Exploring Global Ideas in National Policy for Science, Technology and Innovation

An Isomorphic Difference Approach

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EXPLORING GLOBAL IDEAS IN NATIONAL POLICY FOR SCIENCE, TECHNOLOGY AND INNOVATION

PhD Series 40.2023

Aixa Y. Alemán-Díaz

EXPLORING GLOBAL IDEAS IN NATIONAL POLICY FOR SCIENCE, TECHNOLOGY AND INNOVATION

AN ISOMORPHIC DIFFERENCE APPROACH

Department of Organization | **PhD Series 40.2023**

CBS COPENHAGEN BUSINESS SCHOOL
HANDELSHØJSKOLEN

Exploring Global Ideas in National Policy for Science, Technology and Innovation

an *Isomorphic Difference* Approach

Aixa Y. Alemán-Díaz

Department of Organization

Supervisors:
Professor Alan Irwin, *primary*
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Foreword

It took me years to learn to play like myself.
Miles Davis

Any work of this magnitude does not happen by chance and does not germinate unaided.

My deepest gratitude to my family (nuclear and extended), without them this dissertation would not have been imaginable or worth writing.

Philip, my husband and life partner. You were the original inspiration for pursuing the PhD and have been my steadfast supporter throughout. Our conversations about research, our joint readings, and your constant encouragement were critical to completing it. I learn and grow with you every day. Our plans changed along the way, but you still rooted for me to keep going and attain this professional milestone. Thank you for loving me, challenging me, inspiring me, and believing in me. I love you. This is for you too.

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Abuelita Marina, gracias por las llamadas. Our weekly chats were a great motivation and brought much joy to my doctoral journey. Uncle Bruce, Titi Evín, Tití Iraida & Tío Juan, Tío Jaimito & Tití Flor, Aunt Janet & Michael, Francisco, Tití Maribel, Tití Migdalia & Tío Ariel, Grandma & Grandpa Mork, and Uncle Rich – your cards and messages filled me with love. Tití Migdalia, Tilcia, Tammy and Grandma Lee, you left this world before I could finish this journey, but your memory stayed with me. To all my cousins in Puerto Rico, Texas, and around the world – thanks for all your messages that always brought smiles. Ariel Omar, Ramarit, Ian, and Daniel, you brought so much joy and family love to Denmark with your move in 2021. It

was a highlight of my time at CBS. I am grateful that our families have been able to live close by and grow together.

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This dissertation would not be possible without Alan Irwin and Signe Vikkelsø, who as my advisors, welcomed me into the research world. Your support, crucial guidance and faith in me was paramount. Alan, as my primary mentor you have been a steadfast champion. My work would not have been the same without your advice, guidance, and your spirited collegiality. You have been a generous and supportive discussant with an unwavering trust in my work. Your steadiness, empathy and great sense of humor were critical to my doctoral journey. Thank you and Maja for welcoming Phil and I into your home. Signe, your instructive and insightful feedback has been an asset to my doctoral journey. Your wit will also be remembered - I will not forget to 'peel the onion'. I feel fortunate to have had you as my advisor in this process. Alan and Signe, our conversations, formal and informal, are always a highlight. What a joy it has been to learn, to laugh, and to grow professionally with both of you. I trust it will continue that way. Thanks to both also for helping me celebrate professional and personal milestones in Denmark like family. I am forever grateful.

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And this section would be incomplete without some thoughts about pursuing the PhD during the COVID19 lockdowns, the war in Ukraine, and the reversal of abortion rights in the United States. These global emergencies, regional conflicts, and national policy changes brought anxiety, confusion, and despair. Yet, the pandemic gave me space to be with family; it showed me the ability to be flexible in the face of mounting uncertainty, and showed me how my home, Puerto Rico, a place that has gone through so many natural and human-made shocks, could rally its troops to take care of each other. Living the pandemic with a foot in the United States and another in Denmark was remarkable. The kindness and support of amazing colleagues and the coordinated response in Denmark made me feel very fortunate. The experience in the United States was less uplifting. It meant to witness a country, with ample knowledge and technical ability, which let so many people die, and keep dying from a preventable cause; a country that through its judicial decisions sacrifices the potential of its women and leaves us with less constitutional rights. I am fully aware of the deep loss and grief that as a society we have pushed aside to return to ‘normal’ and keep going. While unsettling, these events make my interest in

policy and ideas all the more relevant. The case for making abortion accessible and safe has been documented in many scientific fields, but the Supreme Court still made its decision. We know how to reduce the spread of COVID-19 and we are still reeling off the effects of the pandemic. And a war in Europe, well that seemed unthinkable years ago, and yet here we are, deep into an armed conflict in Europe with no end in sight. Living through these events reiterates that policy takes more than scientific evidence.

