 21st Century Nanotechnology Research and Development Act proposed budgets from FY 2005 - 2007, and since 2008 NSET proposes an annual aggregated NNI budget as a supplement to the President’s budget. Since 2008 Congress has made efforts to amend, refund, and reauthorize the NNI in different forms, yet formal reauthorization has not taken place yet. Though the annual budget requests are appropriated in general, without Congressional reauthorization continuous funding of the NNI might come in jeopardy when budget cuts are deemed necessary by Congress (Sargent Jr., 2011). Even then, it depends on the congressional appropriation process whether authorized programs will actually get funding.

Table 3.3 gives an overview of NNI funding since 2000 by the different participating agencies and departments. Starting with the six budget-dedicating NNI members in 2000, the overview expands to sixteen participants, which allocated budget to nanotechnology research in the President’s Budget Supplement for fiscal year 2013. The overview shows a tremendous overall growth of federal investments in nanotechnology. Since the establishment of the NNI in 2000, federal agencies and departments have allocated almost $18 billion to nanotechnology research and development\(^2\). In the years before the NNI was established total public nanotechnology funding reached

\(^2\) Many states have made substantial investments in nanotechnology on top of the federal budget. Some indications and a few brief examples are part of section 3.3.3 of this chapter.
almost $1 billion already (Subcommittee on Nanoscale Science, Engineering, and Technology, 2012). The last few years the annual federal research budget for nanotechnology is around $1.8 billion, after rapid and substantial increases between 2000 and 2008. Fiscal year 2009 was an exceptional year, when the budgets of in particular DOE and NSF allowed for an approximate one-off additional $500 million as part of the 2009 American Recovery and Reinvestment Act (ARRA) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2010).

Traditionally, four agencies dedicate the largest budget to nanotechnology research:

NSF, NIH, and the Departments of Energy (DOE) and Defense (DOD). The NSF, NIH, and DOE show a continuous upward trend of funding, while since 2009 DOD funding of nanotechnology research has dropped. This can be explained by overall budget cuts on the DOD science and technology budget, as well as reprioritization of activities (Padron Carney, 2011).

Table 3.3  NNI Funding per Participant

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DOE</td>
<td>87</td>
<td>83</td>
<td>134</td>
<td>134</td>
<td>208</td>
<td>231</td>
<td>226</td>
<td>247</td>
<td>625.8</td>
<td>373.8</td>
<td>380.8</td>
<td>335.4</td>
<td>442.5</td>
<td>3503</td>
</tr>
<tr>
<td>NIH</td>
<td>150</td>
<td>204</td>
<td>221</td>
<td>221</td>
<td>335</td>
<td>359.7</td>
<td>388.8</td>
<td>408.6</td>
<td>509.8</td>
<td>428.7</td>
<td>412.1</td>
<td>426</td>
<td>434.9</td>
<td>4496</td>
</tr>
<tr>
<td>DOD</td>
<td>125</td>
<td>224</td>
<td>220</td>
<td>220</td>
<td>352</td>
<td>423.9</td>
<td>450.2</td>
<td>460.4</td>
<td>459</td>
<td>439.6</td>
<td>415.4</td>
<td>361.2</td>
<td>289.4</td>
<td>4444</td>
</tr>
<tr>
<td>NIST</td>
<td>77</td>
<td>77</td>
<td>64</td>
<td>64</td>
<td>79</td>
<td>77.9</td>
<td>87.6</td>
<td>85.6</td>
<td>116.7</td>
<td>95.9</td>
<td>95.4</td>
<td>102.1</td>
<td>1139</td>
<td></td>
</tr>
<tr>
<td>NASA</td>
<td>22</td>
<td>35</td>
<td>36</td>
<td>36</td>
<td>45</td>
<td>50</td>
<td>19.8</td>
<td>17.4</td>
<td>13.7</td>
<td>19.7</td>
<td>20.1</td>
<td>23</td>
<td>22</td>
<td>359.7</td>
</tr>
<tr>
<td>EPA</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>7</td>
<td>4.5</td>
<td>7.6</td>
<td>12.1</td>
<td>11.6</td>
<td>11.7</td>
<td>17.6</td>
<td>17.5</td>
<td>19.3</td>
<td>135.9</td>
</tr>
<tr>
<td>NIOSH</td>
<td>3</td>
<td>3.8</td>
<td>7.3</td>
<td>6.9</td>
<td>6.7</td>
<td>8.5</td>
<td>9.5</td>
<td>10</td>
<td>10</td>
<td>65.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NIAH</td>
<td>1</td>
<td>1.5</td>
<td>4.6</td>
<td>5.4</td>
<td>7.1</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>37.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NHLBI</td>
<td>0.2</td>
<td>0.5</td>
<td>2.2</td>
<td>2</td>
<td>6.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NIDCD</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>3.2</td>
<td>2</td>
<td>1</td>
<td>7</td>
<td>11.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NIH</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>464</td>
<td>697</td>
<td>760</td>
<td>761</td>
<td>1197</td>
<td>1347.4</td>
<td>1426.1</td>
<td>1554.5</td>
<td>2212.8</td>
<td>1912.9</td>
<td>1850.2</td>
<td>1696</td>
<td>1767.3</td>
<td>17644.8</td>
</tr>
<tr>
<td>of which ARRA</td>
<td>500</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

It should be noted that most of the funds for nanotechnology research seems not to consist of new monies but came from a gradual shifting of priorities in the overall research budgets of relevant agencies. Nevertheless, the prominence given to nanotechnology did support NNI participants in proposing and getting from Congress additional funding for nanoscale research on top of their normal budget requests. For instance, the NSF, as one of the largest participants in the NNI, at least budget-wise, has allocated different percentages of its total annual appropriations since the inception of the NNI to nanotechnology R&D, as reflected in table 3.4.

Table 3.4 NSF Annual appropriation in relation to NSF NNI annual funding.

<table>
<thead>
<tr>
<th>Year</th>
<th>total appropriation</th>
<th>% change</th>
<th>of which NNI funds</th>
<th>NNI funds as % of total</th>
<th>% change in NNI funds</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>4,430</td>
<td>N/A</td>
<td>150</td>
<td>3.30%</td>
<td>N/A</td>
</tr>
<tr>
<td>2002</td>
<td>4,790</td>
<td>8.13%</td>
<td>204</td>
<td>4.30%</td>
<td>36%</td>
</tr>
<tr>
<td>2003</td>
<td>5,340</td>
<td>11.48%</td>
<td>221</td>
<td>4.10%</td>
<td>8.33%</td>
</tr>
<tr>
<td>2004</td>
<td>5,580</td>
<td>4.49%</td>
<td>221</td>
<td>4%</td>
<td>-0.1%</td>
</tr>
<tr>
<td>2005</td>
<td>5,470</td>
<td>-1.97%</td>
<td>335</td>
<td>6.10%</td>
<td>51.58%</td>
</tr>
<tr>
<td>2006</td>
<td>5,580</td>
<td>2.01%</td>
<td>360</td>
<td>6.50%</td>
<td>7.46%</td>
</tr>
<tr>
<td>2007</td>
<td>5,910</td>
<td>5.19%</td>
<td>389</td>
<td>6.60%</td>
<td>8.06%</td>
</tr>
<tr>
<td>2008</td>
<td>6,070</td>
<td>2.71%</td>
<td>409</td>
<td>6.70%</td>
<td>5.14%</td>
</tr>
<tr>
<td>2009</td>
<td>6,490</td>
<td>6.12%</td>
<td>510</td>
<td>7.90%</td>
<td>24.69%</td>
</tr>
<tr>
<td>2010</td>
<td>6,930</td>
<td>6.78%</td>
<td>429</td>
<td>6.20%</td>
<td>-15.88%</td>
</tr>
<tr>
<td>2011</td>
<td>6,860</td>
<td>-1.01%</td>
<td>412</td>
<td>6%</td>
<td>-3.96%</td>
</tr>
<tr>
<td>2012</td>
<td>7,030</td>
<td>2.48%</td>
<td>426</td>
<td>6.10%</td>
<td>3.40%</td>
</tr>
<tr>
<td>2013</td>
<td>7,370</td>
<td>4.84%</td>
<td>435</td>
<td>5.90%</td>
<td>2.11%</td>
</tr>
</tbody>
</table>

Based on the NSF budgets available (National Science Foundation, 2012). NB, 2013 figures reflect the request, not the appropriation. 2009 figures reflect a one-time increase as a result of additional funding through the American Recovery and Reinvestment Act (ARRA).

The total NSF budget allocated to NNI projects rapidly grew to 6% of the total NSF budget, and stabilized at that percentage, with the exception of a one time ARRA investment in nanotechnology research in 2009. Up to 2010 the NSF invested a relatively larger percentage of its annual budget in nanotechnology than the overall
growth of its annual total budget, which leads to the conclusion that the NSF received additional new funding for nanotechnology, rather than redirecting existing funds.

However, over time enthusiasm for additional federal spending on nanotechnology seems to have lessened. That might be explained by the fact that some of the more wildly positive scenarios for nanotechnology applications have not yet materialized (Roco et al., 2011). The more plausible explanation is that nanotechnology has become a real ‘general purpose’ technology, which is so broad in use and applications that a distinct ‘nanotechnology’ label is no longer adequate or necessary. Also, the lower pace of spending reflects the broader pressure on the federal budget, as overall federal spending has been constrained since the economic recession hit in 2008. Though still a substantial program for government funding, government attention for nanotechnology seems to decrease and an urge for revitalization might become apparent, as economic, environmental, and societal challenges remain (Lane, 2005).

3.3.3 The NNI since 2000.

While the goals of the NNI have remained the same over the years, their interpretation and prioritization changed. Such amendments and adaptations came as the NNI achieved meeting certain goals, such as setting up a network of research and education centers, but also followed up to the recommendations of the various external reviews.
by the National Research Council’s review committee and President’s Council of Advisors on Science and Technology’s National Nanotechnology Advisory Panel (NNAP).

*Basic Research:* From the start the NNI centered on a sound scientific base and fundamental research into understanding materials and processes at the nanoscale level. Fundamental research remains a priority even as nanotechnology advances and certain products enter the market, as many uncertainties about the long-term consequences of nanotechnology remain (Roco M. C., 2007) (Whitman, 2007). With nanotechnology development progressing, new insights make research increasingly complex and nanotechnology has become a multi-faceted, general-purpose technology and efforts in basic research continue to clarify unknown phenomena at the nanoscale (Roco M. C., 2011). Thus, the main focus of the NNI remains basic research and almost 50% of its annual total budget is dedicated to areas of focus that can be considered fundamental research (National Nanotechnology Advisory Panel, 2010) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2011).

*Technology Transfer and Commercialization:* Even so, we see over time a greater emphasis on the transfer of knowledge and diffusion of technology. Fundamental research has led to more insights, which can be translated in applications to be commercialized. This, of course, is the main argument for public funding of science and technology: help industry to overcome the earliest, costliest, most uncertain phases of research. When passing the 21st Century Nanotechnology Research and Development
Act, Congress demanded regular reviews of the results of the NNI. Over the years, the
NNI has shifted its attention increasingly to fostering transfer of technology and
commercialization, which includes more research into application and use of
nanotechnology for economic and societal benefits. This shift fits well into the broader
innovation strategy put forward by the executive office of the White House in February
201121 (Sargent Jr., 2011) (Roco et al, 2011) (Subcommittee on Nanoscale Science,
Engineering, and Technology, 2011).

*Fostering State Initiatives:* The NNI Industry Liaison & Innovation Working Group is
dedicated to the support of technology transfer and to the stimulation of innovation
through partnerships with industry, universities, and also with different states that have
an interest in building out existing science and technology clusters or building up new
concentrations of science and technology. At least fifteen states have started
nanotechnology programs, which in general aim to create educational programs,
employment, and economic growth (Committee to Review the National
Nanotechnology Initiative, 2006) (Shapira P. &., 2007). Some states also dedicated
substantial funds to complement federal funding. Although exact data are difficult to
obtain, estimates by Lux Research show that states already invested up to $400 million

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21 Labeled ‘Strategy for American Innovation’, the innovation strategy builds on goals like the NNI: funding
science and technology development to benefit private industry as the ‘engine’ of American economic
growth and prosperity. The innovation strategy is a combined effort of the NEC, OSTP, and the President’s
Council of Economic Advisors (NEC, Council of Economic Advisors, and OSTP, 2011).
Two examples of such state co-funded initiatives seem most prominent: The State University of New York in Albany created a state-university-industry funded College of Nanoscale Science and Engineering at a total investment of approximately $150 million in 2004, to which in 2010 a Center of Nanotechnology Research, Education, and Economic Development was added (College of Nanoscale Science and Engineering, 2012). Southern California traditionally has a strong science community, as it is the home of several prominent University of California campuses, various research institutes, and a large technology-oriented industry. Supported by sizable federal, state, and private funds, the University of California established the California Nano Systems Institute in 2007. For the first four years, California committed $100 million to the institute, under the condition that state funding would be matched by other sources: industry and Federal grants have added another $250 million to the institute’s budget (California NanoSystems Institute, 2011) (Committee to Review the National Nanotechnology Initiative, 2006) (National Nanotechnology Advisory Panel, 2005).

Note that the two cases above are examples of path dependent clustering of research and development: before research funds for nanotechnology became available, both areas already housed prominent semi-conductor expertise. Further miniaturization of semi-conductors is often mentioned as an opportunity of nanotechnology.

The triennial external NNI reviews stress the need to enhance state-federal cooperation to benefit more from the combined leverage of funding from different public and
private sources (National Nanotechnology Advisory Panel, 2005) (Committee to Review the National Nanotechnology Initiative, 2006).

**Small Business Support:** Grants to small and medium-sized enterprises is an instrument that NNI participants increasingly use to stimulate technology and information transfer to industry. Nine of the participating agencies dedicate budget to support small and medium sized enterprises in developing nanotechnology-based products and services through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs. The SBIR & STTR programs were established under the Small Business Innovation Development Act of 1982 (P.L. 97-219) to strengthen the role of innovative small business by creating easier access to federally funded research. Subsequently, Congress passed numerous extensions, the most recent of which extends the SBIR program through 2017. Through 2012 over 112,500 awards have been made totaling more than $20 billion, of which more than 500 awards with a nanotechnology-related subject. Each year the amount of grants related to nanotechnology through the SBIR & STTR programs has increased, since the fiscal year 2010 to more than $100 million annually (Small Business Innovation Research Program, 2012) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2010) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2011) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2012).
The NNI supports technology transfer through a range of public-private partnerships, such as Department of Defense university affiliated research centers (UARCs), which are open for use by private partners (Subcommittee on Nanoscale Science, Engineering, and Technology, 2004). Building and maintaining a network of open access research centers is part of the strategy to achieve the NNI goal to build an infrastructure for nanotechnology research to support its development. Such infrastructure includes facilities, training and education, and a common set of tools, instruments, and definitions. The NNI aims to facilitate individual scientists, for instance through NSF research grants, yet its main focus goes to support multidisciplinary teams at universities and research facilities, which include a growing number of public-private collaborations at a growing number of research centers.

By 2004, the NSF had already established seventeen multidisciplinary research and education centers as part of the NNI’s foreseen National Nanotechnology Infrastructure Network (NNIN). By that time Department of Defense had funded three research centers, NASA established four research centers, and the Department of Energy (DOE) had established five Nanoscale Science and Engineering Centers at various national laboratory sites managed by DOE, adding to pre-existing facilities and science & technology agglomerations as such sites already were well established R&D centers (Subcommittee on Nanoscale Science, Engineering, and Technology, 2004). The number of nanotechnology related centers and knowledge networks, in different forms and formats and of course with different goals, quickly grew to sixty by 2010 and around
100 by 2012. The National Institute of Standards and Technology (NIST), which plays an
important role in nanotechnology by helping to develop common standards, definitions,
metrology, and nomenclature, created its Center for Nanoscale Science, and Technology
in 2007. Although the pace of the expansion of the NNIN is impressive, external reviews
stress the need to keep funding such centers, not so much to further grow the network,
but more to remain up-to-date as the NNIN is a foundation for progress in fundamental
research and the transfer of technology and information (National Nanotechnology
Advisory Panel, 2010).

Growing Focus on EHS Concerns: The 21st Century Nanotechnology and Research Act,
which despite Congressional preparations, has never been reauthorized by Congress,
intends to support nanotechnology development, while addressing the need to fund
research into environmental, health, and safety (EHS) concerns. It appeared difficult to
find the right balance (Fisher & Mahajan, 2006), yet the most notable development over
the years appears to be the increasing and more structured attention that NNI members
give to possible EHS consequences of ongoing nanotechnology development as well as
broader societal consequences such as ethical concerns (Shapira P. &., 2007), (Roco et
al, 2011). The attention includes both using and applying new materials and processes
(partially) based in nanotechnology to replace or amend existing materials and
processes which appear to be harmful or wasteful, as well as looking into how
nanotechnology might have negative consequences for the environment and human
health. A June 2011 memorandum from the White House Emerging Technologies
Interagency Policy Coordination Committee (ETIPC) urges relevant federal departments and agencies to address the EHS aspects in all nanotechnology-related matters is the basis of its responsible development (Emerging Technologies Interagency Working Group, 2011).

The growing attention to EHS concerns and perceived absence of information about possible risks is also seen in annual NNI budget allocations. Funds dedicated to EHS research tripled in size since 2005 (Subcommittee on Nanoscale Science, Engineering, and Technology, 2010) from $37 million to $105 million in the 2013 budget request, which is approximately 6% of total annual NNI budget overall investment in EHS research of around $650 million since 2005 (National Nanotechnology Initiative, 2012). Despite the attention for EHS and the resulting growth of the budget allocated to such research, the total annual investment in EHS issues, at 6% of the total NNI budget, remains relatively small and concerns remain about the availability of research findings:

In its most recent assessment of the NNI, the National Nanotechnology Advisory Panel concluded that the EHS-related research funded by the NNI should be more directed toward the goal of supplying relevant information to policy makers (National Nanotechnology Advisory Panel, 2012).

The NSET coordinates EHS aspects of nanotechnology through the NNI Environmental and Health Implications Working Group (NEHI), which consists of the five main agencies involved in EHS issues: EPA, NIST for standards and definitions, the National Institute for
Occupational Safety and Health (NIOSH) to enhance safety for people working with nanotechnology, the National Institutes of Health (NIH) for general public health, and since 2010 the Food and Drug Administration (FDA) for specific food and medical products (Subcommittee on Nanoscale Science, Engineering, and Technology, 2009). NNI added EHS implications as a separate program component in 2007 to accelerate progress and fill in the remaining knowledge gaps (Subcommittee on Nanoscale Science, Engineering, and Technology, 2008). NSET 2008 and 2011 EHS strategy documents focus on EHS aspects of all nanotechnology-related materials and processes, yet aim to prioritize research of a specific set of engineered nanomaterials\textsuperscript{22}, which seems to be the most likely to be widely used in products and processes (Subcommittee on Nanoscale Science, Engineering, and Technology, 2008) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2011). Research of the EHS aspects of nanotechnology is strongly embedded in international collaborations such as the OECD working party on Manufactured Nanomaterials and the ISO Technical Committee on Nanotechnologies (Environmental Protection Agency, 2011) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2011)\textsuperscript{23}.

Many engineered or manufactured nanomaterials might have a toxic component. NNI participants concluded early on that existing regulatory frameworks should be sufficient

\textsuperscript{22} Engineered nanomaterials, or manufactured nanomaterials, are purposely designed and manufactured materials, as opposite to matter or particles at the nanoscale that appear in nature.

\textsuperscript{23} The international engagement of the various NNI participants, in particular EPA and NIST – to create an international common understanding of standards, definitions, metrology, and terminology -, is the subject of the next section of this chapter (3.3.4)
to cover nanotechnology, including new materials, such as engineered nanomaterials, and novel ways to use well-known materials at the nanoscale, (Roco et al, 2011) (Renn, 2006) (Emerging Technologies Interagency Working Group, 2011). Yet, the manufacturing and use of engineered nanomaterials requires new information and new ways to assess which materials and which ways of using it might be safe or harmful in some way. As such, most engineered nanomaterials fall under the Toxic Substance Control Act of 1976 (TSCA). TSCA gives the Environmental Protection Agency (EPA) authority to regulate the use of chemical materials, which may be toxic in some way. Since 2005 over a hundred new manufacture nanoscale materials are under review by the EPA (Environmental Protection Agency, 2011). TSCA uses an integrated approach, which requires manufacturers of nanomaterials, or of products that contain engineered nanoscale materials or parts, to notify the EPA of its intention and the specifics of the materials. In cases in which well-known materials such as gold or silver are used for the first time at the nanoscale, TSCA requires manufacturers to notify EPA though a ‘significant new use’ notification. EPA and industry work together, sometimes mandated by EPA, but also voluntary as in the case of EPA’s ‘Nanoscale Materials Stewardship Program’, to develop information about nanomaterials and to learn more about the consequences of new use of existing materials, for instance by setting up specific tests of new materials, as much uncertainty remains at this point (Fiorino, 2010) (Environmental Protection Agency, 2011). EPA – industry cooperation is not always successful: The Stewardship Program, for instance, ended in 2009 with mixed results: too few companies participated to make real progress and the main conclusion was that
many gaps remain in the available knowledge of the risks associated with nanomaterials (EPA, 2009).

*Technology Assessment and Public Participation:* Assessing societal implications of nanotechnology and public outreach have been part of the NNI’s strategy from the onset. This role has become increasingly important as growing public awareness of nanotechnology draws more attention to associated risks and uncertainty. Public perception of risks led NNAP in subsequent reviews to recommend an increase in NNI efforts on public outreach to overcome overly positive expectations and unnecessary fears (Drexler E. D., 2004) (National Nanotechnology Advisory Panel, 2008). Coordinated by the NNI’s Nanotechnology Public Engagement and Communication Working Group (NPEC), public outreach programs and various opportunities for the public to influence decision-making - so-called models of participatory governance - became a fixed part of the NNI participants research programs, in particular in the second half of the NNI’s first decade (Roco et al, 2011). After having grown since the NNI’s establishment to an annual budget of approximately $40 million by 2010, the budget dedicated to societal implications and public engagement remains constant (Subcommittee on Nanoscale Science, Engineering, and Technology, 2012).

*The Role of Defense and National Security:* As noted, NNI-specific investments through the Department of Defense (DOD), which allocates half of the total annual science and technology budget of the United States, have decreased over time. Nevertheless
defense and national security motivations continue to be an important part of what the NNI has been set out to do. Notions of national security goals return in each of NNI’s strategy plans. Of course the budget that DOD dedicates to nanotechnology research is, at almost $300 million for fiscal year 2013, very substantial, and DOD remains in the top of overall NNI contributors (Subcommittee on Nanoscale Science, Engineering, and Technology, 2012). However, the notion by Neal Lane and Thomas Kalil, advisors to President Clinton at the time of the establishment of the NNI, that national security and defense became even more important as a driver of government support for nanotechnology research after the events on September 11, 2001 is not confirmed by any further documentation (Lane, 2005) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2011) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2004) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2007). It should be noted that many of the details the overall defense budget are classified and unspecified. While direct funding of nanotechnology research perhaps appears to decrease in recent years, reallocations of DOD funding for science and technology probably include programs that consist of certain nanotechnology components, yet are not included in the NNI overview for any range of reasons.

The relatively low profile of defense and security related research under the NNI umbrella captured the attention of the National Nanotechnology Advisory Panel (NNAP). In its latest assessment of the NNI, the panel suggests that Subcommittee on Nanoscale Science, Engineering, and Technology (NSET) should give more attention to
research related to matters of homeland security and national defense (National Nanotechnology Advisory Panel, 2012).