I end with a personal reflection. I came into this doctorate after over a decade of experience in the policy world. I am a woman from Puerto Rico, trained in public policy for my bachelor's and master's degrees in the United States at an institution with strong positivistic traditions. I sought to bring a more deliberate and critical engagement to my scholarship this time around. The STS training during my doctorate enabled me to re-visit and re-think my position, my education, and the subject of this dissertation. My work suggests that we need to pay more attention to the ideas that get passed on through generations of scholars and professionals, as well as a need for an increased awareness about the assumptions that many of these ideas carry with them. I hope this work invites a re-thinking about the formal and informal education that policymakers receive, how it shapes their views of the world, and the value they would get from an STS sensibility.

Learning to find my voice in this midst of so much took time. As I come to the end of this doctoral journey, I am grateful for all I have learned and the voice I have come to develop and appreciate. I trust that this milestone marks the beginning of further academic and professional pursuits.

Denmark and United States, 2023

Abstract

New concepts are continuously introduced in policies for science, technology and innovation (STI) across the globe, such as 'transformative change' or 'responsible development'. Yet research has shown that ideas, even those that seem omnipresent in current policy for STI, like 'innovation,' come to be understood and are appropriated for distinct reasons in particular contexts. These varied understandings call for research that can uncover how global ideas come to be localized and the varied ways in which the local context informs global understandings in policy for STI. Shedding light on this paradox within policy for STI sits at the heart of this dissertation.

One way to understand the development of global ideas within policy for STI over time is to consider the processes of isomorphism and difference-making that shape them. Not so they are put against each other in contention, but to understand how they work together and sustain each other over time. These dynamics capture the contextualization, multi-dimensionality, and emergence of policy for STI. The dissertation explores the ways in which global ideas are co-produced and how they are given life and made sense of within national policy for STI. I draw on insights from Science & Technology Studies (STS) and institutional theory to advance the conceptual lens of *isomorphic difference*. In doing so, I highlight the critical role of global ideas in shaping national policy for STI while underscoring the familiarity and distinctiveness at work within them.

I draw on policy documents, interviews and participant observation to analyze particular global ideas in policy for STI within a national context and through cross-country comparisons. The first article departs from an exploration of the application of 'diversity' within the National Nanotechnology Initiative (NNI) in the United States. The next article takes on the 'valley of death' trope associated with commercialization efforts globally and traces the ways in which it gets interpreted and domesticated within the NNI. In the third article, I probe how policy instruments are mobilized dynamically to envision an innovation-based future in the United States and China. The fourth article emphasizes how the classic rationales (i.e., mission, curiosity and market) within strategies for STI in China, Denmark and the United States interact, feed into each other, and mutually shape one another over time. By tracing these global ideas across three national settings, new questions are raised about the relationship between STI and public policymaking—especially with regard to local strategies in the face of globalizing pressures and the entangled ways in which global ideas are co-constructed locally.

Dansk Resumé

Nye begreber introduceres løbende i forsknings-, teknologi- og innovationspolitikker (FTI) på tværs af kloden, eksempelvis ”transformative innovation” og ”responsible development”. Forskningen viser dog, at ideer som udbredes globalt og tilsyneladende dominerer FTI-politikker (som for eksempel ”innovation”), forstås og implementeres ret forskelligt afhængigt af de konkrete sammenhænge, de indgår i. Der er derfor brug for yderligere forskning til at afdække, hvordan globale ideer bliver lokalt forankret. Samtidig er det også centralt at forstå, hvordan lokale kontekster informerer globale ideer i FTI-politikker. Afhandlingen fokuserer på og belyser denne paradoksale eller sammenflettede relation i FTI-politikker.

Afhandlingen undersøger udviklingen af dominerende, globale ideer inden for FTI-politik over tid ved at anskue dem som resultat af en dynamik mellem isomorfiske pres og forskelsskabende processer. Disse to dynamikker behandles ikke som modsatrettede dimensioner, men som interagerende og gensidigt konstituerende over tid, og begrebet ”isomorfisk forskel” anvendes til at benævne dette forhold. Ved at følge isomorfiske forskelle belyses såvel ideernes kontekstualisering som deres mangfoldighed og emergens i FTI-politikker. Afhandlingen udforsker, hvordan globale ideer bliver samproduceret, og hvordan de får liv og giver mening inden for nationale FTI-strategier. Jeg trækker på indsigter fra Science & Technology Studies (STS) og institutionel teori for at udvikle analysen af isomorfiske forskelle. Derved fremhæver jeg den afgørende rolle, som globale ideer spiller i udformningen af nationale FTI-politikker, samtidig med at jeg understreger det kendte og det særegne, der er på spil i dem.

Jeg fokuserer på udvalgte globale ideer i FTI-politikker inden for forskellige nationale sammenhænge og forankrer min analyse i politiske dokumenter, interviews og deltagerobservationer, hvor jeg også benytter mig af sammenlignende studier af de udvalgte ideer. Den første artikel udforsker, hvordan ideer om “mangfoldighed” optræder og anvendes i The National Nanotechnology Initiative (NNI) i USA. Den næste artikel tager fat på, hvordan metaforen og begrebet ”Dødens Dal” bliver fortolket og tilpasset i diskussioner af kommercialisering af forskning inden for NNI. I den tredje artikel undersøger jeg, hvordan udvalgte politiske instrumenter dynamisk mobiliseres til at forestille sig og konkretisere en innovationsbaseret fremtid i USA og Kina. Den fjerde artikel fokuserer på, hvordan tre klassiske rationaler (”mission”, ”curiosity” og ”market”) interagerer og ændres i nationale FTI-strategier i Kina, Danmark og USA over tid. Ved at spore disse globale ideer på tværs af tre nationale kontekster rejser der sig nye spørgsmål om forholdet mellem FTI og offentlig politikdannelse, ikke mindst hvad angår lokale strategier i lyset af globaliserende pres og i forhold til hvorpå globale ideer medskabes lokalt.

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Preface

This article-based dissertation reports on the findings and contributions of a doctoral research project from June 2019 until June 2023. The dissertation consists of three sections.

Part I provides an overview of the motivating scholarship, the conceptual lens, and the research design of this dissertation.

Part II comprises four original articles that each represent a specific study related to the overarching research question:

Article 1 – Framing 'Diversity' in Policy: Isomorphic Difference in the United States National Nanotechnology Initiative

Article 2 - Into the 'Valley of Death': *Isomorphic Difference* in Policy for Nanotechnology in the United States

Article 3 – National Variants of Innovation-based Futures in Policy: Varieties of Capitalism and the Frames of Innovation in the United States and China

Article 4 - Blending Curiosity, Market, and Mission Rationales: Capturing *Isomorphic Differences* in National Science, Technology, and Innovation Policies

Part III discusses the findings across the four articles, puts their contributions into perspective, and showcases avenues for future research.

This research is part of the cross-national *Isomorphic Difference*: Familiarity and Distinctiveness in National Science and Innovation Policies study, supported by the Independent Research Fund Denmark (grant number 8019-00044B).

PART I. FRAMING

1. INTRODUCTION

1.1 Global ideas in Policy for Science, Technology and Innovation

New concepts are continuously introduced and adopted in policies for science, technology and innovation (STI)[1] across the globe. Think, for example, about the growing number of countries that include the notion of 'innovation' in a national strategy. There is Denmark's strategy titled Progress Innovation Cohesion (2006)[2], the United States' Strategy for American Innovation (2009, 2011, and 2015)[3], China's Outline of National Innovation-driven Development Strategy (2016)[4] and the 10-year Science, Technology and Innovation Strategy for Africa (2020)[5] to name a few. In the case of the United States, the 'strategy for innovation' was reviewed over the course of President Obama's eight-year tenure, which signals an evolution in what American policymakers wanted to achieve through 'innovation'. The global uptake of 'responsible development' in policies for STI has also flourished in many countries and regions, like the European Union (2013, 2020). This term is meant to address the unintended impact of new technologies and promote the inclusion of society in shaping innovation and its outcomes. In considering these examples, it seems peculiar that countries and regions with such different political, social and economic systems all adopt similar concepts. What does 'innovation' or 'responsible development' mean in each of these contexts? Are these countries or regions trying to be unique or are they joining a broader trend? Is their use of these concepts stemming from similar diagnoses of what the country needs to forge ahead in this world, or does it stem from a unique understanding of 'innovation' or 'responsible development' and what they could provide the country with?