*Grand Challenges*: The original set of ‘Grand Challenges’, the prioritization of areas for research attention, has become less prominent over the years, probably because there were too many and their definitions were unclear. However in the budget supplement for the fiscal year 2011, NSET presented three Nanotechnology Signature Initiatives (NSIs), which were pushed in NNAP’s 2010 NNI review as well as the overall innovation strategy of the White House because of its sharper focus on applications, technology transfers, and possible commercialization: 24% of total NNI budget in 2013 is dedicated in one way or another to the initiatives (Subcommittee on Nanoscale Science, Engineering, and Technology, 2010) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2012) (National Nanotechnology Advisory Panel, 2010).

The Nanotechnology Signature Initiatives are:

- Nanotechnology for Solar Energy Collection and Conversion, to help develop a less carbon-dependent energy supply;
- Sustainable Nanomanufacturing: Creating the Industries of the Future, to help industry to scale up what’s currently possible with and by nanotechnology to a scale that is commercially viable;
Nano-electronics 2020, to further miniaturize OR change the way electronics work today (National Nanotechnology Initiative, 2012)\textsuperscript{24}.

*International Collaborations*: A last aspect of the NNI’s directional changes since 2000 is the level of international engagement and collaboration. As the NNI was conceived in a notion of growing international competition and even a concern of lagging behind other countries in nanotechnology development, American global prominence in nanotechnology has been confirmed since its establishment. In the years, the need to collaborate internationally in creating a common understanding of nanotechnology has strengthened. The different NNAP and National Research Council reviews confirm this need and recommend NNI participants to find international collaborations to accelerate nanotechnology progress (Committee to Review the National Nanotechnology Initiative, 2006) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2009). The globalized economy does not allow a country to set standards by itself. In order to be internationally competitive, products need to meet internationally accepted qualifications. Different international organizations and collaborations, such as OECD and ISO, help governments, scientists, and industries to define such qualifications. NSET added its NNI Working Group on Global Issues (GIN) to coordinate the NNI participants’ efforts in international collaboration in 2007 (Subcommittee on Nanoscale Science, 2009).

\textsuperscript{24} A recommendation of the 2012 NNAP assessment of the NNI suggests that NSET established a specific Signature Initiative for homeland security and defense (National Nanotechnology Advisory Panel, 2012).
Engineering, and Technology, 2007). Section 3.3.4 elaborates on the international engagement of NNI members.

In sum, over the years the NNI has kept a focus on fundamental research, yet it increasingly put more effort towards matters of technology transfer, EHS concerns, and broader societal implications of nanotechnology, while expanding and maintaining a network of multi-disciplinary, open access research infrastructure.

3.3.4 International Engagement of NNI Participants

Stakeholders in nanotechnology development around the world face similar scientific and technological challenges, which include trying to anticipate unknown consequences, both positive and negative, and addressing remaining gaps in knowledge and uncertainties associated with nanotechnology. To create a global common understanding, to facilitate an exchange of information, and to prioritize areas of shared research efforts, the NNI participants seek international collaboration as recommended by the different external reviews of the NNI. Non-proprietary issues, which support but not compromise any efforts by industry to create a competitive edge in the world economy, such as the definition of common standards, metrology, and nomenclature, or research priorities to advance insights in the environmental, health, and safety (EHS) aspects and risk issues in nanotechnology, make up the main part of international collaborations. The International Risk Governance Council (IRGC), an independent global

NSET has always supported an international dialogue. For instance, it organized international meetings in 2004 of twenty-five countries and the European Union (EU) and in 2008, when the number of countries involved had grown to forty-nine and the EU, to discuss common matters of interest in nanotechnology research and development, in particular about risk-related issues (Roco M. C., 2011) (Roco et al, 2011). Since 2007, the NNI’s Global Issues in Nanotechnology Working Group (GIN) coordinates and stimulates the U.S. contribution to international exchange (Subcommittee on Nanoscale Science, Engineering, and Technology, 2007).

Numerous international organizations have become involved in nanotechnology development, leading to new collaborations and networks established by different stakeholders in nanotechnology. For example, representatives of NNI participants are part the Global Nanotechnology Network, an industry-academia-government information exchange network focused on nanotechnology risks and EHS issues (Global Nanotechnology Network, 2011). Until 2011, NSF sponsored the International Council on Nanotechnology (ICON) at Rice University in Texas, to focus on the communication of risks and benefits of nanotechnology. Since NSF funding ended, ICON relies on

A range of international organizations facilitate joint research to better understand EHS risks of nanotechnology, reflecting the growing attention to understanding the risks of manufacturing and use of nanomaterials for the environment and public health. As mentioned in previous chapters, over the years, the Organization for Economic Cooperation and Development (OECD) and the International Organization for Standardization (ISO) have emerged as the main platforms for international knowledge building on EHS issues and nanotechnology metrology, standards, nomenclature and characterization of materials (Sargent Jr., 2011).

The OECD Working Party on Manufactured Nanomaterials (WPMN) was established in 2006 to facilitate international research of the EHS risks of manufactured nanomaterials. The EPA and the National Institute for Occupational Safety and Health (NIOSH) lead the NNI participation in such collaborations. After deliberations on how to proceed and which gaps of knowledge need to be addressed first, WPMN decided on a set of fourteen nanomaterials to be tested following an agreed protocol on a number of indicators that show possible effects of the manufacturing and use of such materials. The U.S. participants in the OECD Working Party on Nanomaterials are sponsors of five of the fourteen test projects, showing the strength of their capabilities while addressing
their goal of creating a responsible way of developing nanotechnology (Organisation for Economic Co-operation and Development, 2009).

The OECD also established the Working Party on Nanotechnology (WPN) in 2007 to address broader policy issues regarding responsible and sustainable development of nanotechnology. The U.S. Department of State, a NNI participant, is a founding member, and the Food and Drug Administration (FDA) recently became involved when WPN started to develop an overall regulatory framework for food and medical products. Any international agreement on such regulatory matters has obvious implications for U.S. corporations that rely heavily on international trade (Organisation for Economic Co-operation and Development, 2010) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2012).

The EPA has been a leading partner in discussing so-called ‘transatlantic’ regulatory convergence between the European Union (EU) and the United States, in particular regarding manufactured nanomaterials, under the U.S. TSCA and EU REACH25. As the U.S. and the EU support the world most important nanotechnology research programs, together they can ‘set the tone’ of how to address regulatory issues, for instance with regard to the remaining risks and uncertainty of nanotechnology. Transatlantic coordination, and trying to overcome differences between the European and American

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25 REACH: Registration, Evaluation, Authorization and Restriction of Chemical Substances (EC law 1907/2006). The next chapter will present REACH in more detail.
regulatory framework, will advance responsible nanotechnology development in the United States and the European Union (Breggin et al, 2009) (Faulkner, 2009).

On another front, experts of both industry and government agencies from 163 countries work together in the International Organization for Standardization (ISO) to set standards and agree on nomenclature and definitions that from the basis of a common international understanding of, in this case, nanoscale science, engineering, and technology. The ISO, a network of national standard setting institutes, sets standards based on consensus in specifically designated technical committees (TC). It established TC 229 Nanotechnologies in June 2005. Yet, many nanotechnology-related matters might be addressed on one of the other ISO TCs, given nanotechnology’s multi- and interdisciplinary character (International Organization for Standardization, 2011). U.S. participation in the ISO is coordinated by the American National Standards Institute (ANSI), and includes experts drawn from a wide range of federal agencies who participate in the various working groups set up under TC 229. Given U.S. economic prominence, ANSI claims that American standards often become worldwide standards through such international collaboration (American National Standards Institute, 2012).

3.3.5 NNI Today - Results and the Future

Today the NNI stands for over a decade of direct federal funding of nanotechnology to the amount of more than $18 billion, in its widest interpretation and execution,
relatively and absolutely by far the largest government program for nanotechnology in the world (Sargent Jr., 2011) (National Nanotechnology Initiative, 2011) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2012).

All external reviews evaluate the NNI as a well managed new and effective though high-level way of cooperation between the various agencies and departments that participate. The NNI is seen as a science driven open program that relies on wide connections to industry and outside stakeholders, such as different states. Overall, all reviews conclude that the substantial investments in nanotechnology as coordinated and presented by the NNI have been well spent (National Nanotechnology Advisory Panel, 2008) (National Nanotechnology Advisory Panel, 2005) (National Nanotechnology Advisory Panel, 2010) (Committee for the Review of the National Nanotechnology Initiative, 2002) (Committee to Review the National Nanotechnology Initiative, 2006)

All reviews also confirm that the United States continues to be the global leader in nanotechnology development and commercialization (National Nanotechnology Advisory Panel, 2005) (National Nanotechnology Advisory Panel, 2008) (National Nanotechnology Advisory Panel, 2010) (Sargent Jr., 2011). However, international competition has intensified, in no small part because over sixty countries have started their own nanotechnology programs, partially inspired or motivated by the establishment of the NNI (Roco M. C., 2011). Yet, given international collaboration, any
build-up of global research capacity benefits the responsible development of nanotechnology in the United States as well.

NNI participants have established a research infrastructure of over one hundred large nanotechnology oriented research centers, networks and uses facilities since the launch of the NNI in 2000 (Subcommittee on Nanoscale Science, Engineering, and Technology, 2011) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2012). Reviews show that universities around the United States have set up educational and training programs. The NNI participants often support such programs, though the initiative and execution remains with the educational institutes (National Nanotechnology Advisory Panel, 2005).

Nanotechnology is on track to become a general-purpose technology, which is based on interdisciplinary synergy between science fields (Roco M. C., 2011). There is not a single application or product, but a wide range of applications is feasible and some of these products have already entered the market (Toth, 2009) (Project on Emerging Nanotechnologies, 2012). The first phase of the NNI - setting up a multi-disciplinary nanotechnology research and development system in the United States - seems to be achieved. The next decade should bring next phase of nanotechnology development, which should help to materialize the promise of nanotechnology by offering fundamentally new products and services based on nanotechnology (Roco M. C., 2011).
The next phase of nanotechnology development needs to increase the transfer and diffusion of technology and knowledge and to speed up commercialization of nanotechnology based products, as fundamental insights in materials and processes at the nanoscale advance (National Nanotechnology Advisory Panel, 2010).

Estimates for the near future for both the world and the United States by market research companies such as Lux Research and Cientifica26 show the following results: By 2015, approximately two million people worldwide are to be working in nanotechnology, of which 800,000 in the United States alone. Of an expected one trillion US dollar global market for products of which nanotechnology components form a key part, the U.S. market is to account for $400 billion. More than 3,000 companies in the United States work in one way or another with some form of nanotechnology (Hullman, 2006) (Palmer, 2009) (Roco M. C., 2011) (Sargent Jr., 2011). Since 2004, NNI members have awarded over $650 million in grants to small and medium sized companies that engaged in nanotechnology research and development in order to support faster commercialization and innovation based on nanotechnology (Subcommittee on Nanoscale Science, Engineering, and Technology, 2012).

Of course official external reviews and wider critical assessment of the NNI have comments and suggestions on the performance and achievements of the NNI as well. Such critique fits traditional opinions about government involvement in science and

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26 Lux Research and Cientifica are commercial consultancy firms. There data are not publicly available. However the sources mentioned referred to their data.
technology in general. The constant call for more rapid application and commercialization of publicly funded nanotechnology for the benefit of society is a part of the most recent external review by both NNAP and the National Research Council.

On a different note is the critique that the NNI is very much a political vehicle and too engaged in applied research instead of in more fundamental research, which might lead to the NNI ‘picking winners’ (Peckerar, 2004). The notion of ‘picking winners’ refers to the possibility that the government, by actively supporting certain research directions, institutes, or companies, but excluding other, often competing, alternatives, determines which directions or companies show most potential, thus disrupting the dynamics of market demand and supply. In the wake of that argument follows the idea that too much focus on rapid commercialization is too aggressive and might be dangerous, as possible harmful consequences of nanotechnology might be overlooked: nanotechnology research should take more precaution given the remaining uncertainties and gaps in knowledge (Sargent Jr., 2011).

In sum, U.S. government support of nanotechnology represents a variation of past practice and reflects lessons learned from previous large-scale ‘Big Science’ government funded and coordinated projects. The set up of the National Nanotechnology Initiative is a new way of addressing an emerging field of science and technology that offers transformative potential for society and mankind: the enactment of a specific legal frame, the decentralized budget authority at the agency and department level, the
number of participating agencies and departments, the coordinating role of a smaller office toward annual budget proposals and a common research agenda, yet allowing great autonomy for the participating agencies and departments, and the regular reviews by outside experts are all aspects, which are not in itself unique, but in combination realize a novel format for a national program in science and technology, that builds on pluralist traditions of policymaking.

Some aspects of nanotechnology, though not specific for nanotechnology itself, did influence the shape of the government approach: The broad and multidisciplinary nature of the scientific field of nanoscale research, with its numerous possible applications as an enabling technology, demanded any government approach to be based on advancing scientific insights when addressing such a complex field of human inquiry, in which so much remained unknown and uncertain. Also, the wide range of possible application initiated the interests of so many federal agencies and departments, which allocate parts of their annual budgets to research.
4.1 Introduction

This study tests the hypothesis whether the shape, size, and policy priorities and preferences of national government support for nanotechnology are driven not by the intrinsic nature of the technology but by longstanding structural and institutional arrangements. It contrasts the government approach of emerging nanotechnology in the United States with that in the Netherlands. One would assume that a legacy of corporatism in the Dutch political system and a tradition of greater government coordination of the national economy might be favorable for the conception of a centralized government program to support nanotechnology development, like in the United States. However, as observed, in the Netherlands the path taken was less directive, more incremental, and more embedded in pre-existing institutional arrangements, both at the national level and, at a higher level of governance, the European Union. The Dutch government relied on existing relations among universities, public research funding organizations, and industries to advance nanotechnology development in the Netherlands, with public support through traditional channels for public research funding. Over time, Dutch government involvement in nanotechnology grew to be more directive and comprehensive by setting clear requirements and policy priorities as a condition for public investments in nanotechnology research and by notably stating a preference for embedding of any Dutch policies in broader European policy frameworks. This chapter offers a larger frame of traditions and institutional
arrangements in Dutch policymaking and the international and European regimes in which Dutch science, technology, and innovation policies are embedded as a prelude to the next chapter, which presents the actual case of government support for nanotechnology in the Netherlands.

4.2 Traditions of Governance in the Netherlands

Traditions of governance in the Netherlands have two dimensions. The first is situated at a national or domestic level of government in the Netherlands: the legacy of long-standing traditions of consociationalism and corporatism in Dutch policymaking. The second lies at European and international levels. European economic and political integration, and the Dutch participation in it, is a phenomenon that started after the devastating results of World War II. Policymaking in the Netherlands is strongly embedded in an international, and in particular European, setting.

In the Dutch parliamentary system, the government – a Cabinet led by the Prime Minister – relies on the support of a bicameral parliament. As with any parliamentary system, new elections typically are called when the parliament loses its confidence in the government (Andeweg & Irwin, 2009). The Netherlands maintains an electoral system based on proportionality, in which any political party reaching the electoral threshold is represented in parliament. As a result legislators from a multitude of political parties fill the two chambers that together form parliament. No political party
has ever won an absolute majority in Dutch parliament. As a result, the cabinet is
typically based on a coalition of the different participating political parties and in general
is based on majority support in parliament (Andeweg & Irwin, 2009). However, for the
first time since the World War II, the 2010 elections resulted in a minority government
(Hylarides, 2011), which relied on broader ad hoc support in parliament.

The last decade have been rather tumultuous for Dutch democracy: increasing voter
volatility, political polarization, and even violence, shook up a previously rather
contented political establishment. This comparative volatility resulted in a rapid
succession of cabinets, six since 2002 (Rijksoverheid, 2012). However, even with this
relative turmoil, there remains a remarkable consistency in successive governing
coalitions: all are led by or include the centrist Christian Democratic party (CDA) and the
business oriented liberal party VVD, with the exception of a three year period between
2007 and 2010 in which CDA formed a coalition with the labor party (PvdA)
(Rijksoverheid, 2012) and the most recent elections which led to a VVD – PvdA coalition,
excluding centrist CDA. Such consistency of coalition partners, out of a range of some
ten political parties represented in parliament, has led to relative continuity in many
areas of Dutch policymaking.
4.2.1 Consociationalism and (neo-) Corporatism

When studying traditions of governance in the Netherlands, two concepts continually emerge: consociational democracy and (neo-) corporatism. Although scholars might disagree about these concepts and their application towards the Dutch way of governing, there is a general understanding that Dutch governance builds on a long tradition of seeking broad consensus about large policy questions. The notion of consociationalism, also referred to as consensus democracy (Kickert, 2003), was brought forward first by Arend Lijphart in describing the way the Dutch political system was set up to accommodate the preferences of different societal groups (also called ‘pillars’) that made up the pluralist Dutch society until the late 1960s (Lijphart, 1968). The idea of consociationalism is to overcome deep societal cleavages by having a political system in which the elites of the different ‘pillars’, represented by different political parties in parliament, agree to find pragmatic solution-oriented compromises for broader policy issues by ways of often covertly negotiated settlements in which all parties have a proportional input (Lijphart, 1968). In the Netherlands such societal groups originate from religious backgrounds (with distinct Catholic and Protestant ‘pillars’) as well as ideological ones, in particular the socialists and in a lesser stringent way a liberal group. A consociational democratic model thus seeks consensus on political issues, explaining why the labels consociational democracy and consensus democracy are used interchangeably (Kickert, 2003). Such a model of governance is characterized by wide and long deliberations and consultation of many stakeholders and parties in the
decision-making process (WRR, 2007) (Bovens, 2005) (Rood, 2005) (Esther, 2011) (McCormick, 2005) (MASIS Expert Group, 2009) (Andeweg & Irwin, 2009). Arguably, such notions of Dutch consociationalism have roots that go back as far as the 16th century, when the provinces, cities, guilds, and powerful international merchants in the low countries during the Dutch ‘Golden Age’ sought to accommodate their interests through structured consultation within the constellation of the Dutch Republic, allowing for social tolerance as long as economic interests were safeguarded (Kickert, 2003). The pillarization of society peaked in the decades after World War II during years of reconstruction, economic growth, and the build-up of the Dutch welfare state (Kickert, 2003). Despite overall declines in pillarization since the late 1960s as a result of greater democratization of society and ongoing secularization of the population, there remain more recent examples of broad-scale political compromise that revive the notion of consociationalism, including the government – labor – industry agreements on income policies in the 1980s (Woldendorp, 2007) or the decision to allow euthanasia under certain well-defined conditions in the 2000s (Green-Peterson, 2007).

A telling example of traditions of consociationalism in Dutch policymaking – labor bargaining rights and income policies – is the system of structured negotiations between different actors or interests groups, facilitated or initiated by government, which has found a much wider application in industrial democracies around the world:
Corporatism or neo-corporatism\textsuperscript{27}. In such a system, in place in most Western European countries in the second half of the 20\textsuperscript{th} century, government invites, or instructs, employers’ organizations and labor unions to cooperate and coordinate decisions on economic, social, income, and labor policy issues in a three party (tripartite) consultation (Siaroff, 1999). Posed as an alternative to a system of classical free market capitalism, the principle of corporatist negotiations is to avoid competition between the different interest groups that may lead to political and social instability and to find common ground to achieve a broad agreement on economic policy (Kickert, 2003) (Woldendorp, 2007).

Although the first examples of corporatism as a tool of policymaking in the Netherlands date from the 1930s, when the first laws on collective labor bargaining were promulgated, by some accounts the most prominent Dutch application of neo-corporatist consultation between government, labor unions, and industry appeared in the early 1980s, when tripartite consultation to achieve economic growth by agreeing to wage moderation was such a success that it became known as the \textit{Polder Model}, named after parcels of land, often below sea level, which were maintained largely through collaborative efforts by farmers (Andeweg R. B., 2000). Even when scholars disagree on the definition of neo-corporatism and how it applies to the Netherlands, there is agreement that corporatist models of consultation and negotiation are part of the  

\textsuperscript{27} The ‘neo’ in neo-corporatism refers to free association of interest groups represented in corporatist consultations in contrast to government organized interest representation in corporatist system, though the terms are used interchangeably to describe such systems in use today (Lehmbruch, 1977).
broader consociationalist tradition of governance that is distinctive for the Dutch process of policymaking (Woldendorp, 2007). It leads scholars to define the Netherlands as a coordinated market economy (Ahlquist & Breunig, 2009).

As mentioned, traditional pillarization of society hardly exists anymore in Dutch society today (Kickert, 2003) (Andeweg & Irwin, 2009). The political system has become more pluralist and in particular in the last decade political discordance has grown. However, much of the pre-existing institutional set up of policymaking remains and enjoys high legitimacy. As a result, in many policy fields multi-stakeholder consultation, which includes government representatives as well diverse non-government actors and interest groups, remains the norm (Kickert, 2003).

4.2.2. International Collaboration and European Multi-level Governance

Dutch policymaking traditionally has a strong international dimension. As a small country located in the heart of the European continent, trade is the foundation of Dutch foreign policy. The Dutch dependence of international trade explains the tradition of widespread international engagement of the Netherlands, which focuses on fostering trade, and maintaining peace, and building international rule of law (Voorhoeve, 1979).

Dutch foreign policy seeks to address international challenges in inter- and supranational cooperation, such as in the European Union, rather than setting out to
formulate a specific national role for the Netherlands and the Dutch government in broader international affairs: a smaller country such as the Netherland may see its interests better represented in a common regime that applies to all its members, than in a continuous international power play in which the interests of larger countries may prevail (Andeweg & Irwin, 2009). Nevertheless, given its international outlook, the Netherlands does not limit itself to the European Union, but, as mentioned, plays an active role in a whole range of international organizations such as the North Atlantic Treaty Organization (NATO), the World Trade Organization (WTO), the Organization for Economic Cooperation and Development (OECD), and the International Organization for Standardization (ISO), to name but a few examples. Based on membership of international political engagement, economic integration, technological connectivity, and personal contacts, the Netherlands is considered one of the most globalized countries in the world (Foreign Policy, 2007).

Its long-standing tradition of international engagement and its dependence on international trade explain the participation in and the contribution to European political and economic integration since World War II. As a founding member of what has become the European Union, a substantial part of Dutch legislation is directly or indirectly influenced by the subsequent European treaties, European laws, directives - which have to be translated into national laws -, guidelines, and European agreements (Versluis, 2011). In fact, policymaking in the Netherlands is often an example of multi-level governance (Hooghe and Marks 2001), in which influence in policymaking is shared
across different levels of government, either local, national, or European, and much interaction between the levels takes place during the policy process from initiation to execution and evaluation.

Nevertheless much discussion remains about how much of national legislation and policies are shaped by the European Union. For example, Bovens (2005) shows that approximately 18% of Dutch laws are directly the result of European directives (Bovens, 2005), while other policymakers and scholars estimate that 40% to 80% of national policymaking in member states of the European Union is influenced to some degree by broader European politics (Bovens, 2005) (Andeweg & Irwin, 2009). The argument goes, for instance, that participants in the national policymaking process, either from government or from outside interest groups, are always aware of broader European influences and consequences: any decision in domestic policymaking has to match high-level agreements as accepted by the EU member states in the different treaties that are the foundation of the European Union.

Regardless of the exact level of European influence from the top down, national Dutch policies are interlinked with European policies in both directions: top down European treaties, laws, directives, and guidelines shape national Dutch policies and the way the government translates and implements European directives into national legislation, while at the same time the standpoints of the Dutch government, and the input of its policymakers, experts, and interest groups, help to mold European policies. Shaping the
supranational regime of the European Union is an ongoing interplay between the Union, represented by its different institutions in which the member countries participate, and the national governments of the member states (Bovens, 2005) (Rood, 2005) (McCormick, 2005).

The foundation for European political and economic integration rests on the principle of *subsidiarity*, which posits that political decisions are to be taken at the lowest level of governance possible: The European Union only will undertake policy initiatives, when member states themselves cannot achieve similar effective results or when the issues at hand have cross-border consequences (McCormick, 2005) (WRR, 2007). Based on the principle of subsidiarity, European policy should thus be complementary to national policies. However, decades of integration, and the ever-widening scope of the European Union policy fields, have made it increasingly difficult to distinguish between national and European interests (WRR, 2007).

Policymaking in the European Union traditionally has a rather ‘functional’ approach. Functionalism, as a theoretical framework applied to cooperation between independent states, refers to a notion in which states work together in specific fields of common interest such as political stability, national security, economic development, or environmental protection to incrementally bridge gaps and be more efficient and effective than acting on one’s own. Functionalist cooperation is based on a certain joint idealism shared by the states. The start of European integration can be assessed
through a functionalist lens (McCormick, 2005) (Versluis, 2011). Today European cooperation is still based a functionalist approach, even if its original idealism seems to have waned a bit. In this regard we can talk about ‘neofunctionalism’ as a theoretical model based on functionalism, but one that assumes that states work together to achieve common goals based more on pragmatism rather than idealistic motivations, meaning that states work together to achieve goals that are in their own national interest (McCormick, 2005) (WRR, 2007) (Versluis, 2011).

Influence of the member states on policymaking in the European Union is not limited to participating in votes on proposal in the Councils or the European Parliament. Besides the domestic implementation of directives and guidelines, which may differ per member state, the preparation of policy proposals in the European Union is in general the result of a co-production process which includes deliberations between European politicians and European bureaucrats - who obviously are citizens from various European countries even as they represent the Union - experts and policy makers that act on behalf of different member countries, and other stakeholders such as representatives from relevant interest and issues groups, and industry (Versluis, 2011). Different Directorate Generals, the executive departments of the European Union, prepare most of the EU policy proposals, at the request of the European Commission. For these policy proposals they ask input from policymakers and experts from the different members states.
Multi-level Policy Preparation

As mentioned in previous sections of this chapter, policy preparation in the Netherlands traditionally is a consensus-oriented process of consultation between all stakeholders involved. The European policy-agenda is filled with issues which might come from different places: the European Commission may conclude that certain topics need European attention, the governments of member states might press the Commission to take action on certain matters, or members of the European Parliament may take such initiatives (Versluis, 2011). Once an issue becomes the subject for European involvement, the Commission informs the member states of its intentions.

The Dutch government established an interdepartmental working group on the assessment of new Commission proposals (BNC), which is led by the Ministry of Foreign affairs. BNC assesses all Commission proposals. It checks whether the proposal meets the criteria of subsidiarity on which European policymaking is based. This increasingly has become more difficult as, at least as perceived by subsequent Dutch governments, the national interest often converges with a common European interest (WRR, 2007). BNC assigns the relevant department that should take up the coordination of the Dutch position of the proposal. In the Dutch tradition of decentralization and broad consultation, it determines which other departments and government agencies that should be involved in the matters (Versluis, 2011). In general, Dutch input in European

28 Which is rather remarkable as the fact that the Ministry of Foreign Affairs leads such a working group shows that the position of the European Union lies in the realm of foreign policy, rather than of domestic policy.
policymaking is pragmatic and expert-based: A 2007 study by the Scientific Council for Government Policy on how to embed European Union policymaking better in Dutch society and how to improve the legitimacy of European policies concluded that the Dutch involvement in European policymaking tends to be technocratic, depoliticized, and, in a neofunctional manner, focused on results and outcomes for domestic policy issues (WRR, 2007) (Andeweg & Irwin, 2009).

Recent studies about the top down influence of ‘Europe’ on Dutch policymaking and the bottom-up influence of Dutch policy standpoints in shaping European policies concluded that Europe has become a general part of Dutch policies. In general the European Union offers the Netherlands a range of opportunities that are in the national interest: For instance, the European Union offers the Dutch government the possibility to transfer politically contentious, expensive, or difficult cross-border issues, such as environmental pollution, immigration, foreign affairs and security, as a whole or partial to the supranational level of the European Union. European pooling of resources may create a shared and possibly more effective and less expensive solution possible. (WRR, 2007).
Also, a European policy initiative is at times a tool to stimulate a coordinated effort within the in traditionally fragmented Dutch policy process to come up with a unified Dutch opinion as input for European deliberations (Andeweg & Irwin, 2009).
Government engagement in science and technology in the Netherlands dates back to the 19th century. However, only in the decades after WW II, and in particular since the late 1960s, has government involvement in science and technology evolved to a more or less comprehensive and institutionalized policy field that includes education, research and research funding, and –increasingly – the notion of innovation. Figure 4.1 gives a timeline of relevant events in the development of Dutch science and technology policy and the institutional establishment that in different ways helped and resulted from that development. While the timeline is condensed, some trends seem clear. First, in the decades since the 1960s a more integrated multi-actor consultation system on matters of science and technology has emerged, marked by collaboration among representatives of government, research institutes, academia, and industry. The government and its advisory councils emphasize participation of private enterprise in publicly funded research and development. Second, the focus of science and technology policies is increasingly on the application of knowledge and on innovation to spur economic growth and advance the Dutch competitive position globally and within Europe. Finally, total public spending on research has remained stable and relatively low never reaching more than 1% of GDP\(^29\).

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\(^{29}\) Below the European targets set in the Lisbon Agenda (2000) and the Barcelona goals (2003) (Muldur, 2006) as will be discussed in the next paragraphs.
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1808</td>
<td>First predecessor of the Royal National Academy of Sciences established</td>
</tr>
<tr>
<td>1876</td>
<td>First government funded research facility: Agricultural test station</td>
</tr>
<tr>
<td>1932</td>
<td>Establishment of the Netherlands Organization for Applied Research (TNO)</td>
</tr>
<tr>
<td>1938</td>
<td>Royal National Academy of Sciences (KNAW) established</td>
</tr>
<tr>
<td>1950</td>
<td>Organization for Pure Scientific Research (ZWO) established</td>
</tr>
<tr>
<td>1950s</td>
<td>Large industrial procurements by government for reconstruction and rearmament</td>
</tr>
<tr>
<td>1957</td>
<td>Public spending on research 0.4% of GDP (Reijnders, 1972)</td>
</tr>
<tr>
<td>1957</td>
<td>U.S. administration establishes the Presidential Science Advisory Committee (PSAC)</td>
</tr>
<tr>
<td>1960s</td>
<td>Growing focus on development of information technology industry</td>
</tr>
<tr>
<td>1966</td>
<td>Dutch government established the Advisory Council for Science Policy (RAWB)</td>
</tr>
<tr>
<td>1970s</td>
<td>Growth of science and technology oriented policymaking</td>
</tr>
<tr>
<td>1972</td>
<td>Establishment of the Scientific Council for Government Policy (WRR)</td>
</tr>
<tr>
<td>1979</td>
<td>Ministry of Economic Affairs starts first innovation program for public - private cooperation</td>
</tr>
<tr>
<td>1987</td>
<td>ZWO becomes main public research funding organization NWO</td>
</tr>
<tr>
<td>1987</td>
<td>Establishment of research advisory councils for each ministry</td>
</tr>
<tr>
<td>1990</td>
<td>RAWB includes technology and becomes the Advisory Council for Science and Technology (AWT)</td>
</tr>
<tr>
<td>1993</td>
<td>Reform of education system</td>
</tr>
<tr>
<td>1997</td>
<td>Establishment of Leading Technology Institutes (LTIs): public - private collaboration</td>
</tr>
<tr>
<td>1998</td>
<td>First public investments in research funded by national income of natural gas sales</td>
</tr>
<tr>
<td>2003</td>
<td>Second FES funding round includes nanotechnology program</td>
</tr>
<tr>
<td>2004</td>
<td>Establishment of the Innovation Platform, led by the prime minister</td>
</tr>
<tr>
<td>2006</td>
<td>Public research spending approx. 0.6% of GDP</td>
</tr>
<tr>
<td>2006</td>
<td>Comprehensive public program to enhance knowledge creation</td>
</tr>
<tr>
<td>2010</td>
<td>FES funding round continues nanotechnology program</td>
</tr>
<tr>
<td>2012</td>
<td>Comprehensive innovation program: <em>TopSectoren</em></td>
</tr>
</tbody>
</table>
In the years of economic depression between the two World Wars, the Dutch government established the Netherlands Organization for Applied Research (TNO), an independent but publicly funded research organization that conducts research for industry and government on a contract basis (Jongbloed, 2008) (TNO, 2012). The Royal National Academy of Sciences was established in 1938 as an advisory council for the government. However, it took the destruction of the years of occupation during the World War II for Dutch government involvement in science and technology to take off. The country needed to be rebuilt after the war and, with the onset of the Cold War, the armed forces had be strengthened to counter the emerging threats from the Soviet Union and its partners in Eastern Europe. Postwar Dutch governments developed a focused industrial policy based on the procurement of materials and equipment (Reijnders, 1972). Direct public spending on research stood around 0.4% of the national GDP around that time (Reijnders, 1972). To foster scientific research, in 1950 the government established the first public research funding organization, ZWO, but limited in involvement in the ZWO’s activities to funding. It hardly concerned itself with how the ZWO aimed to fulfill its mandate (Van der Meulen, 1998).

The government kept its focus on industrial development in the years that followed the reconstruction period. Companies, of which the most notable is the electronics firm Philips, received government support in the development of a viable information technology industry (Van den Ende, 2004). Besides its focus on industrial development, the government widened its attention to the possibilities that science and research
might offer society and the economy. Government involvement in science and technology has, at times, been intense, but note that no ‘Big Science’ – like projects such as in the United States have ever been undertaken by the Dutch government. The creation in the U.S. of the Presidents Science Advisory Committee (PSAC) in 1957 set the example for the establishment of a more formal advisory committee for the Dutch government, which eventually took place in 1966 when the Advisory Council for Science Policy (RAWB) was created (Brickman, 1979), followed a couple of years later, in 1972, by a more broadly mandated Scientific Council for Government Policy (WRR) (WRR, 2012).

Around 1972 public spending on research reached approximately 1% of GDP (Reijnders, 1972), higher than current levels of approximately 0.75% of GDP. More important, the large economic disruptions as a result of 1970s energy crises prompted successive Dutch governments to increasingly focus research spending as key to technological innovation and economic growth. The Ministry of Economic Affairs introduced its first innovation-oriented programs, which funded collaborations between research institutes and industry, for the first time in 1979. These programs are still in place (Van der Meulen, 1998) (Jongbloed, 2008).

The late 1980s and early 1990s saw changes in the national research system, which was perceived to have grown inefficient and disconnected from government and society. In 1987 the rather independent ZWO was reformed to become the nation’s main research
funding organization (RFO), the Netherlands Organization for Scientific Research (NWO). NWO also saw a large increase in its mandate and budget, both focused on accelerating Dutch scientific research in size, scope, and quality. At the same time the links between the NWO and the overseeing Ministry of Education, Science, and Culture became more intense (Van der Meulen, 1998) (Versteegh, 2000). In 1990, the Advisory Council for Science and Technology Policy (AWT) succeeded the RAWB, which broadened its focus beyond basic science to include technology and applied research. In 1993 the national system of universities and professional vocational schools was reformed to allow for more research and development, better linkage to private enterprise, and more diffusion of knowledge created by the educational system (Versteegh, 2000).

The focus on innovation as a principle for government engagement in science and technology intensified in the late 1990s. The government and its RFOs encouraged more public – private collaboration through the creation of Leading Technology Institutes (LTIs) since 1997 (Jongbloed, 2008), as well as what became known as the Economic Reinforcement Fund (FES) to allocates public income from natural gas sales for infrastructure projects. Since 2005 the Economic Reinforcement Fund, which is managed by the Ministry of Economic Affairs and the Ministry of Finance, includes a specific domain for ‘Knowledge, Innovation, and Education.’ Funds from FES and comparable initiatives supplement the budgets of departments that submitted proposals (Commissie Meijerink, 2010) but did not increase the overall public research
budget, which in recent years has averaged around 0.7% of GDP, or around 600 million euro in 2009 (OECD, 2012) (World Bank, 2012).

The Cabinet created the Innovation Platform in 2004 to establishment a broad program of innovation. In 2006 the platform proposed an agenda for investments in knowledge creation: the Kennisinvesteringsagenda 2006-2016 (or Knowledge Investment Agenda) which proposed what the Dutch government, industry, educational institutes, and citizens themselves should do to advance creation and application of knowledge in the Netherlands to be able to compete in the global economy (Innovatieplatform, 2006).

The increasing focus on knowledge and applying knowledge to foster societal and economic innovation has become the focus of an increasingly integrated and comprehensive government program in science and technology that aims to strengthen links between economic development, scientific research, technological progress, and education (Ministry of Economic Affairs, 2004) (Eurostat, 2012). Most recently, within the frame of the lingering European economic crisis, the Dutch government offered its Top Sectoren program to foster public-private research collaboration as the foundation for advancing the Netherland to the global top 5 of knowledge-based economies in the world by 2020. An important cornerstone of this program, developed with consultation of government, academia, research institutes, and industry, is to build on cooperation between research and enterprise in order to develop the most promising and achieving sectors of Dutch industry. The program also seeks to increase total Dutch research
budgets (private and public) to 2.5% of GDP. For 2012 agreements between government and industry foresee a joint investment of around 2.8 billion euro (Ministry of Economic Affairs, 2012).

*Science, Technology, and Innovation Policies Today: Framing & Funding*

Dutch science and technology policymaking and research funding today reflects the institutionalization of consociational democracy after the Second World War. In this regard, the government to a large extent delegates policy preparation and research funding decisions on matters of science, technology, research, and development to a substantive intermediary level of consultation, which is situated between the legislative and executive branches of government (Van der Meulen, 1998) (Brickman, 1979). This intermediary level consists of multiple advisory councils and public research funding organizations, which include representatives from government, research institutes, universities, and industry (Van der Meulen, 1998) (Jongbloed, 2008). A strong focus on consensus and multi-stakeholder consultation remains the norm. Through its participation at all levels of consultation, private enterprise is well represented in decision-making. In fact, public-private partnerships and collaboration between government, academia, and industry in which partners share investments as well as returns, either economic or social, are common in matters of science and technology development in the Netherlands (Versteegh, 2000) (Ministry of Economic Affairs, 2004) (Life Sciences 2020, 2010).
While science and technology policies in the Netherlands have increasingly become focused on innovation, and as such are coordinated by the Ministry of Economic Affairs (ELI), crucial roles remain with the Ministry of Education, Culture, and Science (OCW), which traditionally coordinates public efforts in science, research, and education, and the Ministry of Infrastructure and the Environment (IM)\(^{30}\), which coordinates the governance of risks associated with scientific and technological endeavors.

The two sides of science and technology – its possible benefits and its potential risks - are the cornerstones of Dutch science and technology policies. Over the years Dutch science and technology policies have become more integrated, addressing opportunities of science and technology under the condition of mitigating the associated risks in a single approach. The idea of integrated and comprehensive policies has become the norm and a condition for public funding of research in the Netherlands.

Figure 4.2 presents a condensed overview of the Dutch research system: It shows the many actors and stakeholders involved at the different levels of decision-making, policy preparation, advice, and implementation of science and technology policies. It reflects the double or rather integrated focus of science and technology policies and programs: sustainable, responsible, and risk-conscious scientific and technological progress as the

\(^{30}\) The Ministries sometimes change names (and portfolios) as a result of a cabinet coming in. The Ministry of Economic Affairs recently was renamed the Ministry of Economic Affairs, Agriculture, and Innovation (ELI by its Dutch acronym), showing the growing emphasis on innovation. The Ministry of Education, Culture, and Science goes by its Dutch acronym OCW and the Ministry of Infrastructure and the Environment is known as IM (Rijksoverheid, 2012).
engine of economic and societal development. Industry is strongly represented in advisory councils and in actual research as a partner in public-private research collaborations. The thick intermediary level and the wide range of government policy advisory councils are legacies of consociational inclusion (Van der Meulen, 1998) (Andeweg R. B., 2000). As a result of such tradition of policymaking, at times the Dutch research system is fragmented and decentralized, which may complicate efficient and effective policy formulation and implementation (Nederlandse Organisatie voor Wetenschappelijk Onderzoek, 2006).

Figure 4.1  Overview Dutch Research System

Adapted from and based on (Jongbloed, 2008) (Ministry of Economic Affairs, 2004).
The government, at both cabinet and department level, have formal and informal relations with a whole range of advisory councils and research organizations to help them prepare science and technology policies. Of those councils the most relevant in science and technology policies today are the WRR, KNAW, NWO, the National Health Council, the Social and Economic Council of the Netherlands (SER), and the National Institute for Public Health and the Environment (RIVM). These councils participate in different forms and at different levels. SER and WRR, for instance, are well regarded long standing commissions, officially independent from the government, to advice the government on high scale policy matters. Research funding organization (NOW), the Advisory Council for Science and Technology Policy (AWT), and the Royal National Academy of Sciences (KNAW) are more specifically geared towards matters of science and technology. As NWO and KNAW actively fund, by ways of public money, and manage research activities in their own facilities, their role is more applied. Together with, and overseen by, the Ministry of Infrastructure and the Environment, RIVM prepares the governance of the risks associated with human activity. Note that the arrow in figure 4.2 suggests a single flow of advice from advisory councils towards the cabinet level of government. That is a simplification and only represents the formal direction. In reality the constellation of the Dutch research system allows for much more multi-directional and cross-level consultation, in particular as some advisory councils have multiple roles in the system.
Because of the relatively fragmented set up of the Dutch research system the Netherlands lacks strong national direction of science and technology development, NWO, under the umbrella of the Ministry of Education, Culture and Science is the main organization for public funding of research in the Netherlands. Its annual budget is approximately 300 million euro (Rathenau Instituut, 2012). It aims to foster and fund high quality scientific research in the Netherlands, to build a knowledge-based economy, by, among other instruments, create access to research facilities for researchers and industry, and through international collaborations (Nederlandse Organisatie voor Wetenschappelijk Onderzoek, 2010) (Nederlandse Organisatie voor Wetenschappelijk Onderzoek, 2006).

Two divisions of NWO deserve some extra attention: the Foundation for Fundamental Research on Matter (FOM) and the Technology Foundation STW. FOM acts under the umbrella of NWO as a RFO and program manager of research in physics. Its annual budget is about 90 million euro. FOM seeks collaboration with industry to leverage its research investments (FOM, 2012). The Technology Foundation STW, under the umbrella of NWO, but partly financed by the Ministry of Economic Affairs, focuses on knowledge transfer and diffusion from technical and engineering research to (potential) users in industry. STW seeks strong collaboration between publicly financed research efforts and industry. In almost all its projects and programs, industry participation is a mandatory condition for STW involvement (STW, 2012).
Universities and professional schools – *hogescholen*31 - conduct a substantial part of Dutch research. In addition, quite a range of public and semi-public32 research institutes add to the Dutch research output. Among them are TNO and a range of Large Technological Institutes - *Grootschalige Technologische Instituten* - (GTIs), which focus on fundamental research in for instance energy or maritime matters. Often such research is done in cooperation with or at least made available to non-government stakeholders, such as industry (Ministry of Economic Affairs , 2004).

Increasingly research in the Netherlands is done in public-private partnerships. Like in the United States, the larger part of research and development, with the exception of fundamental research, is financed by industry –, in the Netherlands led by a group of seven prominent Dutch companies, among them electronics company Philips, Akzo-Nobel, and chemicals company DSM. (Ministry of Economic Affairs, 2002): Different sources all indicate the percentage of private research funding well over 50% of the total Dutch R&D investment (Ministry of Economic Affairs , 2004) (OECD, 2012) (Eurostat, 2012). The government promotes and supports such partnerships. Since the late 1990s a range of such initiatives have been established (Life Sciences 2020, 2010) (Ministry of Economic Affairs , 2004): The model of Leading Technological Institutes (LTIs), virtual organizations in which companies and research institutes participate in advancing knowledge centered around specific fields such as nutrition or metals has

31 Also called ‘colleges of applied sciences’ (Jongbloed, 2008).
32 Government funded and chartered but independent institutes.
proved to be successful in allocating public and private funds and resources towards common goals (Ministry of Economic Affairs, 2004). LTIs are built upon pre-existing networks as to benefit from such foundation.

*Funding Trends*

A high-level overview of the funding of Dutch research adds to understanding its priorities and its focus. The government presents an annual budget in addition to more or less regular comprehensive strategic plans for the system of higher education, research, and science, as published in 2004, 2007, and 2011 (Ministry of Education, Culture, and Science, 2011). The plan published in August 2011 focuses on the interaction, alignment, and collaboration between education, research, and industry in the Netherlands based on the specific strengths of Dutch academic research and the expertise of industry. Such focus and specialization should establish a competitive position for the Netherlands in the global economy (Ministry of Education, Culture, and Science, 2011).
Table 4.2 Public Funding of Research in the Netherlands 2012

<table>
<thead>
<tr>
<th>Department</th>
<th>Euro</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Affairs</td>
<td>€ 0.7</td>
<td>0.01</td>
</tr>
<tr>
<td>Foreign Affairs</td>
<td>€ 58.0</td>
<td>1.21</td>
</tr>
<tr>
<td>Security &amp; Justice</td>
<td>€ 26.6</td>
<td>0.55</td>
</tr>
<tr>
<td>Interior and Kingdom Relations</td>
<td>€ 6.1</td>
<td>0.13</td>
</tr>
<tr>
<td>Education, Culture, and Science</td>
<td>€ 3,482.7</td>
<td>72.61</td>
</tr>
<tr>
<td>Defense</td>
<td>€ 69.0</td>
<td>1.44</td>
</tr>
<tr>
<td>Infrastructure &amp; the Environment</td>
<td>€ 118.0</td>
<td>2.46</td>
</tr>
<tr>
<td>Economic Affairs, Agriculture &amp; Innovation</td>
<td>€ 862.9</td>
<td>17.99</td>
</tr>
<tr>
<td>Social Affairs &amp; Employment</td>
<td>€ 2.3</td>
<td>0.05</td>
</tr>
<tr>
<td>Health, Welfare &amp; Sport</td>
<td>€ 170.4</td>
<td>3.55</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>€ 4,796.7</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

Based on and adapted from 2010 – 2016 Overview Research Funding (Rathenau Instituut, 2012).

The overview in table 4.1 shows the build-up of the 2012 budget of approximately 4.8 billion euro, which includes the overall costs of the higher-level educational system. The table shows clearly that the Ministry of Education, Culture, and Science manages the largest part of the national research budget, in particular as that department finances the educational system. The Ministry of Economic Affairs, funding research through specific innovation programs, manages 18% of the total budget. The Ministries of Health and Defense manage but small parts of the national research budget. This does not mean per se that Dutch research is not focused on matters of public health or security. It does show, however, that public funding of whatever the research topic or direction, is mostly coordinated by the Ministry of Education, Culture, and Science and the Ministry of Economic Affairs. The build-up of the budget also shows that regardless of the fragmented, multi-stakeholder, multi-level nature of the research system, at government level the budget responsibility is limited generally to only two departments.
In recent years direct public funding of research and development has declined. It is expected to decline even further as economic circumstances remain difficult (Ministry of Education, Culture, and Science, 2012) (Rathenau Instituut, 2012). However, the government sees opportunities to shift the balance a bit from direct public funding towards indirect public funding as it aims to foster innovation through innovation programs and tax incentives support a growth of research efforts by industry (Ministry of Education, Culture, and Science, 2012). These tax incentives are part of a range of innovation stimulus programs managed by the Ministry of Economic Affairs (Ministry of Economic Affairs, 2011). Further reorganization within the total budget emphasizes the focus on innovation: public and semi-public research institutes, which receive direct funding from the government, will need to adjust to find additional financial resources, as direct government funding will decline. It shows the intention of the government to foster public-private collaboration in scientific and technological research and development (Ministry of Education, Culture, and Science, 2012). The percentage of indirect public funding as part of total public research funding is expected to change from approximately 10% in 2010 to over 20% in 2015 (Rathenau Instituut, 2012), reflecting the choice of the government to focus ever more strongly on innovation and industry participation in research (Rathenau Instituut, 2012).