Flink and Kaldewey (2018) and Kaldewey and Schauz (2018) explain that scholars and policymakers share a common conceptual language. These authors show that '…(h)istorically, such a common language was employed either to challenge the importance of investigator-driven basic research or to defend its relevance for innovation processes' (Flink and Kaldewey 2018)(p.15). These challenges highlight the identification of particular actors—investigators—in the development of national policy for STI. Pfotenhauer and Juhl (2017) have also pointed that

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[1] My use of 'policy for STI' draws on Harvey Brooks' work on the United States (e.g. Brooks 1964, 1968). Brooks describes policy for science as 'the mechanisms, institutions and operating principles through which federal resources are channeled into scientific and technological activities' (Brooks 1968)(p.254). This type of policy defines 'structure, functions, and priorities of science' (Pielke Jr 2007)(p.79). This analytical distinction was useful in focusing my attention on global ideas in the STI landscape that direct where to take countries or science as whole. The STS anchoring of this dissertation reminds me that science and policy are co-produced. Thus, while pragmatic, the distinction between policy for STI and science for policy reinforces 'a perception that science and policy are separate activities which are subject to multiple interrelations, rather than activities that are instead inextricably interconnected' (Pielke Jr 2007)(p.79), see also Guston 2000.

[2] See (Danish Government 2006)

[3] See (NEC and OSTP 2009, 2015; NEC, CEA and OSTP 2011)

[4] See (Original CSET Translation of "Outline of the National Innovation-Driven Development Strategy, 2016)

[5] See (African Union Commission 2020)

'…the state's role in innovation policy...has remained basically the same since World War II (WWII) in some of its core assumptions' (p.69). The trends that these scholars identify refer to historical accounts used to recount the transformation of policy for STI over time, describing changes in their form, direction, and aspirations (e.g. Borrás and Edquist 2019a; Borrás and Laatsit 2019; Elzinga 2012; Godin 2020; Hofmänner and Macamo 2021; Kuhlman and Rip 2018; Kuhlman et al. 2019; Lepori et al. 2007; Schot and Steinmueller 2018; Stilgoe et al. 2013; Stirling 2008). These narratives illustrate the foundational rationales[6] of this policy field and show the endurance of its core assumptions, even when they are challenged over time. These shared accounts describe how policies for STI, especially since World War II, have grown out of 'historically contingent concepts, models and metaphors' that play a symbolic function in policy for STI (Flink and Kaldewey 2018)(p.14).

The travel and adoption of shared concepts across diverse contexts has been well-documented, but here are two examples of some of the ideas that have grown across policy circles:

> 'Emerging technologies … are surrounded by a constellation of fashionable stereotyped phrases such as 'responsible innovation', 'green technology', 'personalised medicine'...' (Bensaude-Vincent 2014)(p.238)
>
> 'Frameworks such as "Responsible" or "Mission-oriented" Innovation, for example, have become commonplace parlance and practice in the governance of the innovation–society nexus.' (Frahm et al. 2021)(p.1)

Policy for STI has been peppered by many phrases that have become commonplace parlance. As I suggested earlier, ideas like 'innovation' (Godin 2017), and its corollaries 'mission-oriented innovation' (Mazzucatto 2018), 'responsible research and innovation (RRI)' (Stilgoe et al. 2013; von Schomberg 2013) or 'responsible innovation' (Frahm et al. 2021) have increasingly entered global policy discussion, emerged consistently within national contexts, and appear across technological realms (Bensaude-Vincent 2014). Ideas like the National Innovation System (NIS) (Freeman 1995; Lundvall 1992, 2010; Edquist 1997) are recognized as influential policy approaches in STI (see e.g., Lundvall 2017)[7] that have become important organizing concepts (Miettinen 2002). Rationales like 'new public management' (Ferlie et al. 2008; Geuna 2001; Paradeise et al. 2009) have also become popular in STI[8]. The spread of these rationales beyond the university sector has led to discussions about the threat of 'academic capitalism' (Slaughter and Rhoades 2004) or 'epistemic capitalism' (Fochler 2016) against the social norms of science and scientific cooperation with adverse long-term effects on the institutions of science (Squazzoni et al. 2013).