Dutch government involvement in science and technology today is based on an integrated approach towards sustainable and responsible development of science and technology to achieve economic growth. Over the years Dutch research system, which
includes a wide range of public and private stakeholders that in broad consultation prepare and implement science and technology related policies, has increasingly turned its focus on innovation to foster economic growth and improve Dutch international competitiveness, as existing Dutch academic strengths seemed to lag in conversion to new products and services. Such policies regard innovation as much broader than scientific progress and technological development; it includes knowledge diffusion, knowledge transfer, and the commercialization of scientific findings and technological breakthroughs (WRR, 2008). A good example is the ambitious Top Sectoren Program established by the Ministry of Economic Affairs to bolster Dutch entrepreneurship, innovation, and competitiveness (Ministry of Economic Affairs, 2012) (Ministry of Education, Culture, and Science, 2012). Nanotechnology has a prominent position in the Top Sectoren Program as part of the program’s ‘High Tech Systems and Materials’ sector (Ministry of Economic Affairs, 2012). Industry is well represented in the system, financing more than half of the total Dutch R&D effort, and public-private partnerships in research and development are common. Rather than developing complete new fields of expertise, which is often very difficult, Dutch science, technology, and innovation policies focus on building upon and expanding existing economic and academic strengths (Adviesraad voor het Wetenschaps- en Technologiebeleid, 2007) (WRR, 2008).
4.4 Science, Technology, and Innovation Policies in the European Union

As part of the European Union, the Netherlands contributes to and relies on European collaboration in research. It sees participation in international research programs as crucial to achieve its national goals. The European Union and its member states acknowledged early on that science and technology foster innovations, which support economic development, and that creation of knowledge is the basis of contemporary economic growth in developed nations (Soete & ter Weel, 1999). EU leaders regard research, science and technology as fields in which joint European efforts are complementary to each member state’s endeavor separately (Kuhlmann S., 2001). A European program for research and development on top of - yet aligned with - the various national programs of the member states, leverages pooled resources towards more and better results than the different national systems together could achieve on their own (Muldur, et al., 2006). Pooling resources creates the needed critical mass to make great advances in science and technology – something relatively small members such as the Netherlands are unlikely to achieve on their own - and a common European effort might be appropriate to address transnational issues (Kuhlmann S., 2001).

In fact, a tradition of collaboration in scientific research in Europe already was established before the economic and political integration formalized into the European Union. The European Organization for Nuclear Research (CERN), founded in 1954 by twenty European countries, is an early example of how pooled resources and
international collaboration yield more results than individual countries may be able to achieve in scientific research (CERN, 2012). Since then European collaboration in scientific research and technological development has rapidly evolved.

The European Union established the so-called framework programme (FP) for research and technological development in 1984 as an additional effort to spur European research output in addition to the research activities of the member states (Muldur, et al., 2006). The Directorate General Research and Innovation (DG RTD) is responsible for the coordination and implementation of the European programs and policies for scientific research and technological development. However, given the wide-ranging goals of government involvement in science and technology, and the possible consequences of scientific and technological progress, various other European DGs are involved in research execution and research funding, notably DG Enterprise, DG Environment (DG ENV), and DG Health & Consumers (DG SANCO).

The framework programme is the main funding mechanism for research in science and technology, and is part of a much broader European effort to make the European Union the most competitive economy in the world, as ambitiously decided as part of the so-called ‘Lisbon Strategy’ during the European summit in Lisbon in 2000. This EU initiative established the European Research Area (ERA) to fill the gap between insufficient national efforts and the potential of European collaboration through the leverage effect of pooled resources (Soete L., 2002). The ERA comprises of all scientific research and
technology development programmes in the Europe Union. It offers a single European market for research and knowledge in which all stakeholders, including scientists, scholars, research institutes, and businesses have the opportunity to collaborate, and compete, freely (European Commission, 2012). The Lisbon strategy emphasized that the focus of transnational European collaboration in scientific research had shifted from creating new knowledge based on basic science towards application and combination of existing knowledge for innovation (Soete & ter Weel, 1999) (Expert Group on Science and Governance, 2007).

The European Union moved to quantify the intentions of the Lisbon Strategy by agreeing on the so-called Barcelona goals, which set the aim of the annual European investment in research and development at 3% of GDP, which is comparable to the annual investments of the United States and Japan. Of the total investments, public investments in research would account for 1% of GDP and investments by industry in R&D for 2% of GDP (Expert Group on Science and Governance, 2007) (CORDIS, 2003).

By 2006, when the 6th installment of the framework program came to an end, the European Commission concluded that too little progress was being made to achieve the goals set in Lisbon (Muldur, et al., 2006) (European Commission, 2011). Input for the design of the consecutive 7th Framework Programme (FP 7, 2007 – 2013) were the different challenges the European Union saw itself confronted with: economic and societal challenges such as slow growth, increasing worldwide competition, pollution, and perceived weak institutional set up of the European Research Area, which appeared
to be an underfunded, complex, multi-layered system that failed to create a solid trans-
European basis for innovation and economic growth (Muldur, et al., 2006). The
European Commission allocated a much larger budget to the 7th framework programme
- almost 50 billion euro for the 2007 – 2013 timeframe, compared to the less than 20
billion euro for the 6th framework programme between 2002 and 2006 (Muldur, et al.,
2006) - and it has established a European research funding organization, the European
Research Council (ERC), which coordinates approximately 15% (7.5 billion euro) of the
total FP7 budget (European Research Council, 2012) (Muldur, et al., 2006).

A key principle of the European Research Area is the perceived duality of its foundation:
strong emphasis of research and innovation, while stressing the need for public
participation and democratic governance (Expert Group on Science and Governance,
2007) to address issues as accountability and legitimacy, which also were important
issues mentioned in the Dutch evaluation of the role of the European Union in Dutch
national policies (WRR, 2007). The European Union deems addressing matters of social
and ethical consequences of scientific and technological progress conditional for
responsible R&D in the European Research Area (Expert Group on Science and

The EU’s Application of the Precautionary Principle to Science and Technology

In 2000, the European Union accepted the precautionary principle as the basis of
research and application of science in the European Union. The precautionary principle
builds on the preventive principle, a part of international law, which requires governments to take action as early as possible when harm to economic activity seems likely. The precautionary principle goes further, adding that even if the scope of harm is not scientifically proven, the presence of uncertainty requires governments to engage in precautionary action to prevent potential harm. The precautionary principle is controversial, as a strict interpretation would make research into unknown effects of scientific application virtually impossible, as dangers and risks always exist. Thus, the argument goes, the interpretation of the precautionary principle need to allow for proportionality, balancing the benefits and the uncertainties associated with research activities (Van Calster, 2008) (Expert Group on Science and Governance, 2007) (European Commission, 2000). In 2004 the government of the Netherlands declared the precautionary principle and the application of proportionality as the foundation of its risk policies (Ministerie van Volkshuisvesting, Ruimtelijke Ordening and Milieubeheer, 2004).

_Framing the EU’s Research Funding_

In 2010, the EU spent 0.76% of its GDP on public investments in R&D, far below its own target and much less than the United States, which spent 1.2% of GDP (Eurostat, 2012, p. 20). This difference might be explained by the exceptional high public funding of research through the U.S. Department of Defense (Muldur, et al., 2006). However, industry investments in R&D in the EU were also below target: the European private sector invested 1.24% of the European GDP on research in 2010. That brought the total
European investment to 2% of GDP, a full percent point under its goal, and 0.8% less than the total government and industry investment in research in the same year in the United States, which came to 2.8% of GDP (Eurostat, 2012, p. 28).

Such underinvestment might be the result of strenuous economic circumstances in the European Union. The financial and economic crisis starting in 2008 had major consequences for the agenda of the European Union and the attainability of the goals put forward in at the Lisbon summit in 2000. Partly in response, in 2010 the EU agreed to ‘Europe 2020’, a renewal of the Lisbon Strategy that seeks to support smart sustainable economic growth, create jobs, and address issues like climate change, energy supply, and poverty. The Barcelona Target of spending 3% of annual GDP on research and development is confirmed as an explicit goal of the strategy (European Commission, 2012).

As part of the broader Europe 2020 strategy, in 2011 the European Union established the Framework Programme for Research and Innovation, ‘Horizon 2020’ to succeed the 7th Framework Programme, which comes to an end in 2013. ‘Horizon 2020’ aims to consolidate and simplify the current European research constellation and to address the matter of the European paradox in research by spurring public and private investment in R&D: It brings together different European programs and agencies such as the 7th Framework Programme and the European Research Council under DG RTD and the innovation parts of the Competitiveness and Innovation Programs (CIP) under DG
Enterprise, that include the activities of the European Institute of Innovation and Technology (EIT), which aim is to combine research, education, and innovation oriented businesses into the (European Commission, 2011).

Figure 4.3 gives a high-level overview of the instruments and agencies involved in the Innovation Union. Besides the Structural or Cohesion Funds of the European Union, which are used to overcome economic and social disparities between different member states and regions of the EU, the program includes FP7 and CIP funds. European research facilities, in which member states collaborate, such as Euratom, are part of the European Research Area. CERN, though not a EU facility, is an important research partner for the EU.

Fig. 4.2 EU Horizon 2020: Overview Innovation Union Instruments

(European Commission, 2011).
Horizon 2020 integrates the European Research Area with the European innovation efforts in a so-called ‘Innovation Union’. Its priorities are to facilitate excellent science, create European industrial leadership, and address various societal challenges. The program has a budget of 80 billion euro for 2014-2020, of which 25 billion euro is allocated to science (the ERC’s budget increases by 77%), 18 billion euro to innovation and access to R&D for industry, including small and medium enterprises, and 32 billion to addressing the ‘Grand Challenges’ (European Commission, 2011). Horizon 2020 explicitly mentions nanotechnology as a priority on the European research agenda.

The Innovation Union furthers the ERA establishment of a single market for knowledge, research, and academic exchange. It stimulates innovation ‘close-to-market’ to create rapid business opportunities. Since the announcement of the Lisbon Strategy in 2000, European efforts in scientific research and technological development have more and more concentrated on strengthening innovation and the link between researchers, research institutes, education, and business.

*Multi-level Policy Convergence*

Multi-level convergence between national research policies of the member states, such as in the Netherlands, and the European Union is noticeable. One could argue, for instance, that Dutch government funding of science and technology started to support research to specifically achieve innovation and economic development earlier than the European Union. Also, the inclusive approach towards public-private partnerships,
which is a cornerstone of the European’s new economic program Horizon 2020, has a long tradition in the Netherlands (Life Sciences 2020, 2010).

Given the focus of transnational European research collaboration on innovation and economic development, a remark about the tension that exists within such multi-level collaboration is necessary: Transnational engagement in research and development is always a mix of collaboration and competition (Kuhlmann S., 2001): Joint efforts will yield better and faster results because of pooled resources, be it budgets, facilities, or most importantly brains. In fact, science by definition has an international side, as it is not limited to borders and develops bottom up, often at an individual researcher level (Expert Group on Global Governance of Science, 2009). Yet, given the common understanding that science and technology help to spur economic growth and increase the competitive position of countries in the global economy (Soete & ter Weel, 1999), the results of scientific collaboration is seen as advancing national interests. Thus the neofunctional approach towards international engagement in research sometimes evolves to a certain ‘techno-nationalism’ placing the national interest ahead of the common interest (Adviesraad voor het Wetenschaps- en Technologiebeleid, 2004) (Expert Group on Global Governance of Science, 2009). Though far from techno-nationalism, the ambition of the Dutch government to be among the most competitive economies in the world, and thus in the European Union as expressed in its Top Sectoren Program reflects the tension between collaboration and competition (Ministry

4.4 Conclusion

Dutch policymaking has two traditions that influence the way science and technology related policies are established. The legacy of consociationalism and neo-corporatism in policymaking allows for a broad multi-layered multi-stakeholder consultation process on policy matters at hand. The tradition of international and in particular European engagement of Dutch society and its political system has led to a preference of transnational embedding and cooperation of Dutch policymaking. Through its membership of the European Union, a multi-level governance approach of many policy matters has become the norm.
Chapter 5  The Dutch Case: Nanotechnology Support Embedded in Existing Policies and Multi-level Governance

5.1  Introduction.

The working hypothesis of this research states that government support for nanotechnology is not driven by the intrinsic nature of the field of science and technology but by long-standing structural and institutional arrangements.

One would assume that a legacy of consociationalism and corporatist practices in policymaking in the Dutch political system would be favorable to the conception of a coordinated and centralized government program to support nanotechnology development in the Netherlands. However, Dutch government support for nanotechnology appears to be less directive, more incremental, and more embedded in existing institutional arrangements. The Dutch government initially relied on existing relations among universities, public research funding organizations, and industries supported by government for nanotechnology development in the Netherlands, supported by public investments through traditional research funding channels. Over time, Dutch government involvement in nanotechnology grew to be more comprehensive and directive, and, by outspoken policy preference, embedded in broader European policy frameworks and international collaborations.
As brought forward in the preceding chapter, Dutch policymaking traditionally has a strong international and European dimension. The relationship between the Netherlands and the European Union (EU) reflects an interlinked system of multi-level governance as described by Hooghe and Marks (2001). In this regard, membership of the European Union allows national governments to defer authority on certain policy fields to the European level. However, the EU membership always requires Dutch legislators, Dutch civil servants, and Dutch members of the European Parliament, as well as a broader range of Dutch stakeholders in European policy matters to engage in European policy processes and it demands the implementation of European laws, regulations, and guidelines into national Dutch legislation. Over the years the interaction between the different levels of governance has become a more or less established routine. An important argument made in this chapter is that government involvement in nanotechnology in the Netherlands is an example of such multi-level European and international governance, in which responsibility for policymaking is shared across different levels of government and harmonization of policies and regulations is a goal actively pursued by the Dutch government (Ministry of Economic Affairs, 2008) (Ministry of Infrastructure and the Environment, 2011).

This chapter presents the case of Dutch government support for nanotechnology as it elaborates on nanotechnology development in the Netherlands since the 1990s.
The two Streams of Nanotechnology Research: Applications and Risks

Government promotion of nanotechnology development in the Netherlands has evolved since the 1990s along two streams – the first focused on research for economic growth, the second on addressing concerns about broader environmental, health, and societal impacts. These streams over time converge.

The first stream, taken up in the 1990s by universities, research institutes, and leading industry, is focused around nanotechnology as an enabling technology that creates ample opportunities of innovative solutions for pressing societal matters, such as energy supply and environmental pollution, while offering a great potential of economic returns. In the Netherlands this stream of nanotechnology research emerged bottom-up: scientists in universities and research institutes as well as researchers linked to industry started to do studies of the possibilities of nanotechnology, seeking, where needed, possible and desirable, additional funding for their research through existing research funding organizations and channels overseen by the Ministry of Education, Culture, and Science and the Ministry of Economic Affairs (Gielgens, 2012). Such basic research in nanotechnology obviously is the basis for application and commercialization of nanoscale research.
The other stream involves research into the risks and uncertainties that are associated with nanotechnology and, in particular, with manufactured nanomaterials. In the Netherlands risk-related research has evolved in a more top-down manner: after advances in nanotechnology gained more recognition and the possibilities of nanotechnology seemed frontier-less in the early 2000s, from 2005 onwards government advisory councils for science and public health have begun to steer towards increased government involvement in the development of nanotechnology. Their aim was to make sure that risks of nanotechnology and the remaining knowledge gaps were properly addressed as a condition for the responsible development of nanotechnology and the use of nanomaterials. Government coordination of such risk related research lies with the Ministry of Infrastructure and the Environment.

A better understanding of risks and the need to reduce uncertainty overall is seen as in the common interest of all stakeholders. The Dutch government, Dutch industry, and the Dutch scientific community, all strongly connected to a European and broader international environment, acknowledged early on that addressing the risks and remaining uncertainties of nanotechnology within national boundaries would be

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33 No international consensus exists on the definition of nanomaterial, though it includes references to the size of two dimensions of the matter at hand should be less than 100 nanometers. Also, organic particles of nanometer size exist in nature, yet current research tends to be focused on the possibility of creating inorganic nanomaterials or applying nanoscale particles of either inorganic or organic matter in novel, which explains the term ‘manufactured’ or ‘engineered’ nanomaterials (SCENHIR, 2010). The European Commission definition, communicated on October 18, 2011 uses the following definition for nanomaterial: “a natural, incidental or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50 % or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm-100 nm” (EC L275/38).
ineffective and inefficient, as production, use, and commercialization of manufactured nanomaterials takes place in a wider European and international setting (Ministry of Infrastructure and the Environment, 2012). Therefore the Dutch government, arguing that an international harmonized set of agreements would be beneficial to all, urged stakeholders to address these issues through a strong focus on international collaboration within the European Union, the Organization for Economic Cooperation and Development (OECD), and the International Organization for Standardization (ISO). The Dutch Cabinet has stated a strong preference that any Dutch regulation on the risks associated with nanotechnology to be embedded in European regulation: the Cabinet’s 2008 Nanotechnology Action Plan says about dealing with the risks associated with nanotechnology that “the short term aim of the Cabinet is the embedding of European legislation” (Ministry of Economic Affairs, 2008, p. 4). To the Dutch, such international collaboration can yield faster and better results than a relatively small country like the Netherlands can achieve on its own. Having a better understanding of the risks and uncertainties that linger also links issues of public concern about negative effects of nanotechnology applications. Addressing risks and uncertainties, and relaying correct and up-to-date information to all stakeholders in nanotechnology including the general public, advances the general acceptance of such new scientific and technological developments as nanotechnology.

The need of broad public acceptance of nanotechnology in society as a condition for successful technological innovation and economic development is the point where the
two streams come together: addressing risks and uncertainties, and involving the
general public. As such, the Dutch emphasis on international collaboration to gain better
insights of the potential risks of nanotechnology has a neofunctional aspect.
International collaboration in this field is ultimately in the national interest: “it is only by
dealing carefully with the risks that the Netherlands will be able to exploit
[nanotechnology’s] opportunities to the full” says the Cabinet’s 2008 Nanotechnology
Action Plan (Ministry of Economic Affairs, 2008, p. 3). In this regard, as discussed below,
Dutch and European policies on nanotechnology research are converging around a
strong focus on international cooperative research of risks, an emphasis of the
innovative potential of nanotechnology and the possibilities for economic and societal
returns, and an increasing notion that diminishing risks and addressing any public
concerns is conditional for the success of nanotechnology.

In the last decade, the Netherlands and as the European Union each have put forward
action plans for integrated and responsible development of nanotechnology. Such
programs address both streams: research, development and innovation in one, and risk
research and public engagement in nanotechnology in the other (European Commission,
2005) (Ministry of Economic Affairs, 2008). Dutch government involvement has evolved
over time from a program of rather detached non-centralized funding of basic
nanotechnology research towards a more directed and integrated national effort, in
which nanotechnology, as an enabling technology that is closely linked to other so-
called NBIC technologies\textsuperscript{34}, is embedded in broader innovation programs both in the Netherlands and in Europe under the condition that risks and uncertainties associated with nanotechnology are addressed at the same time. This shift from basic research to more applied R&D is not unique to the Netherlands, but part of a broader movement within the European Union and even the United States towards more directed R&D funding to support economic development.

International collaboration is the basis of the Dutch efforts with regard to research on risks and remaining knowledge gaps. The Dutch government explicitly states that it prefers a European response to the risks associated with nanotechnology over any national approach: in its 2010 review of the activities announced in the 2008 Nanotechnology Action Plan, the Cabinet states that it favors a “long-term approach to develop risk-assessment methods and definitions, standards, and measurement instruments in international collaboration” (Ministry of Economic Affairs, 2010, p. 3)\textsuperscript{35}. The international focus emphasizes an evolving multi-level governance system of the European Union, in particular with regard to environmental protection, the use of chemicals, and matters of consumers and workers safety and public health. Both the government of the Netherlands and the European Commission seek to address these

\textsuperscript{34} NBIC: Nanotechnology – Biotechnology – Information technology - Cognition sciences and technologies, which are increasingly converging because of their inter- and multidisciplinary character (Ministry of Economic Affairs, Agriculture, and Innovation, 2011).

\textsuperscript{35} Translated from Dutch by author.
issues within the existing available legal and regulatory framework at the national and European level.

Despite strong scientific output, the Netherlands currently lags in nanotechnology-related innovation. This phenomenon is not unique to one country, but reflects a broader ‘European innovation paradox’ of high-quality science not readily converted into successful applications, (Ministry of Economic Affairs, 2004). In recent years global competition has increased as other countries around the world have invested more heavily in nanotechnology research and development. The United States, Germany, Japan, South Korea, and China lead the global competition and the Netherlands is not part of this front group (Miyazaki & Islam, 2007).

However, the Cabinet, Dutch industry, and Dutch research institutes emphasize that the Netherlands is well equipped to build out its global position in nanotechnology.

Combined public and private investments in nanotechnology research, estimated to be as high as 400 million euro for the 2005 and 2006 period (Ministry of Economic Affairs, 2008), show a clear aspiration to be a leader in nanotechnology (Walthout, van Keulen, van Est, Brom, & Malsch, 2009), though more investments are needed to re-attach to the global leading group (Nederlands Observatorium van Wetenschap en Technologie, 2010).
As put forward in its 2008 Nanotechnology Action Plan which has become the basis of Dutch government support for nanotechnology research, the Dutch Cabinet, based on a coalition of Christian-Democrats (CDA) and the liberal pro-business party (VVD), sought to create a climate for responsible and economically viable development of nanotechnology, based on four premises: (1) an ambitious agenda for research and business opportunities in the Netherlands; (2) an inclusive approach to address ethical, social, and legal issues pertaining to nanotechnology; (3) a program to stimulate public engagement in the development of an overall governance approach; and (4) an emerging regulatory model that acknowledges the risks and remaining uncertainty associated with the use and production of manufactured nanomaterials (Ministry of Economic Affairs, 2008). The action plan aimed to build a viable nanotechnology R&D system based on backing so-called ‘winners,’ supporting the development of areas of expertise and specialization in which Dutch industry, universities, and research sectors have proven strength and success, such as high tech systems and materials, clean water, food, and energy (Ministry of Economic Affairs, 2012).

The next section of this chapter offers an overview of the evolution of Dutch government involvement in nanotechnology since the 1990s. It includes the broader European and international frame of such involvement and presents the current set up. Today’s status obviously is not fixed, as technology, society, and related governance approaches are in constant interactive flux, nor has the coming-into-being of today’s status been a linear one-dimensional process. Such givens make that the next section
not always follows a strict chronology. However, it does weave together more or less chronological the different steps taken by Dutch, European, and international stakeholders in nanotechnology research towards what we see as today’s nanotechnology governance framework.