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[6] Borrás (2012) provides a useful discussion of the underlying tensions found in the governance of STI described by Flink and Kaldewey (2018).

[7] The advent and increasing influence of institutions of global governance in STI, like the OECD, provide normative influences for the adoption of models like NIS (Irwin et al. 2021; Frahm et al. 2021; Godin 2020).

[8] New public management suggests a retreat of the state and the introduction in the public sector of competitive and corporate practices that have an impact on research and higher education policies (Ferlie et al. 2008; Paradeise et al. 2009).

And yet amid such homogenizing pressures (Lemola 2002; Holzinger et al 2011), countries also strive to be unique and highlight the special ways in which they conduct research in responsible ways (Doezema et al. 2019) or in support of national missions (Robinson and Mazzucatto 2019). They follow 'distinct paths' in how they organize their national funding agencies or balance their research funding portfolios (Lepori et al. 2007)(p.372). Countries address similar issues in ways that are deeply embedded in their national traditions and ways of working (see Irwin et al. 2021 for a Danish example or Kierkegaard et al. Under Review for a Chinese example). Countries also adopt global models in the hopes that they will address nationally perceived ailments (Pfotenhauer and Jasanoff 2017).

This dissertation is about the ties between such broader sets of ideas, concepts and rationales in policy for STI and the local contexts in which they take form. This work addresses such ideas, concepts, models, metaphors and rationales as *global ideas* in policy for STI, i.e., shared ideational elements of policymaking. It follows such global ideas to see how they travel and are understood in different settings. Scholarship in STI and Science and Technology Studies (STS) have termed such broader ideas as 'frames' (Schot and Steinmueller 2018), 'rationales' (Laranja et al. 2008; Braun 2006), 'travelling concepts' (Flink and Peter 2018), 'models' (Godin 2006, 2015; Pfotenhauer and Jasanoff 2017), 'buzzwords' (Bensaude-Vincent 2014) or 'metaphors' (Flink and Kaldewey 2018). In public policy studies, ideas have been described as 'worldviews, paradigms, norms, ideologies, knowledge, beliefs, forms of language, visions and policy proposals' (Kettell and Cairney 2010)(p.302) (see also Campbell 2002). While each of these terms can be considered an object of study on their own, this dissertation treats these notions as similar because they all focus on tracing similarity (or dissimilarity) across contexts (Godin 2017; Jasanoff and Kim 2013; Elzinga 2012).

The adoption of global ideas across countries can be read as a process of convergence about what government funding for universities, technology institutes and other organizations should or should not be used for (Capano 2023; Schot and Steinmueller 2018). These global ideas enable consensus or contestation in policy for STI (Flink and Kaldewey 2018); they propose a seamless adoption across contexts pointing to isomorphism (DiMaggio and Powell 1983); and suggest the identification of the 'best' ideas globally (Lemola 2002). However, the growing adoption of global ideas across distinct contexts raises the question of whether countries are embracing the same recipe or using them differently as ingredients in their own national policies for STI. For example, the NIS has been criticized for overlooking 'situated political contexts and local realities' that could strengthen its application (Delvenne and Thoreau 2012)(p.216) and national adaptations of RRI have been shown to 'make visible aspects of responsibility not readily apparent in abstract, European or global scale discussions' (Doezema et al. 2019)(p.323). Critics also contend that 'our present understandings and practices of STI policy are not sufficient to address Grand Challenges and set priorities accordingly' (Kuhlmann and Rip 2014)(p.1). They also question whether new policy models are needed (Mowery et al. 2010). These challenges cast a shadow over global ideas as a means to address global, or even national, STI needs.

While global ideas in policy for STI appear generic with a stable meaning, it is not clear how they come to be understood across contexts, or what 'survives' across different interpretations. This uncertainty casts global ideas as somehow durable beyond national borders, but also uniquely contextual in the practice of policy for STI. This tension between what is perceived as universal, and their contextual meaning-making calls for research that can pursue global ideas and investigate how they are understood and manifested locally. First, understanding these global ideas and what they advocate for, or 'idealize' in terms of modes of governing socio-technical systems, is paramount. Second, following such global ideas into different contexts and investigating what they 'idealize' there is just as crucial. How are global ideas understood locally and how do they mix with national rationales in policy for STI? What are the flexibilities and differences of the broadly accepted global ideas? These questions are important to understand and describe contemporary policymaking[9] for STI in ways that account for both standardizing and contextual differences emerging within and across countries.

1.2 Research Question

Research about policy for STI can benefit from studying homogenizing trends across countries and how these pressures are contextualized within countries (Irwin et al. 2021; Pfotenhauer and Jasanoff 2017). Approaches to the study of policy for STI often address pressures to conform and differentiate separately suggesting a need for research on how the global and local work together and sustain each other over time, not as a point of fusion, but as a way of creating new possibilities within national and global contexts. To contribute toward this puzzle, this dissertation asks the following research question:

How are global ideas in policy for STI understood within specific contexts?

This question puts global ideas as a critical phenomenon in current policy for STI and instigates an inquiry into their deployment and adaptation within national contexts. This dissertation investigates the presence of global ideas in policy strategies for STI within one specific national context and through cross-country comparisons. Two articles investigate specific global ideas such as 'diversity' and the 'valley of death' in the United States, while the third article compares policy instruments in China and the United States as they imagine an 'innovation-based future', and the fourth article traces three basic rationales in STI strategies across China, Denmark and the United States. The national empirical case focuses on nanotechnology policy as a locus where global policy pressures are negotiated (Roco 2011) and where the United States has also taken a particular way of developing its national program (Merzbacher 2020). The cross-national comparisons focus on broader policy for STI strategies that enable tracing global pressures within and across specific contexts. This combined approach addresses the research question by tracing the adoption and adaptation of specific global ideas in increasingly complex ways, i.e., single country versus cross-countries, single technological area versus general policy

[9] This dissertation does not try to explain how global ideas diffuse in science (Cheng et al. 2023), to find ideational explanations of policy change (Kamkhaji and Radaelli 2022)(p.842), or to justify the ascent or failure of particular global ideas within a national or international contexts (Kettell and Cairney 2010; Carstensen 2015).

for STI, and one global idea versus multiple global ideas. These moves provide different, yet complimentary perspectives to answering the research question.

The empirical analyses are guided by the conceptual lens of *isomorphic difference* (Irwin et al. 2021), which brings together two strands of research that each have sought to pursue questions of sameness and difference, with their own emphasis: STS and institutional theory. *Isomorphic difference* offers an interesting and relevant approach to understanding global ideas anew, both as a set of rules that may govern and shape social life as well as political and economic orderings, but also in unexpected ways. In the four articles that comprise this dissertation, I draw mainly on document analysis of policy documents to trace the balance between isomorphism and difference in policymaking for STI. How countries manage the balance between following the global crowd and setting a distinctive direction is core to this dissertation.

1.3 Structure of the Dissertation

The dissertation consists of three parts: this framing chapter (Part I), four research articles (Part II) and a discussion and conclusion (Part III). Part I includes the framing paper for the dissertation, which ties together the individual articles to provide an overview of the motivations and research questions, the theoretical foundations guiding the research, as well as the research design, data and methods of this dissertation. This part is divided into three sections, i.e., Section 1 Introduction, Section 2 Literature Review and Section 3 Conceptual Lens and Research Method.

Part II includes the individual articles which represent specific empirical cases related to the overarching research question drawing on the conceptual lens of isomorphic difference. This part consists of four individual articles. Below is a short summary of each article and how they contribute to the dissertation as a whole. Table 1 provides an overview of the articles included in Part II summarizing their main research question, setting & methods, cases, key arguments, conceptual space, and target audience.

The first article analyzes national understandings of diversity, an increasingly relevant global idea in policy for STI, within the context of the National Nanotechnology Initiative (NNI) in the United States through strategic documents, interviews, and participant observation. The interplay between diversity as a global construct and the localized expressions in the United States suggest that diversity is central to the NNI and nanotechnology policy. The conceptual lens of *isomorphic difference* directs the analysis into the contexts in which diversity is imagined and enacted in the NNI providing an example of national level analysis. The findings underline the co-existence of three diversity frames in the United States policy for nanotechnology, which challenges diversity as a taken-for-granted category in policy for STI.