5.2 Nanotechnology in the Netherlands

An Early Uptake of Nanotechnology

The development of nanotechnology in the Netherlands is marked by early initiation of scientific research at different universities and research institutes and by early uptake of nanoscale research by Dutch industry, in particular by sizeable international corporations based in the Netherlands, such as Philips, ASML, DSM, and Akzo-Nobel (FOM, STW & NanoNed, 2008). In 2006, Dutch economic activity in nanotechnology ranked third in the world relative to the size of its economy. However, in absolute measures the Dutch position is better characterized as leading the group of countries that aspire to become global leaders in nanotechnology (Ministry of Economic Affairs, 2008) (Lux Capital, 2003) (Ministry of Economic Affairs, Agriculture, and Innovation, 2011). In the early 2000s the Netherlands ranked fourth in the EU when measured in the number of research publications on nanotechnology (Miyazaki & Islam, 2007). Later in the decade the Netherlands placed in the global top three together with the United States and Switzerland for nanotechnology R&D with highest scientific impact based on the number of citations. This position was partly based on international collaboration in
research including Dutch scientists (Nederlands Observatorium van Wetenschap en Technologie, 2010).

Such disproportionate (to the size of the country) impacts reflect existing Dutch strengths in research. Since the 1990s, Dutch universities, in particular the universities of technology in Delft, Eindhoven, and Twente, have developed notable interdisciplinary nanoscience research operations, based on their pre-existing strengths in areas like material sciences and information technology. Early on the universities and industry set up collaborations and knowledge exchange by establishing R&D networks and partnerships and opening up their facilities for commercial research and development. For its part, Dutch industry—ranging from large multinational corporations to mid- and small sized firms—recognized nanotechnology’s potential relatively early. As mentioned, prominent and large multi-national Dutch enterprises as Philips and ASML initiated nanoscale research programs in the early 2000s (FOM, STW & NanoNed, 2008). In 2006 thirteen out of the thirty largest Dutch companies, accounting for two-thirds of private research and development (R&D) budget in the Netherlands, engaged in targeted nanoscale research. By 2006, approximately 275 Dutch companies used nanomaterials or nanotechnology in some way, most as part of a larger manufacturing process (Ministry of Economic Affairs, 2006).

Overall Dutch nanotechnology research in the earlier 2000s relied heavily on public funding, with up to 70% of nanotechnology research being funded publicly before 2004.
(Miyazaki & Islam, 2007). More recently the balance has shifted, and private enterprise now accounts for more than 50% of all Dutch nanotechnology R&D spending (FES Initiative 2009 HTSM, Oct. 2009).

A Chronological Overview of the Government Approach of Nanotechnology Development

Figure 5.1 shows a condensed timeline of notable developments of Dutch government involvement in nanotechnology research since the late 1990s. The timeline includes an international dimension, mainly European, to bring forward the interlinked events on national and international levels and shows the convergence and acceleration of government involvement at different levels during the last decade. Also, the overview includes government action regarding nanotechnology as a tool for economic development and innovation as well as government action to address risks and uncertainties associated with nanotechnology towards a more integrated approach of responsible development of nanotechnology.
Figure 5.1  Timeline Nanotechnology in the Netherlands and its international context.

<table>
<thead>
<tr>
<th>Netherlands</th>
<th>timeline</th>
<th>European Union &amp; International Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start scientific strengths in materials science, biotech, and ICT</td>
<td>1970s</td>
<td></td>
</tr>
<tr>
<td>Start nanotech R&amp;D at universities</td>
<td>1990s</td>
<td></td>
</tr>
<tr>
<td>Industry takes up nanotech R&amp;D</td>
<td>2000s</td>
<td></td>
</tr>
<tr>
<td>NWO &amp; FOM start to fund nanotech in regular programs</td>
<td>2001</td>
<td></td>
</tr>
<tr>
<td>Cabinet co-funds Nanomimpuls</td>
<td>2002</td>
<td>EU FP6 2002 - 2006: NMP priority funds 1.3 billion euro nanoscale R&amp;D</td>
</tr>
<tr>
<td>KNAW report &quot;How Big Can Small Actually Be?&quot;</td>
<td>2004</td>
<td></td>
</tr>
<tr>
<td>NanoNed established - BSIK funded - 2004 - 2010</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Universities start joint research facilities for nanoscale R&amp;D</td>
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<tr>
<td>Specific NWO call for nanotech research</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st FES round Knowledge, Innovation, and Education</td>
<td>2005</td>
<td>ISO TC 229 Nanotechnologies</td>
</tr>
<tr>
<td>NWO strategy &quot;Towards a Multidisciplinary Nanoscience Programme&quot;</td>
<td></td>
<td></td>
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<tr>
<td>Health Council report</td>
<td></td>
<td></td>
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<tr>
<td>Cabinet Vision on Nanotechnology &quot;From Small to Great&quot;</td>
<td>2006</td>
<td>OECD Working Party on Manufactured Nanomaterials</td>
</tr>
<tr>
<td>Towards a National Nanotechnology Initiative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>REACH implemented</td>
<td>2007</td>
<td>EU REACH Regulation on Chemicals</td>
</tr>
<tr>
<td>KIR nano established</td>
<td></td>
<td>EU FP7 2007 - 2013: continues NMP priority: 3.5 billion euro</td>
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<tr>
<td>Cabinet requests NNI to compose a nanotech SRA</td>
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<td>Cabinet Nanotechnology Action Plan</td>
<td>2008</td>
<td>OECD Working Party on Nanotechnology</td>
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<td>Strategische Research Agenda Nanotechnologie</td>
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<td>EU Precautionary principle applicable to nanomaterials: &quot;no data, no market&quot;</td>
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<td>Public Dialogue Nanotechnology (CDMN) 2009 - 2011</td>
<td>2009</td>
<td>EU REACH to cover nanomaterials</td>
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<td>2nd implementation report Action Plan</td>
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<td>EU ENMAC established</td>
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<td>Point One Innovation Program established</td>
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<td>HTSM proposal FES</td>
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<td>1st Implementation Report Action Plan</td>
<td>2010</td>
<td>EU Nanotech specific regulations for food and cosmetics</td>
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<td>NanoLab NL formalized</td>
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<td>NanoNext NL</td>
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<td>2nd implementation report Action Plan</td>
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The Start of Public Funding for Nanotechnology Research

As shown in Table 5.1 and as noted in Chapter 4, direct investments by the Dutch government in nanotechnology research start in the early 2000, led by the government research funding organization NWO - the Netherlands Organization for Scientific Research. NWO funds research through its own programs and through its divisions with
specific fields of attention like the Foundation for Fundamental Research on Matter (FOM), which supports high quality physics research, and the Technology Foundation (STW), co-funded by the Netherlands Department of Economic Affairs, Agriculture, and Innovation (ELI), which stimulates collaborations among university researchers and potential users from industry by supplying funds and offering project management services (NWO, 2010). From 2001 onwards, NWO and its divisions funded basic nanoscience research as part of their annual programs. In 2005 STW – in collaboration with FOM and other NWO divisions - set up a specific nanotechnology program, allocating 10 million euro for nanoscale research projects, to be executed by nanotechnology research institutes linked to different Dutch universities (Nederlandse Organisatie voor Wetenschappelijk Onderzoek, 2005) (NanoNed, 2008).

In 2002, a newly formed Cabinet, based on a coalition of the centrist Christian Democratic party (CDA) and the business oriented VVD\(^{36}\), with a strong focus on innovation and economic growth, partially funded NanoImpuls, a combined research initiative of industry, the applied science research institute TNO, and seven universities. STW took up the role as NanoImpuls’ program administration. As an example of co-funding, the Cabinet invested 23 million euro and the consortium partners 22 million, to complete NanoImpuls’ 45 million euro budget (Gielgens, 2012). The first program of a sequence of consortia in Dutch nanotechnology development, NanoImpuls was led by

\(^{36}\) A CDA – VVD coalition would be the basis of subsequent cabinets until the elections of 2012, with the exception of a three-year period between 2007 and 2010 in which CDA formed a coalition with the labor party (PvdA), and since November 2012 a VVD – PvdA coalition, see also Chapter 4 (Rijksoverheid, 2012).
David Reinhoudt, director of the MESA+ Institute for Nanosciences at Twente University, one of the first nanotechnology-specific research institutes in the Netherlands, established in 1999 (MESA+, 2001). The partners established NanoImpuls as a first phase of a more expansive and longer-term collaboration in the field of nanotechnology. As indicated in the previous chapter, close cooperation between industry, universities, and research institutes in public-private partnerships is quite common in the Netherlands\(^{37}\). These partnerships are typically funded jointly. Combined public - private funding of research programs has become the norm for successive national investments in nanotechnology research (Commissie Meijerink, 2010) (FES Initiative 2009 HTSM, Oct. 2009). NanoImpuls - labeled a ‘national nanotechnology program - was the first in a range of successive initiatives in this field. NanoImpuls focused on four fields of attention – so-called ‘flag ships’ -, of which the ongoing miniaturization of transistors was the most prominent. NanoImpuls invested around 23 million euro in the research ‘flag ships’ and 17 million euro in research facilities (MESA+, 2004) (FOM, STW & NanoNed, 2008) (Gielgens, 2012).

NanoNed, initiated in 2004 as the successor of the NanoImpuls program, continued the industry – university – research institute collaboration framework to advance nanotechnology development in the Netherlands for the five-year period between 2004 and 2010. The consortium consisted of seven Dutch universities, the research institute

\(^{37}\) Another example is MicroNed, a program similar to NanoImpuls and its successor NanoNed, but focused on more conventional ways of miniaturization (MicroNed, 2012).
TNO, and Philips. A range of other companies joined as participants in various NanoNed projects. NanoNed identified a range of focus fields for research based on traditional strengths of Dutch research and industry: ‘Beyond Moore’, which refers to ‘Moore’s Law’ stating that every two years the number of transistors on integrated circuits doubles, thus demanding continuous further miniaturization of transistors; nanomaterials; bio-nano applications, which looks at the interface between nanoscience and cell biology; and nano-fabrication. Equally notable, NanoNed also established a Technology Assessment (TA) program to evaluate developments in the different focus fields to ensure that societal and ethical issues associated with nanotechnology were also being addressed, among them the governance of risks and uncertainty.

Research funding organization NWO’s division Technology Foundation STW continued in its role of program administration. NanoNed’s budget for the project period of 2004-2010 was approximately 190 million euro, of which more than 90 million euro were reserved for eleven so-called ‘flagship’ research programs, 80 million euro for research facilities, and 5 million euro for its technology assessment program (NanoNed, 2008) (Gielgens, 2012). These public investments came from the Economic Reinforcement Fund.

From 1994 onwards the Dutch government has, on occasion, used income from natural gas sales to fund larger infrastructural projects that benefit the Dutch economy. Such investments may also include projects in science and innovation. These incidental
funding rounds have been known under different names, such as ICES/KIS3 or BSIK

Besluit Subsidies Investeringen Kennisinfrastructuur (Resolution Investment Subsidies Knowledge Infrastructure), but today are most commonly referred to as funding through the Economic Reinforcement Fund (FES) (Ministry of Economic Affairs, Agriculture, and Innovation, 2011; Ministry of Education, Culture, and Science, 2003). In 2005 the Government established the fund, which is managed by ELI and the Department of Finance, to allocate public income from natural gas sales for infrastructure projects in a more systematic way. The fund includes a specific domain for ‘Knowledge, Innovation, and Education.’ FES distributed funds in 2005, 2006/7, and twice in 2009, supplementing the budgets of departments that submitted proposals (Commissie Meijerink, 2010).

As with NanolImpuls, matching funds from the NanoNed consortium partners, including the universities and TNO, were conditional to receive public funding for the initiative. As various partners in the consortium are publicly funded - universities are funded by the Department of Education, Culture and Science (OCW), while consortium partner TNO, one of the largest independent research organizations in Europe, receives up to a third of its annual research budget from the Ministry of Economic Affairs - large portions of these matching funds supplied by the consortium partners actually are also public sources. In addition to the public investments in the subsequent nanotechnology consortia, the main research funding organization of the Dutch government, NWO, allocates a substantial part of its annual budget toward nanoscale research (Rathenau
Instituut, 2012). After more funding became available, various universities fostered the acceleration of nanotechnology research in the Netherlands by opening new research facilities or expanding pre-existing facilities to do nanotechnology research. The three Dutch universities of technology in Twente, Delft and Eindhoven, joined by the Groningen University, set up facilities that reflected their respective areas of strength. The MESA+ Institute for Nanotechnology at Twente University, which is one of the largest nanotechnology research centers of the world, aims to offer an environment for small businesses in the field to develop. The Kavli Institute for Nanoscience at Delft University focuses on a wide range of fundamental nanotechnology research including nanoscale fabrication. And the Zernike Institute at Groningen University focuses on advanced materials. Each of these is a globally renowned research center. The collaboration between these different university-linked nanotechnology research institutes that ensued is the basis for what has become known as NanoLabNL, a network of research facilities, concentrated in four locations, which stimulates research on nanoscale materials and fabrication, offers access to scientists, research institutes, and industry, and is connected to international research programs (NanoLabNL, 2012).

Informally started in 2004 under the umbrella of NanoNed with a budget of 80 million euro for the 2004 – 2010 period (NanoNed, 2008), NanoLabNL was formally established and separately funded by a FES grant in December 2011 (NanoLabNL, 2012).
A European Dimension for Nanotechnology Research Funding

Of course, as this and the previous chapters have indicated, Dutch nanotechnology research and activity has to be assessed in a wider frame than the national surroundings. Dutch nanotechnology research has benefitted from European Union programs to a great extend over these years. The EU started to fund nanotechnology research through its regular framework research programmes early on. Between 2002 and 2006, the EU allocated approximately 1.4 billion euro under the ‘Nanotechnologies and Nano-sciences, Knowledge-based Multifunctional Materials and New production Processes and Devices’ activity field of Framework Program 6 (FP6) (European Commission, 2005). An array of projects proposed by Dutch industry and research institutes, among them most universities, were funded by FP6. For instance, a multinational research collaboration in the field of medical materials, led by the Netherlands Organization for Applied Scientific Research (TNO), received 8 million euro for the period of 2006-2010 (TNO, 2009) (Ministry of Economic Affairs, 2010).

Beyond Research Funding: Conception of a Comprehensive Government Approach on Multiple Levels

This acceleration of research combined with the high expectations of scientific breakthroughs in the field of nanotechnology, supported by significant public and private investments in nanoscale research, triggered concerns about the risks and remaining uncertainties associated with nanotechnology and about the broader societal impacts of nanotechnology both in the Netherlands and in the European Union.
In 2004, at the request of the Ministry of Education, Culture, and Science (OCW), the Royal Netherlands Academy of Arts and Sciences (KNAW) published a report ‘How Big Can Small Actually Be?’ on the possible opportunities and consequences of nanotechnology. OCW used the report to inform the Dutch parliament about the significant opportunities offered by nanotechnology while also addressing the remaining uncertainty about potential risks. The report recommended that the government should continue to make public funding available for fundamental and applied research (KNAW, 2004).

In the same year, the European Commission announced its intention to develop a common European strategy for nanotechnology development within the EU, to include attention to both opportunities and risks of emerging nanotechnologies (European Commission, 2004). In 2005 the European Commission published ‘Nanosciences and Nanotechnologies: An action plan for Europe 2005-2009’ (European Commission, 2005). Input for the European strategy and the following EU action plan came from representatives of the member states. The Dutch government working group on the assessment of European Commission proposals, which, as mentioned in the previous chapter, assesses all proposals that come from the European Commission or European Union agencies to determine whether and how the Dutch government should be involved to ensure an optimal outcome for the Netherlands, its citizens, businesses, and other stakeholders, asked the Ministry of Education, Culture, and Science to oversee the
Dutch contribution to the deliberations of the content of the European action plan on behalf of the government (Mout, 2010).

The 2005 EU Action Plan sought to foster a common approach to the responsible development and commercialization of nanotechnology (European Commission, 2005). It laid out four pillars of government response to nanotechnology that reoccur in the more specific national approach of the Netherlands formulated in 2006 and 2008: (1) A strong focus on research and business opportunities, as nanotechnology offers a wide range of opportunities for societal and economic returns; (2) The need to address ethical, social, and legal aspects; (3) The condition to foster public engagement and knowledge of nanotechnology to avoid any later resentment because of misinformation; and (4) The assessment of risks and uncertainty associated with nanotechnology. The EU action plan identified the promising possibilities of nanotechnology and aimed to reinforce nanoscale R&D as part of the European Union’s research program and innovation capacities. Reflecting wider EU policies to increase the international competitiveness of the European economy, the European Nanosciences and Nanotechnologies Action Plan aimed to stimulate industrial uptake of new knowledge in the emerging field. It also stressed the need for public participation to address potential concerns for public health, worker safety, consumer protection, and the environment.

The plan recommended that the European Commission’s Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) assessed appropriate risk assessment methodologies for manufactured nanomaterials. In doing so, the
Commission placed manufactured nanomaterials under the larger umbrella of European and international regimes with regard to potentially dangerous chemical substances and requested relevant parties, and in particular the member states, to help to develop an overall regulatory approach to nanotechnology and nanomaterials. The EU action plan stressed its preference for international collaboration, and mentioned the United Nations (UN), the World Trade Organization (WTO), and the Organization for Economic Cooperation and Development (OECD) as relevant platforms to exchange information and develop instruments aimed at assessing and ultimately managing any risks associated with nanotechnology (European Commission, 2005).

*Broader International Embedding of Dutch Governance Activities*

Picking up on the trend of nanotechnology research around the world, the International Organization for Standardization (ISO) established its Nanotechnology Standards Committee (TC229) in 2005. TC 229 goals are to develop standards and terminology for nanomaterials and nanotechnology. Since 2005 thirty-four countries joined the ISO committee on nanotechnology. Another eleven countries have taken up an ‘observant’ role, meaning that they monitor the activities and results of the committee. TC 229 has formulated more then twenty standards thus far (International Organization for Standardization, 2011).
The Netherlands Normalisation Institute (NEN) coordinates the Dutch contribution to ISO TC 229 in cooperation with RIVM, the National Institute for Public Health and the Environment funded by the Ministry of Infrastructure and the Environment (IM). RIVM also takes part in the deliberations of the nanotechnology committees formed by both the Netherlands and European Standardization Institutes (resp. NEN and CEN), thus establishing a common viewpoint at all levels of governance (Van Teunenbroek, 2010).

Given ISO’s stature as a leading organization in setting international standards - its membership of 163 countries and the breadth and acceptance of its standards give evidence of that - the Dutch Cabinet aims to avoid specific Dutch standards, preferring instead to express Dutch viewpoints in deliberations about standards within ISO or CEN. In doing so, the Cabinet seeks both to strengthen the influence of Dutch business in setting standards and to position the Netherlands as a leader within ISO (Ministry of Economic Affairs, 2008)

Following the creation of ISO’s TC 229 on Nanotechnologies, the OECD Chemicals Committee established its so-called working party focused on nanotechnology: the Working Party on Manufactured Nanomaterials (WPMN) started in 2006 and addresses health and environmental safety issues of manufactured nanomaterials. WPMN aims to develop and coordinate research strategies to fill knowledge gaps about the risks associated with nanomaterials and to stimulate data gathering. An important WPNM objective is to define a minimum set of data on manufactured nanomaterials that manufacturers should supply in order to get approval for production and use in the
market (OECD, 2010). The Ministry of Infrastructure and the Environment coordinates the Dutch participation in WPNM. The Netherlands participates in four of the nine steering groups the WPMN has established since 2006. The Dutch actively contribute: for instance, to help describe risk parameters, RIVM conducted a study of nano-silver particles as a potential case of the representative set of data that companies producing or using manufactured nanomaterials might submit before being allowed to market their products (Ministry of Economic Affairs, 2010), while TNO contributed research to projects of the steering group on exposure to manufactured nanomaterials (Ministry of Economic Affairs, 2008).

In 2007 OECD’s Committee on Scientific and Technological Policy created the Working Party on Nanotechnology (WPN). The goal of the WPN is to help and advise governments to formulate policies for the responsible development of nanotechnology (OECD, 2010). Dutch participation is coordinated by the Ministry of Education, Culture and Science and the Netherlands actively participates in this working party: as of January 2013, the Netherlands will chair the WPN. Past and ongoing projects of this OECD working party include work on Public Engagement, Indicators & Statistics, Inventory of Responsible Development policies and their implementation (Mout, 2012).

As the Dutch contributions to the OECD’s working parties exemplify, the establishment of these international collaborations on nanotechnology risk-related research in the OECD WPMN gave Dutch researchers the opportunity to participate in and contribute to
joint international research, which has since, as this chapter will argue below, become the principle of Dutch governance of nanotechnology-related risks and remaining uncertainties. In its May 2011 update to Parliament about the progress in the implementation of its policies regarding the risks and uncertainties associated with nanomaterials, the Ministry of Infrastructure and the Environment confirms that the Cabinet “dedicates itself to control possible risks of nanomaterials as soon as possible and does this through international collaboration” (Ministry of Infrastructure and the Environment, 2011, p. 7)\(^38\).

Towards an Integrated Approach of Nanotechnology Development

Government advisory councils support a risk-conscious approach of emerging nanotechnology and see an opportunity for international cooperation in addressing existing knowledge gaps. In April 2006, the Health Council of the Netherlands (Gezondheidsraad), an independent scientific body that advises government and the parliament on matters of public health and health care, published a report concluding that nanomaterials could be hazardous for human health and warned of a broad gap in knowledge about risks associated with exposure to nanomaterials. Given such uncertainty, the Council advised the Cabinet to stimulate and direct further multidisciplinary nanoscale research through financial and other incentives. The Health Council at that time regarded the existing regulatory framework, both at the national and European levels, sufficient to cover any associated risks. It stressed that risk

\(^{38}\) Translated from Dutch original by author.
assessment should take place within international regulatory regimes on chemical substances such as the new European protocol on chemical substances Registration, Evaluation, Authorization of Chemical Substances (REACH), which was at that time prepared (Health Council of the Netherlands, 2006).

Following these reports and findings, the Cabinet informed Parliament of its view on nanotechnologies in the Netherlands in a November 2006 vision statement, ‘From Small to Great’, prepared under coordination of the Department of Economic Affairs (Ministry of Economic Affairs, 2006). The content of the document mirrored the outline of the European Commission’s 2005 Action Plan, with sections on business and research opportunities; societal, ethical, and legal issues; public engagement; and risk assessment. The Cabinet stressed the Dutch position in nanotechnology, articulated its great economic potential, and expressed its intention to contribute to a supportive research climate and to the economic competitiveness of Dutch industry. In the document, the Cabinet focused attention on the uncertainty and risks associated with nanoscale materials, and the lack of standardization of definitions, methodologies, and research strategies in the field. The Cabinet concurred with the advise of the National Health Council as put forward in their 2006 report in its conclusion that the existing legal and regulatory framework was sufficient to deal with any potential risks from nanotechnology, conceding that amendments might be needed as new knowledge came to light. In its 2006 vision document, the Cabinet states that “current prevailing legislation and rules offer sufficient handles to control the risks”, while it will “continue
to consider whether adjustments in legislation is needed to control potential risks” (Ministry of Economic Affairs, 2006, pp. 5-6)39 The Cabinet also stated its preference for any Dutch governance approach to be embedded in an overall European approach, arguing that much of applicable legislation in fields of product safety and environmental protection already takes place at the European level (Ministry of Economic Affairs, 2006).

The Cabinet took a range of initiatives to further develop its vision on nanotechnology development in the Netherlands, including the establishment of a dedicated interdepartmental commission for the coordination of an integrated governance approach of nanotechnology (ION), led by the Ministry of Economic Affairs, but with specific areas of attention to be overseen by other departments. By choosing the Ministry of Economic Affairs as the leading department, the Cabinet indicated that it saw nanotechnology as an important asset to further economic development and innovation. The Department of Infrastructure & Environment (IM) would address environmental protection and chemicals regulation, the Department of Health, Welfare, and Sport would look at issues pertaining to public health, and the Department of Social Affairs and Employment would focus on occupational health and safety issues.