The second article examines how the ‘valley of death’ trope has been interpreted and domesticated in the United States NNI. The ‘valley of death’ serves as a metaphor that taps into a well-established cultural trope and provides a particular framework for the relationship between science, technology and innovation. The conceptual lens of *isomorphic difference* highlights how the global idea works in different ways within the national context. By drawing

on historical documents, participant observation and interviews, the article provides a unique empirical mapping of the valley of death in policy for STI in the United States. The analysis helps look anew at a common STI trope that is often seen as unproblematic.

The third article examines how countries build an innovation-based future through the adoption of particular policy instruments in national STI strategies. Two national contexts –the United States and China—provide unique domestic contexts for analyzing the presence and evolution of three policy instrument families over a 20-year period. The conceptual lens of *isomorphic difference* reveals the interaction between global and national pressures and shows the heterogeneity of understandings of policy instruments that emerges from this interplay. As a result, the analysis challenges the idea that national features are in conflict with global pressures, and thus, extends the conceptual lens by showing national variants of innovation-based futures. Ultimately, the findings provide a cross-cultural account of global ideas that enables an analysis across policy contexts, identifying important patterns of similarity as well as meaningful difference in policy for STI across nations.

The fourth and last article compares national STI strategies across three highly different countries: to what degree and how do they address the same or different phenomena? It provides a fresh perspective on national ideational elements and their combination in policy for STI. The article approaches this puzzle by developing a novel analytical framework of three rationales of research investment ('curiosity,' 'market,' and 'mission' present in STI literature to capture ideational familiarity and distinctiveness in policies for STI. The conceptual lens of *isomorphic difference* enables the identification of variation in these global ideas over time in three national contexts: the United States, China and Denmark. Findings reveal that the three countries exhibit an ideational blend of curiosity, market and mission rationales, suggesting that familiarities across settings can be as noteworthy as the differences. The article analyzes the presence of these global ideas in selected policy documents in the aforementioned countries from 2003–2020.

Table 1. Articles in the Dissertation

#	Title	Research Question	Setting & Method	Case	Key Argument	Conceptual lens	Target Audience
1	Framing 'Diversity' in Policy: Isomorphic Difference in the United States National Nanotechnology Initiative (NNI)	How is 'diversity' understood within the National Nanotechnology Initiative in the United States?	United States, 1999-2023 Document studies; Qualitative interviews; Participant observation	National Nanotechnology Initiative	Diversity in policy for STI, comes to be constitutive of nanotechnology policy and must be understood as a situated object whose framings imply vastly different social, organizational and political arrangements.	Isomorphic difference	Working paper *Science and Public Policy*
2	Into the 'Valley of Death': *Isomorphic Difference* in Policy for Nanotechnology in the United States	How is the valley of death interpreted and domesticates in the United States NNI?	United States, 1999-2023 Document studies; Qualitative interviews; Participant observation	National Nanotechnology Initiative	The 'valley of death,' a trope, metaphor, and travelling concept in policy for STI, illuminates and distinctively shapes and directs innovation processes in the United States.	Isomorphic difference	Working paper *Science & Technology Studies*
3	National Variants of Innovation-based Futures in Policy: Varieties of Capitalism (VoC) and the Frames of Innovation in the United States and China	To what extent do states adopting an innovation-based future absorb global frames or retain their national features?	United States and China, 2000-2020 Document studies	National STI strategies	National variants of innovation-based futures are situated closer to their distinct VoC framework than it would be suggested by the global Frames of Innovation.	Isomorphic difference	*Technological Forecasting and Social Change* (submitted)
4	Blending Curiosity, Market, and Mission Rationales: Capturing *Isomorphic Differences* in National Science, Technology, and Innovation Policies	What are the ideational similarities and differences in national policies for STI?	United States, China and Denmark, 2000-2020 Document studies	National STI strategies	Three rationales in policy for STI emerge as 'blends' across countries that converge towards notions of novelty and technological development.	Isomorphic difference	Working paper *Minerva*

Part III discusses the findings, strengths and weaknesses of this approach, and their contributions to scholarly understandings of global ideas in national policy for STI. The section looks *across* the empirical cases to show how the local become sites that not only receive global pressures to conform but also shape and generate new understandings of global ideas in policy for STI. Discussions in this part highlight the complexity and diversity of interpretations that global ideas take within and across countries. This part also reflects on the contributions that the dissertation makes to STS and institutional theory from its adoption of the conceptual lens of isomorphic difference and suggests ways in which isomorphic difference could be developed in the future. The section concludes with lessons learned from the research process as a whole that can serve those interested in pursuing global ideas in policy for STI. Part III is divided into two sections, i.e., Section 4 Discussion and Section 5 Conclusion.