At the request of the Cabinet, the three departments created an knowledge and information point for the risks associated with nanotechnology within the National

39 Translation from Dutch by author.
Institute for Public Health and the Environment (RIVM) called, based on its Dutch acronym, ‘KIR Nano’ to identify and monitor scientific advances in the field of nanosciences and nanotechnologies. KIR Nano takes part in scientific programs such as those initiated by the EU, the OECD, and the ISO. The aim of KIR Nano is to share relevant information on responsible development of nanotechnology within the government (RIVM, 2010). The KIR Nano observation point does not conduct research itself, however, its staff - mainly scientists and experts in fields that include research and development at the nanoscale - maintains a large network of contacts with the research community and the venues where policies, both domestic and international, are prepared. KIR Nano monitors activities taking place in the EU, including the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), the European Food Safety Authority (EFSA), and the European Chemical Substances Protocol (REACH), as well as in the OECD, the UN World Health Organization (WHO), the Food and Agriculture Organization (FAO), and the Society of Environmental Toxicology and Chemistry (SETAC). Often the RIVM itself acts as a participant in these forums (Van Zijverden, 2010).

A Netherlands Nano Initiative?

In 2006, following the publication of its vision document, the Cabinet requested a collaboration of industry, research institutes, and NanoNed – the Dutch nanotechnology collaboration of industry, universities, and research institutes - , working under the ‘Netherlands Nano Initiative’ to develop a Dutch nanotechnology research agenda
(Ministry of Economic Affairs, 2006). The name ‘Netherlands Nano Initiative’ often appears in documents, yet, it does not represent an organization, nor does it have any formal meaning. It could hint to the United States National Nanotechnology Initiative (NNI), however there are no suggestions that the Netherlands Nano Initiative ever aimed at a similar government-led set up as the U.S. NNI. It appears that the Netherlands Nano Initiative label just points to the broad group of stakeholders (industry, research institutes, universities, and research funding organizations), which eventually were involved in putting together, at the request of the Cabinet, a ‘Strategic Research Agenda for Nanotechnology’ (SRA): A longer-term strategy for nanotechnology research and development in the Netherlands. Already before the Cabinet’s request, which came in the wake of its 2006 vision document on nanotechnology, a broad group consisting of the consortium partners of NanoNed together with representatives of the government’s main research funding organization NWO and its divisions STW and FOM informally had started discussion about the future of nanotechnology development in the Netherlands for the years after 2010, when the funding for NanoNed would end. Such future scenario should include the Strategic Research Agenda for Nanotechnology requested by the government and would built on broader themes of national strengths and challenges pointed out by NWO and the government, such as ‘water,’ ‘energy’, ‘food’, and – specific for nanotechnology – ‘ risks and toxicology’ (Reinhoudt, 2006) (Gielgens, 2012). The themes of the SRA were based on a 2005 NWO strategy document, *Toward a Multidisciplinary Nanoscience Programme* (Nederlandse Organisatie voor Wetenschappelijk Onderzoek, 2005) (FOM, STW & NanoNed, 2008).
The Strategic Research Agenda would be the basis on which an, at the time, labeled Netherlands Nanotechnology Initiative was to be developed. The Netherlands Nano Initiative would be a public – private partnership, similar to the NanoNed and NanolImpuls collaborations and, unlike the United States National Nanotechnology Initiative, the initiative did not foresee or request direct government coordination. The participants in the discussion in this discussion argued that some kind of national coordination was desirable at that point to ensure continuance of research funding and to decide on a common roadmap for nanotechnology development in the Netherlands (Reinhoudt, 2006).

The 2008 Nanotechnology Action Plan

In June 2008, the Dutch Cabinet, after the elections based on a new coalition led by the Christian-Democrat party and joined by Labor Party (PvdA) and a smaller left-oriented party, continued the path set out by previous cabinets and followed up on its 2006 nanotechnology vision by presenting its ‘Nanotechnology Action Plan’. The plan, prepared by the Interdepartmental Working Group on Nanotechnology (ION) and based on the 2006 vision document, incorporated the most up-to-date scientific findings, and reflected information and agreements from European Union and other international initiatives. The 2008 plan, which has since become the basis of Dutch government involvement in nanotechnology, mirrors the pillars of nanotechnology research development as put forward by the European Commission 2005 action plan: strengthen research and business opportunities, seek an inclusive governance approach addressing
societal and ethical concerns, and address risks and remaining uncertainty associated with nanotechnology for health and the environment. The Dutch action plans reconfirmed the strong position of Dutch industry and research institutes at that time, but stressed the need to continue investing in further development. The plan strongly situated nanotechnology research in the Netherlands in its wider European setting, referring to participation in a number of European Framework Program projects and other European collaborations.

The Seventh EU Framework Programme (FP7), running from 2007 to 2013, continued the Nanosciences, Nanotechnologies, Materials and New Production Technologies (NMP) research theme. The EU Directorate General on Research and Innovation estimates that within the timeframe of FP7 the total expenditure on nanoscale research funded by the European Union and the national governments of its member states will be around 3.5 billion euro (EC, 2010) (Cordis, 2012).

In the 2008 Nanotechnology Action Plan, the Cabinet acknowledged the remaining gaps in knowledge with regard to risks and uncertainty of nanotechnology, and articulated that, as development of nanotechnology in the Netherlands is heavily embedded in and depending on international circumstances, further research should take place in European and international collaboration, in particular within the OECD and the ISO. The Cabinet concluded that existing legislative and regulatory framework, already embedded in European regulations such as the REACH protocol on the use of chemical
substances, seemed sufficient to address nanotechnology, yet it repeated that new knowledge about risks could result in amendments to existing laws and frameworks (Ministry of Economic Affairs, 2008).

An Example of Multi-level Governance: The European Union’s REACH Protocol for Chemical Substances

As nanoscale research started to offer opportunities to develop, fabricate, and use new materials of existing materials at an unprecedented small size, national and international regulators of, for instance, chemical materials needed to address these novel materials. In June 2007, the Dutch government adopted the EU’s directive on the Registration, Evaluation, Authorization of Chemical Substances, or REACH (EC 1907/2006). REACH was implemented as part of Dutch legislation and it replaced all existing policies with regard to the use of materials and chemicals in the Netherlands (Ministry of Housing, Spatial Planning, and the Environment, 2008).

Through its application of the precautionary principle, REACH gives greater responsibility to industry to manage the risks from chemicals and to provide information on the chemical substances they intend to use in production. Manufacturers are required to gather a specific set of data on the properties of the chemicals they produce or use. These data are registered in a central database operated by European Chemicals Agency (ECHA). In doing so, REACH seeks to fill remaining gaps in information about chemicals in use as well as new substances entering the European market (European
Commission, 2010). As REACH required industry in the chemical branch to report data on the use of chemical materials in new ways, often disclosing more details than previously demanded, concerns about implementation costs of REACH for the sizeable Dutch chemical industry – as mentioned prominent international companies as Akzo Nobel and DSM originate in the Netherlands - were part of the REACH-related debate in parliament in 2006. However, evaluation of the REACH implementation shows that, despite substantial implementation costs, industry appreciates the benefits of harmonized European regulation and clarity of definitions for chemical substances (Ministry of Infrastructure and the Environment, 2011)

Originally, REACH did not specifically address manufactured nanomaterials. The Dutch government, clearly favoring European collaboration in achieving harmonization of any efforts to regulate the production and use of manufactured nanomaterials, shared its concerns about the slow progress being made to achieve a proper oversight of nanomaterials under REACH and the consequences for nanotechnology development with the European Commission and the European Chemical Agency, which oversees REACH implementation. In 2008 at the request of, among others, the Dutch Cabinet, the European Commission, set up a subgroup under the REACH Competent Authority on nanomaterials (CASG oN) to address regulation of engineered materials at the nanoscale under REACH (Ministry of Economic Affairs, 2008). The government agreed with the conclusion of the European Commission that the REACH regulatory framework in principle offered sufficient possibilities to cover manufactured nanomaterials (Ministry
of Economic Affairs, 2008), however felt that the assessment of how this should be done remained slow in reaching conclusions. Through Dutch participation in this group, the Cabinet aimed to stimulate, ensure and accelerate European collaboration in developing a common strategy for the risk assessment of manufactured nanomaterials under the REACH protocol. The Ministry of Infrastructure and the Environment leads the Dutch participation in the CASG oN, while other Dutch ministries and research institutes contribute where feasible (Van Teunenbroek, 2010).

In June 2008 the European Commission (EC) declared the precautionary principle applicable to nanomaterials. While the Commission takes collective decisions, multiple interests within it are clearly present. For example, the Commission includes the commissioner responsible for industry and enterprise, as well as commissioners responsible for environmental issues and matters of consumer or worker safety. Such diversity of opinion is apparent with regard to manufactured nanomaterials and the precautionary principle. A strong view of the principle argues that as knowledge of the risks associated with such materials remained incomplete and insufficient, they should be considered as potentially hazardous for humans and the environment until proven otherwise. From an economic perspective, however, such strict interpretation of the precautionary principle might hinder technological advancement and economic growth (Van Calster, 2008). The Commission, aiming to balance environmental and consumer safety concerns with the economic opportunities offered by emerging nanotechnology, went on to state that manufactured nanomaterials are covered under the substance
definition of the REACH protocol, and reconfirmed that it considered the existing legislative and regulatory framework sufficient to cover all aspects of nanotechnology. Yet, the Commission added that amendments to REACH might be needed, as new insights would come available. The Commission stated that it preferred international collaboration, in particular within the OECD and the ISO, to address issues about testing methods, toxicity of manufactured nanomaterials, characterization of materials, and exposure levels to manufactured nanomaterials. It sees international collaboration in the OECD and the ISO as a help to “facilitate a global convergence in standards for the implementation of regulation” (European Commission, 2010, p. 8). In its 2010 implementation report on its Nanosciences and Nanotechnologies Action Plan, the Commission concludes that international cooperation in nanotechnology research is strong and it mentions the European Union’s participation in the OECD working parties as well as the ISO technical committee on nanotechnology (European Commission, 2010). The Commission referred to FP7 for public funding of risk research related to nanotechnology (European Commission, 2008).

The Commission’s view that the existing regulatory framework were sufficient to cover manufactured nanomaterials was challenged in April 2009 when the European Parliament passed a resolution by large majority (391 in favor out of 400 votes) that disagrees with the Commission’s assumption and required it to do a thorough review of existing legal and regulatory frameworks (European Parliament, 2009). Environmental and consumer interest groups favored the resolution, while industry representatives
warned that overly strict regulations would hinder innovation (Euractiv, 2009). The Directorate General Environment commissioned the review. Its report, released in September 2011, concludes that while existing legislation in principle can cover nanotechnology, absence of data make it difficult to fully assess the possible environmental and health dangers on nanotechnology. As a result, the report concluded, the precautionary principle should apply (Milieu Ltd and AMEC Environment & Infrastructure UK, 2011). These lacunae in knowledge led the Commission, and its DG’s Environment and Enterprise & Industry to continue to gather information and fund research to fill in remaining gaps, in particular executed under the oversight and control of the REACH subgroup on nanomaterials (CASG Nano) (EC Directorate General Environment, 2012)

Broader Dutch Policy Priorities for Nanotechnology Support in the Netherlands:

Responsible Development and Societal Outreach

Nanotechnology fits in well in overall government policies of supporting and building a knowledge-based economy through public investments innovation and research. Amid at some times contentious political developments during the first decade of this millennium, the ‘science, technology, innovation, education’ policy cluster remained relatively uncontroversial and opposition parties went along with the overall government approach on this topic. Coalition parties in subsequent cabinets, as well as most opposition parties stressed the opportunities that nanotechnology offered for the Dutch industry and academia, yet acknowledged gaps in knowledge about longer-term
risks and uncertainties. These concerns and balanced approach were reflected in the Cabinet’s 2006 vision document and confirmed its 2008 Nanotechnology Action Plan. The Green Party (Groen Links) stressed in 2008 that the precautionary principle should apply to nanotechnology, as so much remained unknown (Groen Links, 2008). The Cabinet’s Nanotechnology Action Plan explicitly included attention for the opportunities nanotechnology offered as well as its possible risks and wider societal consequences. In the 2008 Nanotechnology Action Plan, the government invited a broad group of stakeholders to participate in the responsible development of nanotechnology in the Netherlands. A couple of initiatives are telling examples of such intention: The ‘Sounding Board on Risks of Nanotechnologies’, the set up of an industry – government collaboration to exchange information and research findings on risks associated with nanotechnology, and the establishment of the ‘Commission Public Dialogue Nanotechnology’ (CieMDN).

As part of the Action Plan, the Cabinet announced, in typical Dutch fashion of consensus mediation, the formation of the Sounding Board on Risks of Nanotechnologies, consisting of experts from government, industry, and civil society organizations, to facilitate agreement among participants on how to deal with the potential risks of manufactured nanoparticles in the workplace and in consumer products. Among the participants in the board are different ministries as well as government agencies in charge of workers conditions and food safety, several industry and trade organizations representing the chemical industry, the cosmetics industry, and the insurance industry,
different enterprises, among them leading chemical companies such as DSM, labor union FNV, consumer safety organization Consumentenbond, and several environmental protection groups such as Vereniging Leefmilieu, Stichting Natuur en Milieu, and the Dutch division of Women in Europe for a Common Future (WECF) in addition to representatives of NanoNed (Ministry of Infrastructure and the Environment, 2012). The goal of the group was to exchange information and to formulate a common Dutch opinion on matters with regard to the risks associated with nanomaterials that were to be shared at the European and broader international deliberations on rulemaking and regulations for nanotechnology and the use of nanomaterials.

A 2012 evaluation report of the activities of the Sounding Board shows that the members of the group focus on exchange of information, for instance about the progress in the EU, OECD, and ISO meetings about nanomaterials and nanotechnology and how to accelerate and harmonize research and its priorities. Also, the group addresses regularly new ways to reach out to other stakeholders, such as universities and small and medium sized companies that may work with nanoscale materials, to make sure these are well-informed about risks and remaining uncertainties of handling nanomaterials. The participants in the group actively seek international collaboration to shape the research and policy agenda: in 2011, for instance, Consumentenbond, FNV, Stichting Natuur & Milieu, and WECF sought cooperation with their European umbrella-organizations to accelerate the progress of policy matters related to addressing the risks of manufactured nanomaterials (Ministry of Infrastructure and the Environment, 2012).
In its evaluation report, the group concluded that its meetings had been fruitful and helped to create a common viewpoint on matters at hand. The group will continue to meet (Ministry of Infrastructure and the Environment, 2012).

Soon after the publication of the Cabinet’s Nanotechnology Action Plan in 2008, the Confederation of Netherlands Industry and Employers, the Netherlands Chemical Industry Association, and the Dutch Government came to an agreement to stimulate the exchange of information between industry and government on issues surrounding the assessment of risks associated with nanotechnology. In addition to sharing results of publicly funded research, the agreement sought to facilitate research done by Dutch industry in so-called ‘pilot projects’ can be used as input for European and OECD programs. The intention of this agreement was to stimulate industry participation in contribution to risk-related research (Ministry of Economic Affairs, 2010).

Also in the 2008 Action Plan, and established on March 31, 2009, the Cabinet announced the formation of the ‘Commission Public Dialogue Nanotechnology’ (CieMDN) to support a public debate on the respective benefits and risks of nanotechnology. A so-called public dialogue is a model to engage a wide range of stakeholders in the discussion on a particular topic. It is not a formal instrument, and the shape, form, and timing of a ‘public dialogue’ differs. A model of public dialogue aims to foster citizen participation in political decision-making (Enthoven, 2005). The government initiated a broad public dialogue on nanotechnology by forming CieMDN
and instructing the commission to set up and execute a public dialogue. The CieMDN has since conducted a program that invited proposals to stimulate a national debate, which consisted of a range of discussions and events all over the country (Commissie Maatschappelijke Dialoog Nanotechnologie, 2010). The commission offered funding and an overall framework and a web portal for people, groups, and organizations that wanted to contribute to a discussion about whether and how nanotechnology in the Netherlands should develop. Some examples: a consultancy company created a series of television documentaries on nanotechnology, broadcasted on national television in the Summer of 2010; a popular-science magazine dedicated a nanotechnology edition to nanotechnology in July 2010; a publisher of educational materials set up a teaching package on nanotechnology for high school students; an interfaith philosophy group organized a seminar on ethical consequences of nanotechnology; games, websites, cartoons, and an information booth on a popular multi-day music festival were part of the national dialogue on nanotechnology, which consisted of more than thirty-five initiatives, sponsored by CieMDN (Commissie Maatschappelijke Dialoog Nanotechnologie, 2011). When presenting its results in January 2011, CieMDN concluded that the Dutch public in general is positive about the possibilities of nanotechnology, but acknowledges the potential negative side effects that need to be addressed. The consensus was that public funding of nanotechnology is justified as it offers huge opportunities, yet comes with many remaining unknowns and potential risks. CieMDN’s overall conclusion is captured well in the title of its report: ‘Responsibly
Onwards With Nanotechnology (Commissie Maatschappelijke Dialoog Nanotechnologie, 2011).

An Integrated Approach

The focus on an integrated and multi-level approach of dealing with the risks and remaining uncertainty of nanotechnology was reinforced by a report produced by the Social and Economic Council of the Netherlands (SER) and published on September 5, 2008. A prominent example of mediating institutional arrangements aimed to incorporate interest groups in the policymaking process, the SER consists of employers, trade and labor unions, and Cabinet appointed independent experts equally. The council renders advice only in consensus, so its recommendations are highly regarded and very influential. The SER concluded that since under the precautionary principle materials with uncertain risks are to be handled as hazardous substances, exposure to these materials should be prevented or minimized. The SER referred to the Dutch ‘Working Conditions Act’ of 2007 and industry guidelines for working with nanoparticles to direct employers to supply a safe and healthy workplace (SER, 2008).

As requested by Parliament, the Cabinet regularly informs Parliament of the interdepartmental handling the approach of the risks associated with nanotechnology (e.g., March 2008, June 2009, May 2011, May 2012). The Cabinet’s view, as expressed in successive reports, remains in line with previous views and recommendations by the

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40 Translation from Dutch by author.
SER, the National Institute for Public Health and the Environment (RIVM), and the Health Council and is embedded in the European and international governance approach. The Cabinet confirms that the precautionary principle is the basis of the Dutch and European approach of risks associated with nanomaterials. While the Cabinet will not establish a specific regulatory system for nanotechnology, it applies existing legislative and regulatory frameworks, in particular the European REACH protocol for chemical substances, to the production and use of nanomaterials (Ministry of Housing, Spatial Planning, and the Environment, 2008) (Ministry of Housing, Spatial Planning, and the Environment, 2009). Even so, a 2010 review of the existing regulatory framework commissioned by the Ministry of Infrastructure and the Environment indicated that upholding the precautionary principle within the Netherlands is more difficult than at the European level, as the principle is clearly introduced in EU legislation but less evident in existing Dutch policies. Yet, the review concluded, the precautionary principle will play an important role in any regulatory actions on nanotechnology, as much of such action takes place at the European level, at which the precautionary principle has been declared applicable (Oosterhuis & Peeters, 2010). The review argues that the European Union, as well as other international organizations, in which the Netherlands participates, are working to accentuate existing regulations, such as the REACH protocol for chemical substances, to nanoscale materials. As REACH does not mention ‘nano’ specifically, amendments may be needed to cover nanomaterials in the future as a result of the findings of the REACH subgroup on nanomaterials (Oosterhuis & Peeters, 2010). The review also argues that remaining uncertainties should not be the cause of
delay in taking precautionary measures when threats to the environment or human health arise as a consequence of the use of nanotechnology and nanomaterials.

In its 2012 update to parliament, the Cabinet indicates that many knowledge gaps remain and indicates that it will seek an acceleration of risk related research (Ministry of Infrastructure and the Environment, 2012), as understanding risks is conditional for successful application of nanotechnology and, from the government’s view, the slow pace of risk related research threatens Dutch prominence in nanotechnology. Moreover, the Cabinet in its letter to parliament on this matter dated on May 22, 2012 stressed the need to address these gaps through international collaboration, in particular within EU and OECD, by stating that “The Netherlands depend on international agreements, preferable in the form of a harmonized European approach”\(^{41}\) (p. 2) and pledged Dutch cooperation in sharing research results and funding international research initiatives (Ministry of Infrastructure and the Environment, 2012).

The government efforts described above show a notable convergence of governance at multiple levels in dealing with the risks and remaining uncertainty of the use and production of nanomaterials. In the EU’s second implementation report of the status of the 2005-2009 Action Plan (October 2009), the European Commission concluded that between 2007 and 2009 only 5% of the total research expenditure on nanotechnology within the EU was allocated to risk research, and called on industry to improve their

\(^{41}\) Translated from Dutch by author.
input to risk research. The Commission stressed its involvement with the OECD Working Party on Manufactured Nanomaterials in its efforts to developing test methods and guidelines for risk assessment and concluded that the standardization work done by ISO is needed to support the worldwide convergence of standards as the basis any regulatory approach (European Commission, 2010). The European Commission’s action was not unique, as government agencies worldwide concluded that more research is needed, while data are still insufficient, to fully understand the risks associated with nanotechnology. A recent study by Falkner and Jaspers (2012) argues that remaining uncertainties hinder a consistent harmonized regulatory approach. These remaining knowledge gaps do not take away broad public and private support of continued nanotechnology research given the promise of great economic and societal returns, yet risk assessment has become an integral part of the overall research agenda for nanotechnology.

*Building on the Strategic Research Agenda: Further integration in Dutch Nanotechnology Development*

As requested by the Cabinet following its 2006 vision document on nanotechnology, the participants in the Netherlands Nano Initiative presented their ‘Strategic Research Agenda’ (SRA) for nanotechnology in 2008 (FOM, STW & NanoNed, 2008). The SRA has since become the guideline of nanotechnology research in the Netherlands. It is used as the scientific basis of the cooperation between government, industry, and research institutes in nanotechnology development as put forward in the Cabinet’s 2008
Nanotechnology Action Plan. The 2008 SRA proposal foresaw a continuous annual investment of 100 million euro for a ten-year period (2010 – 2020). Of the total funding of the research programs proposed under the SRA, 50% was to be carried by industry, and 35% by public funding through universities and research organizations, while EU FP7 and other European research programs were expected to contribute 15% of the annual budget. The budget proposal was rather aggressive in its tone; leaders of the Netherlands Nano Initiative argued that actual total decreases in R&D funding in the Netherlands (Rathenau Instituut, 2012) had harmed Dutch prominence in nanotechnology. The priorities of the research agenda were chosen along two lines: First, achieving national strengths and opportunities in nanoscale research in areas such as nanoscale miniaturization, nanomaterials, the convergence between bio- and nanotechnology, and the fabrication of nano-sized electronica; and, second, addressing national (and global) societal challenges, such a health, food, energy, and water. The SRA sought links to other existing research initiatives, such as MicroNed, a public–private collaboration that focused on microscale research.

The SRA budget proposed an allocation of 25% of the funds to nanoscale applications, 20% to generic nanotechnology research, 20% to nanotechnology infrastructure and open access to industry and research institutes to nanotechnology labs, such as those of NanoLab NL, 10% to invest in education and training of scientists, and 15% to risk-related research (FOM, STW & NanoNed, 2008). The 15% budget allocation for risk-related research follows the explicit request of the government that “at least 15% of the
research agenda will be devoted to risk-area research for a minimum of five years” (p. 11), which shows the further integration of specific risk-related research in general nanotechnology research (Ministry of Economic Affairs, 2008). It is an example of what is meant with the label ‘responsible development’ of nanotechnology in the Netherlands.

In 2009 the Dutch government announced a new round of funding through the Economic Reinforcement Fund (FES), which distributes public income from the sale of natural gas to projects that support the economic infrastructure of the Netherlands. The 2009 FES round aimed in particular to continue public funding for previously FES-funded projects and programs that proved to be successful, such as NanoNed. The Ministry of Economic Affairs, the leading ministry in the field of innovation, asked several programs to make a combined proposal for this funding cycle to continue their programs. A consortium consisting of several programs financed partly through FES funds in earlier rounds, which included NanoNed, MicroNed, and a research facility specialized in electronics, the Holst Center at Eindhoven University, in 2010 gained approval for a renewed program that runs until the end of 2016: NanoNextNL (Gielgens, 2012). In the new set up NanoNextNL works together with the research institutes that are part of NanoLabNL, the network of research facilities. However, unlike under the preceding NanoNed program, funding for NanoLabNL is based on a different government grant, separated from NanoNextNL. The NanoNextNL program received 125 million euro in public funding, starting in 2011. Matched by the other consortium partners,
NanoNextNL’s total budget for 2011 – 2016 is 250 million euro (FES Initiative 2009 HTSM, March 2009) (FES Initiative 2009 HTSM, Oct. 2009). The goals of NanoNext NL are to continue existing research programs, integrate microscale research in the program, and fulfill the Strategic Research Agenda as presented to the Cabinet in 2009, in order to expand upon the Dutch academic and industrial position in the field of Nanotechnology.

*Nanotechnology as part of Top Sector ‘High Tech Systems and Materials’*

‘High Tech Systems and Materials’ (HTSM) is one of the nine Dutch ‘Top Sectors’ that together make up the subject of the government’s current overarching innovation program *Top Sectors*, which was introduced in the previous chapter. As one of the largest economic clusters, expanding the HTSM sector is based on public – private cooperation. It reflects a traditional way of organizing collaboration in the Netherlands: The partners sign so-called ‘innovation contracts’, which lay out the agreements about R&D priorities and funding (Ministry of Economic Affairs, Agriculture, and Innovation, 2012). Within the HTSM cluster, nanotechnology is regarded as a so-called ‘ecosystem’, an enabling technology that covers activities across the different sectors of the program (Ministry of Economic Affairs, Agriculture, and Innovation, 2012).

Figure 5.2 gives an overview of the HTSM *Top Sector*. As the chart suggests, nanotechnology is one of the top sectors (in green), but also cross cuts different sectors, as the nanotechnology ecosystem (in orange).
The Cabinet chose to fund the HTSM proposal based on its condition that it would include successful FES funded research programs. The HTSM program, started in 2011, includes NanoNextNL, which was already the largest program funded by FES and received a budget commitment by the cabinet in 2010 for the period 2011 – 2016.

In a European Setting

The subsequent public - private partnerships in nanotechnology research are not unique for the Netherlands. Public – private cooperation in research and development
has become more important in the different European research programs as well, based on the view that a common research agenda between industry and government funded institutes was essential to overcoming the aforementioned ‘European paradox’. For example, the EU’s Seventh Framework Programme seeks to stimulate public-private cooperation through so-called joint technology initiatives. Five such initiatives have been formed since the start of FP7. In 2008 the European Commission and thirteen EU member states, including the Netherlands, collaborated with industry, research institutes, and universities to set up the ENIAC Joint Undertaking for nano-electronics. ENIAC aims to coordinate and fund European research in nano-electronics by defining and implementing a common strategic research agenda, award funding to participants, and promote synergy between different European research efforts in the field (European Commission, 2007) (ENIAC, 2010). Since its establishment ENIAC has awarded Dutch companies more than 60 million euro (ENIAC, 2012) (Point One, HTAS & M2i, 2010). ENIAC is not the only European technology initiative that supports a field as broad as nanotechnology: Artemis, which focuses on embedded computing systems and the Catrène cluster for Application and Technology Research in Europe fund nanotechnology research as well. To help Dutch industry benefit from the opportunities and funding offered by these European collaborative initiatives, the Ministry of Economic Affairs (ELI) has established a specific innovation program called Point One, linked to the department’s innovation agency, that coordinates and facilitates access and participation of Dutch companies in research funded by these European research initiatives (Agentschap NL, 2010).
As this chapter comes to a conclusion, an overview seems appropriate. Figure 5.3, based on a range of Dutch government and European Commission documents, offers a view of the successive nanotechnology research programs in the Netherlands, mostly public-private partnerships partially funded by the government and their embedding in broader Dutch and European research and innovation programs.

Fig. 5.3 Successive Dutch Nanotechnology Research Programs and their Embedding in Broader Dutch & European Research and Innovation Programs.


As Fig 5.3 shows, nanotechnology as part of the HTSM Top Sector is not limited to the NanoNextNL program. The so-called HTSM Roadmap Route ‘Nanotechnology and Dutch
Opportunities’ includes besides NanoNextNL, NanoLabNL - which since 2010 is separately through FES - and the government’s research funding organization NWO’s ‘Nano Call’, a research program focused on funding fundamental nanoscale research.

The HTSM Nanotechnology Road Map builds strongly on the three pillars of the research system: public funding, research & education, and industry. It aims to overcome the paradox that sees a slow or partial uptake by industry of scientific findings and technological breakthrough. The Road Map shows the plans of the different participants and their ambitions for the 2012 – 2020 framework (Ministry of Economics, Agriculture, and Innovation, 2012).

Risk-related research and technology assessment, which addresses broader societal consequences of new technologies such as nanotechnology, have become an integral part of the research agenda and reflect the government’s request of an integrated (or responsible) approach of publicly funded nanotechnology research. Of the total budget 15% is allocated towards risk research and technology assessment (FES Initiative 2009 HTSM, Oct. 2009) (Walthout, van Keulen, van Est, Brom, & Malsch, 2009). In its latest letter to inform parliament about the progress in the Cabinet’s approach of nanotechnology research in the Netherlands, the Cabinet mentioned that NanoNextNL and the NWO Nano Call even go beyond the 15% minimum condition set by the Cabinet and allocate 22% of their combined budget to risk research and technology assessment (Ministry of Economic Affairs, Agriculture, and Innovation, 2011).
5.3 Dutch Government Support for Nanotechnology until 2016

In its support for nanotechnology development, the Dutch government relies on pre-existing relationships, established institutional arrangements, and policies in the Netherlands, in Europe, and beyond: A succession of public – private consortia has advanced nanotechnology research in the Netherlands since 2002. Its current installment, NanoNextNL and its linked network of facilities NanoLabNL, have received government funding through 2016. Public funding for the nanotechnology consortia comes from a specific government fund for economic reinforcement. It is new and additional budget, on top of traditional annual research funding. The government sets two clear conditions: it requires the consortium partners to match the public funding of these collaborations and it requires that 15% of the budget is dedicated to risk-related research. The interests of the industry involved in the public - private nanotechnology collaborations and the advancement of scientific insights explain that the years the nature of nanotechnology research has increasingly become more applied. However, public research funding organizations, notably NWO, continue to fund basic or fundamental nanoscale research.

While the Netherlands has a strong international position in nanotechnology research, actual industrial application and commercialization does not yet allow the Netherlands a front-runner’s position. However, the aspirations of industry, research institutes, and the government are to join the group of countries that lead in nanotechnology research.
and development through an active program embedded in a broader innovation program – the *Top Sectoren* program – that focuses on advancing the Dutch competitive position in the European Union and in the world. This Dutch innovation program fits in a wider European frame of innovation programs, such as Horizon 2020.

As a highly internationally connected society and economy, the Netherlands depends on international agreements. Its prominent position and high aspirations in nanotechnology make that the Netherlands relies on international cooperation in nanotechnology, in particular regarding matters of the setting of standards, deciding on nomenclature, definitions, and measurements, and not in the least how to address risks and remaining uncertainties associated with nanotechnology. Clearly, and by outspoken preference in the 2008 Nanotechnology Action Plan and the subsequent progress reports (Ministry of Economic Affairs, 2008) (Ministry of Economic Affairs, Agriculture, and Innovation, 2011), the Dutch governance approach of in particular the risks associated with nanotechnology is embedded in multi-level European and broader international policymaking settings. The 2008 Nanotechnology Action Plan mentions that “[t]he short-term goal of the cabinet is the embedding of European legislation, the most significant part of which is the REACH Regulation” (Ministry of Economic Affairs, 2008, p. 4). The Netherlands actively contributes to international regulatory initiatives to shape its outcomes.
Yet, given its importance for the development of nanotechnology in the Netherlands, Dutch policymakers are concerned about the slow pace of progress in risk-related research. The government of the Netherlands seeks acceleration of such collaboration, and harmonization of its outcomes, within the European Union and through its participation in the OECD and ISO committees and working groups. It stresses the overall embedding of regulation of nanomaterials in the European protocol on chemicals REACH. Dutch participation in NANoReg, a project proposal for risk-related research recently submitted to the European Commission, exemplifies how the Netherlands seeks to contribute to harmonization of decisions taken at different venues: The NANoReg project follows up on various OECD WPNM projects to generate metrology for nanomaterials. Several Dutch research institutes and companies will participate (Ministry of Infrastructure and the Environment, 2012).

Understanding risk and addressing uncertainties is necessary for successful nanotechnology development. Broad adoption of nanotechnology applications in society is hindered when questions remain about the possible risks that such applications carry. The government favors an integrated ‘responsible’ approach of nanotechnology development, addressing both opportunities and risks (Ministry of Economic Affairs, Agriculture, and Innovation, 2011) and it has, over the years, become
increasingly explicit in its request for an integrated approach of nanotechnology.

Different quotes reflect that⁴²:

“The Cabinet holds the opinion that this development [of nanotechnology as contribution to economic growth] needs to be in balance with adequate risk control. ...[The Cabinet] shares the opinion of the Second Chamber [of Parliament] that without risk control, there are no opportunities” (Ministry of Infrastructure and the Environment, 2011, p. 2).

“The Cabinet holds the opinion that these developments should be in balance with risk control and therefore aspires an integral approach of nanotechnology, as to make use of the opportunities in a sensible manner” (Ministry of Economic Affairs, Agriculture, and Innovation, 2011, p. 2).

“It is only by dealing carefully with the risks that the Netherlands will be able to exploit its opportunities to the full (Ministry of Economic Affairs, 2008, p. 2)

As nanotechnology developed in the last decade and a half, a convergence of policy priorities is discernible between the Dutch and European levels of governance: the focus to stimulate research and industrial uptake in the emerging field on nanosciences and nanotechnologies in order to benefit from its great opportunities; the urge to address any social, ethical, and legal concerns; the wish for public engagement in the development of nanotechnology; and the need to balance opportunities with a clear assessment of the risks of nanotechnology and the uncertainty that remains, preferably in international collaboration. Again the notion of responsible development of

⁴² Translated from Dutch by author.
nanotechnology, which integrates general nanotechnology research and risk-related research, is noticeable. The Dutch government has taken an active and directive approach in addressing risks and consequences of nanotechnology, which is exemplified by its condition that at least 15% of research programs that receive public funding should be dedicated to risk-related research (Ministry of Economic Affairs, 2008).

Dutch nanotechnology efforts link to the European Union research agenda. The Netherlands is actively involved in European research. Dutch research programs receive more than the ‘just return’ in European funding. ‘Just return’ means that a country receives a percentage of the overall spending that is similar to the percentage it contributes to the total budget (Ministry of Economic Affairs, Agriculture, and Innovation, 2011). In 2009 Dutch researchers received 5.5% of total European funding for nanotechnology R&D, while the ‘just return’ percentage is 4.8%. The Cabinet estimates that public investment in nanotechnology research in the Netherlands amounted to 150 million euro in 2010. This includes specific nanotechnology programs such as NanoNextNL and NanoLabNL, research funded through universities, innovation tax incentive programs of the Ministry of Economic Affairs, and European research funding through FP7 and ENIAC projects for research conducted in the Netherlands or by Dutch research institutes and companies (Ministry of Economic Affairs, Agriculture, and Innovation, 2011).
As exemplified by the formation of the Sounding Board on Risks of Nanotechnology in 2008, the National Dialogue on Nanotechnology between 2009 and 2011, and KIR Nano, the Cabinet stimulates participation of all stakeholders in the policy formation process. Such stakeholders include numerous organizations: for instance industry and industry associations, labor unions, universities and research institutes, consumer organizations, environmental protection groups, and the general public. It might be of help that the Netherlands is a small country, and, though densely populated, the number of people involved in the development of nanotechnology, either in science, industry, government, or civil society, is limited: formal and informal interactions are common and frequent. The 2008 Strategic Research Agenda for Nanotechnology, developed at the request of the Cabinet, has set the priorities for current nanotechnology research in the Netherlands. It is based on broad consultations between government, research institutes, universities, and industry.

By funding different nanotechnology-related programs within the national innovation program *Top Sectoren* and through the annual budgets of the research funding organizations, the Cabinet regards nanotechnology research funding as a settled matter for the coming years, and well embedded in broader innovation and research programs aimed at serving a wide and enabling field of science and technology (Ministry of Economic Affairs, Agriculture, and Innovation, 2011).
Chapter 6  How Varieties of Government Support for Nanotechnology Reveal the
Stimulus of Global Competition, the Power of Existing Institutional
Arrangements, and the Opportunities of Multi-level Governance.

6.1  Introduction.

This study began with the hypothesis that national government support for
nanotechnology is driven not by the intrinsic nature of the technology but by
longstanding structural and institutional arrangements. It tests this hypothesis by
examining drivers of government promotion of nanotechnology - its shape, size, and
policy priorities and preferences - in the United States and the Netherlands.

In the United States, pluralist political traditions and reliance on classical liberal market
economics would suggest a detached national government approach, leaving the
initiative for technology research and development to market actors. At the same time,
a legacy of corporatism in the Dutch political system and a tradition of greater
government involvement in the national economy would suggest a government-led
policy on nanotechnology development.

The story suggests otherwise. Early on, the United States government established the
National Nanotechnology Initiative, a broad yet thin, overarching federal mechanism to
promote nanotechnology development. It is a novel approach of policymaking that
nevertheless, left ample autonomy for the ultimately twenty-seven participating federal departments and agencies. In this regard the NNI reflected pluralist arrangements of American policymaking. More telling, concerns among relevant policy elites that foreign countries might challenge American global leadership in science and technology drove the desire to coordinate an expanding range of federally funded nanotechnology research activities and rapidly increase public investments in nanoscale research to an average annual $1.8 billion annually.

In the Netherlands, by contrast, the path taken reflected a legacy of Dutch corporatist policymaking practice: slow, incremental, and embedded in the pre-existing institutional arrangements. The Dutch government did not lead, but instead was content to rely on longstanding relations among universities, public research funding organizations, and industries to advance nanotechnology development in the Netherlands. However, over time, Dutch government involvement in nanotechnology grew to be more supportive, sizeable, comprehensive, and directive – in particular by requiring substantial investments in risk-related research as a condition for public funding, and by outspoken preference embedded in broader European policy frameworks.

To explain the differences between the two approaches of government support for nanotechnology, this chapter returns to the drivers of policymaking for science and technology presented in Chapter 2. This chapter also elaborates on an alternative explanation of the observed variance of government promotion of nanotechnology.
based on the specific vested interests of the actors involved in shaping government support for nanotechnology. This chapter concludes with broader insights on what drives government involvement in science and technology policies, and suggestions for further research.

6.2 Explanatory Factors – Sets of Independent Variables

6.2.1 The Intrinsic Nature of Nanotechnology

Unlike, for example, nuclear physics, whose lethal capacity forces governments to strictly regulate its applications and secure research in the field (Hewlett & Holl, 1989), or stem cell research, whose implications encounter vocal ethical objection, the intrinsic nature of nanotechnology as such does not appear to be a particularly influential factor in shaping government involvement. That is, in contrast to other technologies, the specific characteristics of nanotechnology per se do not seem to drive policy approaches in either country.

This being said, two ideas associated with the broad field of nanotechnology did influence government approaches in both the Netherlands and the United States: (1) the idea that nanotechnology is an enabling field of science and technology offering potentially transformative (and lucrative) opportunities and possibilities to address a wide range of national and international challenges, and (2) the notion that at this point...
in time much remains unknown and uncertain about possible consequences of the applications of nanotechnology and the production and use of (manufactured) nanomaterials.

_Nanotechnology as an Enabling Technology_

The broad field of ‘nanotechnology’ is a telling example of what is called an enabling or ‘general purpose’ technology. As such, it serves as the foundation for and supports rapid radical and possibly revolutionary breakthroughs in numerous scientific directions (Palmberg, 2009). Nanotechnology, like information technology, is likely to change the way we do things across many aspects of daily life. Its enabling character triggered governmental response to its possibilities, and the breadth of its reach stimulated support for public investments in research and development.

For example, in announcing the National Nanotechnology Initiative (NNI) in January 2000, President Clinton hailed nanotechnology as “The Next Industrial Revolution,” a claim reflecting assumptions of scientists, industry, and policymakers in the United States that advancements at the nanoscale might have revolutionary consequences for society (White House, 2000). The continuous generous support for the NNI suggests that such assumptions have not abated.

In the Netherlands, the Cabinet’s 2006 Nanotechnology vision document and its 2008 Nanotechnology Action Plan use the argument of nanoscale research as a wide multi-
purpose area of science and technology to support its view that such emerging scientific field deserves government attention and, when feasible, public funding to advance research and support Dutch global competitiveness (Ministry of Economic Affairs, 2006) (Ministry of Economic Affairs, 2008), and increasingly in more applied research directions with direct economic impacts (Ministry of Economic Affairs, 2008).

*Concern about Uncertainty*

In neither case do we find a deterministic view among stakeholders that progress in nanotechnology is an autonomous and irreversible process. However, at times, some politicians, scientists, advocacy groups, and writers expressed technology-deterministic views to draw possible Doomsday scenarios of nanotechnology getting out of hand. The autonomous self-replicating nanobots, as suggested by Eric Drexler in *Engines of Creation* (Drexler E. K., 1990), led to a polemic of opinions arguing in favor and against a possible moratorium of nanotechnology research (Joy, 2000) (Kurzweil, 2001). The nanobots were addressed in congressional hearings about nanotechnology, where Richard Smalley explained why he thought that nanotechnology’s remaining uncertainties should be addressed by accelerating research, not by a moratorium, as the promises of nanotechnology were so grand (Smalley, 1999).

While this study finds little in the specific nature of nanotechnology as such driving policy responses, the fact that so much remains unknown about the long term effects and consequences of nanotechnology has shaped how governments approached this
new and broad field of science and technology. In both cases, and particularly in the
Netherlands, public concerns about risk and uncertainty led governments to make
adjustments in policy priorities and to increase budget allocations for risk-related
research.

6.2.2 Traditions of Governance and the Policymaking Process

Both cases show that traditions of governance and the institutional arrangements of
policymaking and execution are the most powerful explanatory factors in the shape of
government involvement in nanotechnology.

Despite a dominant notion of governance in the United States that stresses the
importance of free markets, respect for individual rights, the role and power of rather
autonomous interest groups, and an inclination to limit government involvement, U.S.
government engagement in science and technology development is as old as the
country’s independence. It has grown ever since, with broad support, as science and
technology help to ensure national defense, advance knowledge, offer wide societal
returns, and not in the last place foster economic growth (Greenberg, 2001).

This research suggests that the American government approach to nanotechnology
research and development it at variance with previous practice and, as such, is an
example of policy innovation. Noticing at the end of the 1990s that multiple federal
agencies and departments had started to fund various nanotechnology research
projects, acknowledging nanotechnology’s potential, and concerned by increasing
foreign competition, science policy advisors in the National Science Foundation and the
White House proposes a program to coordinate federal support for nanotechnology
research. The National Nanotechnology Initiative, confirmed in 2003 by the 21st Century
Nanotechnology Research and Development Act (United States Congress, 2003) has not
been a centralized, directive ‘Big Science’ effort with a single department or agency in
charge. Rather, its small coordinating office seeks to set priorities in a coordinated
research agenda, avoid duplication of research and facilitate information exchange even
as it leaves ample room for its participating departments and agencies.

In this regard, the NNI is a variation of a pluralist approach to policymaking
(Subcommittee on Nanoscale Science, Engineering, and Technology, 2000). However, on
reflection, the NNI also appears to be a more political vehicle than a unified research
program. Its coordinating role is limited as it does not have actual budget authority and
is not mandated to direct the participating agencies and departments in setting their
research priorities and budgets. Its main task is to aggregate and promote, pulling
together various federal research initiatives and presenting them to Congress as a
unified nanotechnology development agenda. Such an arrangement avoids the
controversies of a large directed government program, such as the ill-fated Super-
conducting Supercollider, by maintaining the broadest possible base of political and
budgetary support. In this sense, the NNI’s origins and its operations reflect the pluralist representation of active and intense interests.

By contrast, the Dutch political system is based on a legacy of consensus seeking among different factions of society and by neo-corporatist structured consultation of various interest groups in policymaking. Though barriers between such societal factions have diminished since the 1960s, a general understanding of broad stakeholder consultation as the basis of policymaking remains prevalent in today’s politics. Policymaking is deemed to be an inclusive process in the Netherlands. It allows ample room for participation in the process of an array of government and non-government actors, often through existing structured arrangements for consultation.

Government involvement in the promotion of emerging nanotechnology reflects this tradition in several ways. The Sounding Board on Risks of Nanotechnologies, in which government, industry, scientists, labor unions, and various other interests groups are represented, and the 2009 Public Dialogue on Nanotechnology, which invited the general public to discuss nanotechnology through numerous events, both part of the Cabinet’s 2008 Nanotechnology Action Plan, exemplify such tradition of inclusive consultation (Ministry of Economic Affairs, 2008).

The legacy of corporatism, however, is most visible in the way the Dutch government has relied on well-established pre-existing institutional arrangements for science and
technology development in the Netherlands. Industry, research organizations, and universities, traditionally maintaining close links as a result of the corporatist traditions of the political and economic system in the Netherlands, set up collaborations to further nanotechnology without a need for government involvement or coordination. Public research funding organizations, of which the most important is the Netherlands Organization for Scientific Research (NWO), started to fund nanoscale research early on, but mainly through existing programs.

From 2002 onwards, a succession of public – private research consortia received additional public funding – outside of the annual appropriations for public investments in research and development – from what has become known since 2005 as the Economic Reinforcement Fund Under the condition of ‘matching funds’ by the participants in the partnerships. Since 2002 and budgeted towards 2016, the Cabinet has awarded some 250 million euro ($325 million) of new and additional funds for nanoscale research to the different public – private nanotechnology consortia in the Netherlands. This approach is a break with tradition in the way the Dutch government supported science and technology. It offered a new way of non-regular research funding through the Economic Reinforcement Fund (FES) and introduced the requirement of matching funds from research program participants as a condition for awarding public funding.
The institutional set up of government support for nanotechnology in both the United States and the Netherlands shows innovation in policymaking, yet hardly in a way that matches the possibly transformative nature of the technology it is supposed to support. In both countries, the organization of support for nanotechnology corresponds to long-standing policymaking practices: allowing much autonomy for the participants in a centralized government initiative fits the American pluralist traditions and the reliance on pre-existing institutional arrangements and relationships between different interest groups to advance scientific progress and technological development suits the legacy of consensus democracy and corporatism in the Netherlands.

6.2.3 Responses to National Challenges

National challenges, and the possible responses to them, often have great impacts and wide consequences. These issues tend to shape the priorities of the national policy agenda, explaining why national and international priorities might differ (Hall & Soskice, 2001).

As noted, with the dissolution of the Soviet Union – and until the full emergence of China, if that happens – the United States is arguably the only global superpower. It is the world’s largest economy, maintains the world’s most powerful military force, and has long held a leadership position in scientific inquiry and technological development, including nanotechnology. As mentioned, the realist theoretical framework for
international affairs argues that a country’s relative place in the international structure determines the way it will advance its national interests (Waltz, 1988). Given the United States’ global leadership position, it is in the U.S. national interest to continue and confirm its power and international influence, in particular at times when other countries emerge as powerful competitors. A challenge of the American global position in science and technology is a challenge to American hegemony in general, as the loss of its leadership position will have tremendous consequences for the American economy and its military, and thus for its national security.

Realist theory argues that states and their governments will use their power to grow and protect their national interests (Morgenthau, 2006). It is in this regard that concerns about global competition in science and technology motivated the U.S. government to create the NNI in 2000. Worries that international competitors, mainly in Asia, were outpacing the United States in nanotechnology development and challenging American leadership in science and technology triggered the conception of the World Technology Evaluation Center (WTEC) (World Technology Evaluation Center, 2012). WTEC deliberations led eventually to the National Nanotechnology Initiative promoted by policy elites determined to maintain American prominence in science and technology, and to reap the greatest possible benefits from nanotechnology (McCray 2005). As such, arguments for a coordinated nanotechnology initiative reflect broader American goals in the international arena.
By comparison to the United States, the Netherlands occupies a very different place in the international structure. The relatively small size of its society, economy, and science system puts the Netherlands in a position where it needs to consider other ways to protect and further its national interests. As a result, the Netherlands has sought international and European collaboration to ensure its national security. Protected by the shelter of the North Atlantic Treaty Organization (NATO) and integrated in the European Union, the Netherlands does not regard international competition in science and technology as a matter of national security. However, like in the United States, the Dutch government’s main goal is to achieve global prominence in an especially promising and potentially transformative field, and, in particular, not to miss out on its potential economic and societal returns.

As a smaller country – and with an economy much more reliant on international trade than the United States – the Dutch have much to gain by international agreements and understandings that create a level playing field in which the Dutch might compete more successfully. Embedding Dutch policy within international agreements is also more efficient and effective than developing and enforcing specifically Dutch regulatory regimes and policies. In the case of nanotechnology, the Dutch government explicitly favors international, and European specifically, regulatory approaches for nanotechnology, over purely national efforts to promote responsible development in ways that address both the opportunities and the risks of nanoscale applications as developing.
Different positions in the international structure lead to different approaches of government support for nanotechnology. The United States sees a challenge of its global prominence in science and technology as a potential threat to its international standing and may, given its political, military, and economic strength, choose to ‘go-at-it’ alone when countering challenge. The Dutch position in the international structure hardly allows for such an approach. Therefore, it seeks international agreements and collaboration to ‘level the playing field’ among its competitors. Regardless of their ultimate motivation, support for nanotechnology in both the United States and the Netherlands appears to be a function of the national challenge to build out and maintain a strong position in the world economy combined with the academic and industrial strength of pre-existing expertise in what has become the broad field of nanosciences and nanotechnology. In both countries, in the United States earlier than in the Netherlands, the recognition of such challenge and the identification of such strength as a response to the challenge appear to be based on the interplay of the scientific community, industry, research funding organizations, and government.

6.2.4 Broader Policy Frameworks

This study defines a policy framework as a comprehensive set of policy recommendations, guidelines, procedures, rules, and laws geared towards a common goal such as economic development. Upholding national security and fostering a strong position in the global economic system, however the most prominent, are not the only
challenges governments aim to address by supporting science and technology development. This research has assessed four policy frameworks in which the government approach of nanotechnology development in the United States and the Netherlands is embedded: (1) Economic Development & Innovation Policy; (2) Education, Science, & Technology Policy; (3) Defense & National Security Policy; and (4) Risk Policy.

In the United States the goals of the National Nanotechnology Initiative (NNI) and the shifts in attention of the NNI since its establishment in 2000 show the embedding of the NNI into three broader policies frameworks: (1) Economic and innovation policies; (2) science and education policies; and (3) attention to environmental risks, health matters, and broader societal consequences (United States Congress, 2003). The history and organization of the NNI places nanotechnology development in the United States clearly in a setting of science and technology policy as a mechanism to maintain the United States’ dominant global position by fostering and creating new and additional business activity through public investments in R&D. Industrial engagement, joint public- private research efforts, and technology transfer from research institutes to industry are priorities in the American government approach.

How the U.S. government approach to nanotechnology development links to the broader framework of education, science, and technology policies is most apparent in three aspects addressed by the NNI: (1) a focus on investing in basic research; (2)
aim to develop and use federal research facilities for nanotechnology by non-
government scientists and industry; and (3) the goal to create an educational program
and training to establish a skilled workforce (Subcommittee on Nanoscale Science,
Engineering, and Technology, 2000) (Subcommittee on Nanoscale Science, Engineering,
and Technology, 2011). Policymakers saw emerging nanotechnology as an opportunity
to revive fields of science and technology such as physics, chemistry, and engineering,
which seemed to have become of lesser interest to young people, stimulating new fields
of study in the educational system, thus creating a new generation of scientists and
engineers (Smalley, 2000) (McCray, 2005).

The 21st Century Nanotechnology Research and Development Act mentioned the
requirement that a national nanotechnology program should address environmental
and health risks of nanotechnology and demanded attention for broader ethical, legal,
and social implications of nanotechnology to be part of such a program (United States
Congress, 2003). These requirements link to policy frameworks of environmental
protection, public health, labor conditions, consumer safety, and so on, all of which, for
argument’s sake, are combined here under the label of risk-related research. From the
start the NNI research agenda included environmental, health, and safety (EHS) risk-
related research. However, as nanotechnology research advanced, the lack of progress
in risk related research left many remaining uncertainties and caused concern that
public fears of such risks might become an obstacle to further development of
nanotechnology. As a result, the NNI added an Environmental, Health, and Safety
Aspects component to its program in 2007 (Subcommittee on Nanoscale Science, Engineering, and Technology, 2007) (Subcommittee on Nanoscale Science, Engineering, and Technology, 2008). The overall budget allocated to risk-related research has since tripled in size (Subcommittee on Nanoscale Science, Engineering, and Technology, 2010), but remains at approximately 6% of the total NNI budget modest. In particular compared to the Netherlands, where the government requires 15% of all nanotechnology research investments to be dedicated to EHS issues as a requirement to receive government funding (Ministry of Economic Affairs, 2008).

One should note that matters of national defense and security, while mentioned in the 21st Nanotechnology Research and Development Act and in the different NNI strategy documents of the last decade, do not play a quite overt role in the shape of the United States government support nanotechnology. Nevertheless, its influence should not be underestimated: The Department of Defense, which allocates over 50% of the total U.S. annual government investment in research and development (Sargent Jr., 2012), is together with the NSF and NIH the largest contributor to the overall federal effort in nanotechnology: it has dedicated more than $4 billion to nanotechnology research since the establishment of the NNI in 2000 (Subcommittee on Nanoscale Science, Engineering, and Technology, 2012).

Like in the United States, three broader policy frameworks help to shape the Dutch government’s approach of nanotechnology development: (1) Economic policies geared
towards innovation, which have become strongly interlinked with (2) Science and technology policies geared towards supporting such innovation by funding research and facilities and (3) Risk policies, which broader goal is to ensure that any economic or scientific activity in the Netherlands fits the requirements as laid out by the government’s overall approach to risks for society, environment, and human health.

Unlike in the United States, policies regarding matters of national defense or national security did little to shape Dutch government support for nanotechnology. The Dutch Ministry of Defense plays only a limited role in funding science and technology. Dutch continuous reliance for national protection on international security regimes such as NATO and its embedding in the European Union have established circumstances in which policies supporting science and technology development have lost much of their relevance for national security and defense.

However, science and technology - and nanotechnology most prominently - play a pivotal role in the broader framework of policies for economic development and innovation, which aim to expand the international competitiveness of the Netherlands: Application and commercialization in the field of nanosciences and nanotechnologies is designated as an eco-system of the so-called top sector ‘High Tech Systems & Materials’, part of the ambitious national innovation program Top Sectoren. The goal of the Top Sectoren program is to place the Netherlands in the worldwide top of knowledge-based economies by 2020, by increasing the overall Dutch annual
investment in research to 2.5% of GDP (Ministry of Economic Affairs, Agriculture, and Innovation, 2012), which, remarkably, is still short of the 3% goal that the European Union has set as part of its Horizon 2020 program.

Strong industry involvement in the Dutch public – private nanotechnology collaborations fosters a tendency to seek for application and commercialization of nanotechnology. Such shift from funding fundamental research towards investing in more applied directions of research and development to address specific economic or social goals converges science and technology policies with economic policies. This trend is noticeable in the United States as well as in the Netherlands and the European Union.

The third broader policy framework that shapes the Dutch government approach to nanotechnology is the set of policies that address risks associated with any human activity. After an initially detached response to emerging nanotechnology, the Dutch government approach increasingly became more engaged and directive. Since 2006, the Cabinet actively supports an integrated approach of responsible nanotechnology development: the government stresses that understanding risks and addressing remaining uncertainties is instrumental for successful nanotechnology development (Ministry of Economic Affairs, 2006). In return for public funding, the government requests a minimum of 15% of the total research budget to be spent on risk-related research (Ministry of Economic Affairs, 2008).
Overall, then, government promotion of nanotechnology in both the United States and the Netherlands is shaped by broader policies frameworks and policy priorities of economic and innovation, global competitiveness, science and technology, and, more clearly in the Netherlands than in the United States, of broader societal consequences, which include environmental matters, issues of public health, worker safety, and public participation.

6.2.5 Inter- and Supranational Multi-level Governance and Convergence

In today’s globally interconnected world, domestic policy frameworks are embedded in international consultations, deliberations, agreements, treaties, and laws. Both the United States and the Netherlands rely on international cooperation to support their domestic policy goals. As argued before, how they do so, to what extent, and with which goals, differs and is heavily dependent on each country’s relative position in the international world structure. Where the United States might exercise its power to set the tone for the rest of the world to follow, the Dutch have to rely on international collaboration to maintain and grow its position. Such emphasis on international collaboration has a clear neofunctional aspect for the Dutch: international collaboration in this field is ultimately in the national interest.
Multi-level Governance

The Dutch government explicitly states its preference of a European response to the risks associated with nanotechnology (Ministry of Economic Affairs, 2010). The international focus emphasizes an evolving multi-level governance system of the European Union, in particular with regard to environmental protection, the use of chemicals, and matters of public health. It is interesting to note the degree, to which the risks dimension of Dutch nanotechnology policies is embedded in, and seeking to shape, broader European policy frameworks. It seems, therefore, that while the Dutch may see economic development as a more national strategy, the tendency to share research and policy on environmental and health risks to a broader EU level reflects calculations that the Dutch comparative advantage resides within broader European policy networks. In fact, government involvement in nanotechnology in the Netherlands is an example of multi-level governance (Hooghe & Marks, 2001), in which influence in policymaking is shared across different levels of government, in particular between the European Union and the national level.

As nanotechnology develops, a convergence of policy priorities is discernible between the national and European levels of governance: the focus to stimulate research and industrial uptake in the emerging field on nanosciences and nanotechnologies in order to benefit from its great opportunities; the urge to address any social, ethical, and legal concerns; the wish for public engagement in the development of nanotechnology; and the need to balance opportunities with a clear assessment of the risks of
nanotechnology and the uncertainty that remains, preferably in international collaboration. In this regard, the Dutch Cabinet’s 2008 Nanotechnology Action Plan reflects much of the European Commission’s 2005 Action Plan for Nanotechnologies (European Commission, 2005) (Ministry of Economic Affairs, 2008). Both the government of the Netherlands and the European Commission seek to address these issues within the existing legal and regulatory framework. The Dutch government relies on and seeks to shape the EU’s REACH protocol for the use of chemicals to include manufactured nanomaterials (Ministry of Economic Affairs, Agriculture, and Innovation, 2011).

The Dutch Cabinet aims to harmonize regulations and policy approaches among different levels of governance, since the Netherlands, and various other EU members as well as representatives of the European Union itself, also participate in the Organization for Economic Cooperation and Development (OECD) and the International Organization for Standardization (ISO) committees and working groups on nanotechnology (Ministry of Economic Affairs, Agriculture, and Innovation, 2011). An examples of such harmonization attempts of converging multi-level governance is ‘NANoReg’, a European Union project which follows up on various OECD Working Party on Manufactured Nanomaterials projects to generate general metrology for nanomaterials (Ministry of Infrastructure and the Environment, 2012).
In both countries, the government’s approach to matters of the risks and remaining uncertainties of nanotechnology, as well as finding agreements on such matters as scientific definitions, nomenclature, and measurements, includes some levels of international cooperation, most prominently within the OECD and ISO. However, the Dutch government has made international rule making a policy principle. As mentioned, the efforts of Dutch representatives are not merely altruistic: Dutch engagement in international rulemaking is strategic and has a clear neo-functional aspect. By contrast, the U.S. attitude towards international collaborations appears at times more rhetorical than practical, reflecting overall American ambivalence about international collaboration. International engagement is certainly not a priority among the participants of the National Nanotechnology Initiative. This difference might be explained by the fact that any successful development and application of nanotechnology in the Netherlands will always take place in an international – or at least European – market, in contrast to the larger domestic market in the United States.

6.2.6 Alternative explanations: Interests?

This study argues that structural and institutional independent variables offer most value in explaining the observed variance in government support for nanotechnology. A relative country’s position in the world’s international structure defines to a great extent what a country wants and can do to support emerging fields of promising science and technology, such as nanotechnology. Existing traditions and institutional arrangements for policymaking are powerful and resilient factors in how a government
responds to the challenges and opportunities posed by such possibly transformative enabling field of science and technology.

An alternative approach to explain the observed variance between government support for nanotechnology in the United States and the Netherlands is based on the analysis of interests of the various actors involved in shaping government action and setting its policy priorities and preferences. Explanations based on the direct interests of the actors involved the subject of study is a theoretical framework that generally used to clarify different political outcomes through comparison of various cases: how did direct interest and expected rewards motivate actors to be involved and how did that shape the ultimate outcome. Interest-based explanations seek to explain political outcomes as the result of competition between actors, which aim to see their own interests best served (Hall, 1997).

This study argues that such an interest-based approach yields ample results yet is unable to explain to a great extend the shape, size, and policy priorities and preferences of government support for nanotechnology in either the United States or the Netherlands: It is in the interest of the United States to maintain and protect its global prominence in science and technology and it is in its power to aggressively expand its scientific and technological capacities. This national interest obviously motivated the wish to support nanotechnology, but it fails to explain in more detail the actual shape
and scale of the National Nanotechnology Initiative, nor its stated policy priorities and preferences.

Being a smaller country, highly dependent on international trade, the Dutch have much to gain by international agreements and understandings: it is more efficient and effective than developing and enforcing specifically Dutch regulatory regimes and policies. The Dutch reliance on international collaboration has a neofunctional aspect: international collaboration in this field is ultimately in the national interest as it levels the paying field of the competition. However, the Dutch government’s preference for embedding any nanotechnology policies in broader European and international collaborations should be explained as a function of its international position and experiences with multi-level governance in international rulemaking rather than specifically national interest-driven.

At the level of the actual nanotechnology programs and policies in the United States and the Netherlands, several factors play towards interest-based explanations of the shape of government support for nanotechnology, but ultimately they are not convincing: One might explain the large number of participants in the U.S. National Nanotechnology Initiative (NNI) by arguing that it fits in such interest-based tradition of distributive policymaking: if an agency does not join a new forum on a specific policy issue, it will not receive funding to address such topic. Yet, the fact the NNI combines the different requests of the participating departments and agencies in an aggregated supplement to
the overall budget requests allows the participants individually to lobby Congress for funding appropriated for nanotechnology research. It allows all its participants great autonomy: they can organize their own research projects, set their own research priorities, and request and allocate their own research budgets. The overarching program is limited to the coordination of the overall research agenda, to facilitate outreach to various interest groups, and to the aggregation of the combined budget requests of the participants as an annual NNI budget request. Such set up creates coordination, momentum, and attention for nanotechnology research promotion. It is likely advantageous for the participants, but it does not invite competition among participants or between participants and government agencies and departments not participating. There appears to be little to lose for government agencies and departments with an interest in nanotechnology research – note that of all twenty-seven participants, sixteen actually fund nanotechnology research – to join the National Nanotechnology Initiative.

The interest-based approach also falters in arrangements of the Dutch government support for nanotechnology Netherlands. The preferred practice of public – private partnerships could likely be a vehicle for those participants in the partnership to benefit greatly from government support, while those not included would miss such opportunities. It would be in the interest of the insiders to keep the partnership small. However, the succession of Dutch public – private partnerships in nanotechnology that are supported by government funds, so as NanoNextNL, are set up to welcome as many
partners as possible. The reasoning behind that is the condition of ‘matching funds’ – the government requirement that the participants in the partnership match any government funding of the research program in a 50/50 ratio - stimulates an open and inclusive set up of the collaboration, so that as many as possible contribute: it shows, more than 100 partners have joined NanoNextNL (NanoNextNL, 2013).

6.3 Broader insights

The findings of this study contribute to our understanding of the factors that motivate and shape government support for emerging fields of science and technology. First, it affirms that distinct national styles of policymaking (Vogel, 2012), in this case the pluralist approach of the United States versus the consensus-seeking tradition in the Netherlands, lead to divergent policy responses to similar phenomena.

Second, and more critically, this analysis shows the power of long-standing traditions of governance and institutional arrangements for policymaking in shaping science and technology policies. In the United States the shape of the National Nanotechnology Initiative is an innovative government response that respects traditions of pluralism, yet establishes a variance of past practice to allow centralized coordination and oversight and avoids ‘Big Science’ connotations. The Dutch approach shows that political traditions of consensus-seeking and structured consultations have established such a strong infrastructure that government support for new technologies may rely on such pre-existing arrangements and can be embedded in broader existing policy frameworks.
Third, the Dutch experience in particular sheds lights on how smaller nations use emerging multi-level governance in policy fields of science and technology to strengthen their international position and competitiveness and advance their national interests. Certainly with regard to policies on risks and uncertainties associated with emerging science and technology, for which, given the international nature of research, development, application, and commercialization of scientific findings and technological innovation, national policies are likely to be inefficient and ineffective, shaping a policy response through broader multi-level governance offers great opportunities for smaller countries such as the Netherlands. In particular within the European Union, but also in other international organizations and collaborations such as the Organization for Economic Cooperation and Development (OECD), smaller member states are in a position to actively help to shape international rules, regulations, and regimes, that have large consequences for domestic policies and that may carry substantial national benefits. All members of such organizations and collaborations have the opportunity, and more likely, are even required give input to decision making at such levels. By steering international rules and regulations towards formats and shapes that match national interests, small countries may achieve an international environment that is favorable for its domestic situation. For instance national governments may set out to establish an international regulatory approach that fosters its national industry. The insistence of the Dutch government to delegate the development of any regulatory approach to emerging nanotechnology to European and international levels of
governance and to actively contribute to such deliberations as to further Dutch interests in nanotechnology development is an example of that.

Fourth, this study furthers our knowledge of multi-level governance in the European Union and beyond in showing a convergence of levels of governance: The Dutch Cabinet’s 2006 vision document and its 2008 nanotechnology action plan have clear similarities to the European Commission’s preceding 2005 nanotechnology plan. However, this study notices that multi-level governance is not directed in a singular way. Of course the European Union sets rules, regulations, and policies to be implemented and applied in the member states, yet, the governments of members states are in a position to strongly influence the shape, content, and priorities of such European policies. The case of nanotechnology shows that different levels of governance interact, exchange, copy, and compliment content in the policymaking process. In particular with regard to policy matters pertaining research into the societal and ethical consequences of nanotechnology, we see a convergence of policies at different levels: Over the years integration of risk-related research and attention for the social, ethical, and legal aspects of emerging nanotechnology into the overall publicly sponsored nanotechnology research agenda, has led to a more comprehensive integrated approach of responsible nanotechnology development in the European Union. Such integration is strongly pushed by the Dutch government. Multi-level governance in European may include levels of governance and decision-making beyond the boundaries of the European Union. As so many countries are members of both the EU and the
OECD, they are in a position to contribute to and influences policies and recommendations in both regimes. This study shows a tendency of harmonization of agreements between European and OECD levels of governance and an exchange of information between the different groups.

Fifth, while the intrinsic nature of nanotechnology appears not to have shaped government response, its enabling disposition and overall potential induced many governments to actively fund nanoscale research and development. Literature shows that possible economic returns and innovation have become important incentives for governments to invest in science and technology, in particular since the late 1980s when the end of the Cold War and neoliberal reforms allowed for trade, and thus global economic competition, to flourish (Rosenberg N., 1994) (Branscomb L. M., 1998). This study advances our insights on such motivations as it shows that concern of ‘missing out’ and losing the opportunity to build up a competitive position in nanotechnology motivated many government to invest heavily in nanotechnology, at times shifting funding from fundamental research further down the line towards applied research and development as to accelerate the time to applications and commercialization of scientific and technological findings. Such shift explains the insistence of, for instance, the Dutch government, to have industry involved in any publicly funded research program. Governments in the United States, the Netherlands, and in the European Union have made nanotechnology research a prominent part of much broader innovation programs.
Further research

The findings of any study lead to more questions and other directions for further research. This project is no exception. For instance, the apparent novelty of the United States National Nanotechnology Initiative approach to cross-agency coordination may be an example of government involvement in even newer fields of science and technology. Yet, is how innovative is this it? This study argues that the NNI, even with its efforts at coordination, allows its participants wide autonomy, and as such is a variation of pluralist policymaking. In historical terms, the NNI cannot be labeled ‘Big Science’, but research comparing it to prior government support for science could test whether it is a real break or simply a variation on a longstanding theme.

We might also look more into the field of policy venues, the locus of where policies are shaped and where governance takes place (Stone, 2008). As discussed, the European level of governance is highly influential for the Netherlands. However, the OECD and ISO are important venues even in shaping the foundations of U.S. government approaches to nanotechnology. What makes such venues so prominent, in particular when there is an increasing number of international organizations which might be suitable to address matters such as nanotechnology?
In the case of the Netherlands, it is useful to continue to compare the strong focus on public–private cooperation in research seen with nanotechnology with experiences in other emerging fields of science and technology. A comparison of different programs would help to expand our understanding about the effectiveness of arrangements. It is also worth further exploration of multi-level governance of risk-related research and policymaking as an integrated approach. As part of such research, it is worth asking whether a trend of convergence of is likely to be observed between different levels of governance, for instance between the European Union and its member states, as the European integration continues. As noted, one wonders about convergence between different international levels of governance, such as the harmonization of the European regulatory approach of manufactured nanomaterials and OECD policy recommendations in that field, in particular as membership in both organizations overlap to a great extent.

Given this attention for multi-level governance, from a comparative perspective, what do the findings of this study mean for other countries in the European Union that work to maintain or achieve a prominent position in supporting technology development? Analyzing the government support for nanotechnology of larger European countries like Germany and the United Kingdom would advance our insights about the opportunities and constraints offered by European governance.

Interesting questions also arise about the way we might notice integration between fields of government attention that previously were dealt with more separately such as,
for instance, risk-related policies and innovation policies into a more comprehensive approach. Is such approach viable, efficient, or effective? Given the greater complexity of emerging fields of science and technology, the ever-increasing global competitiveness of applying and commercializing scientific insights and technological advancements, and the rising costs of supporting science and technology development, how governments organize themselves to promote research and development while also protecting public health and the environment is increasingly important. This study sheds lights on those dynamics.


London School of Economics and Political Science, International Relations Department: http://www2.lse.ac.uk/internationalRelations/centresandunits/regulatingnanotechnologies/nanopdfs/REPORT.pdf


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