2. LITERATURE REVIEW

The relationship between broader sets of ideas and local variations or interpretations has been addressed by various social science traditions, notably within STS and institutional theory. In this section, I first review STS theories and approaches with a focus on policies for STI. Then, I present institutional literature that addresses global and local ideas and specifically within policies for STI. The literature identified is the result of extensive search and dialogue with scholarly experts about the contents of the dissertation. While this is not an exhaustive overview of all debates, contributions, or viewpoints, it identifies the debates that have inspired this dissertation. Finally, I summarize the areas in need of more knowledge and where this thesis seeks to contribute.

2.1 STS Approaches

STS scholars generally focus on the ways in which scientific practices, concepts, and ideas are shaped (Latour 1987; Nowotny et al. 2001; Godin 2017; Flink and Kaldewey 2018; Flink and Peter 2018) and rendered into localized practices and knowledge claims (Godin 2006; Irwin 2006). Ideas and technologies are often treated in the same way, i.e., following their emergence and relationship with social-material orders and practices[10]. A dominant interest in this field is how scientific ideas and technologies are stabilized and accepted. Core concepts are convergence and standardization (Fujimura 1987, 1988, 1992), immutable mobiles (Latour 1990), as well as interpretive flexibility and closure in the development of new technologies (Bijker 1995; Bijker et al. 1989; Pinch and Bijker 1984). Fujimura (1987, 1992) describes how packages of theories and technologies make research 'doable' providing stability and simplification that facilitates the incremental development of scientific knowledge. Similarly, although with different concepts, Latour addresses how ideas are inscribed in technologies that

[10] Scholarship on the sociology of technology, for example, investigates the influence of technology on the social world and vice versa (Latour 1997; although beyond STS see also Orlikowski 1992).

stabilize these ideas, but also translate them (Latour 1997). His concept of immutable mobiles[11] provides a way to think about phenomena whose form and function remains stable across different contexts and places especially in STI. Other scholars focus on the 'rhetorical closure mechanisms', i.e., ways in which the meaning of an artifact is socially constructed and over time reaches a closure. This mechanism suggests that the artifact has diminished interpretive flexibility which leads to the establishment of a dominant meaning (Bijker 1995)(p.86). Closely related, controversy studies focus on the "battle of ideas"; how the meaning of a term or a technology may be contested as different actors and networks seek to expand their understanding vis-à-vis competing understandings, e.g. (Nelkin 1992). Thus, STS approaches tend to focus on conflicts and translations of ideas (Fujimura 1992; Star and Griesemer 1989; Callon 1986).

In the STS tradition, the sociology of translation has focused on why and how similar innovations develop differently in particular networks. Callon (1986) argued that a 'program' (e.g., a global idea) acquires stability support from actors and materials as a result of a process of 'problematization,' 'interessement,' 'enrollment,' and 'mobilization.' These moves can result in subtle or profound changes in the 'program' suggesting 'interactivity' between actors and networks (Latour 1991). In this tradition, 'translation' enables an explanation of the global spread and uptake of ideas, visions and policies. Seminal work by Star and Griesemer (1989) explored the role of material objects (i.e., boundary objects) in translating between scientific actors, an approach that emphasized a move between discrete communities of meaning. These boundary objects can also be concepts found in debates about policy for STI (Flink and Kaldewey 2018), due to their interpretive flexibility. However, as the STS notion of boundary objects was taken by management scholars, these objects were conceived as 'translation machines of shared meaning' (Martin et al. 2012)(p. 1194). This suggests that even the notions used to explain the movement of ideas can shift in focus as they travel between scholarly traditions.

STS scholars have also sought to understand the dynamics of policy for STI (see e.g., Bhupatiraju et al. 2012; Felt et al. 2017; Hess and Sovacool 2020; Jasanoff 1990). STS scholarship can take global ideas off their pedestal and unpack their assumptions and constitutive properties that are often reified and taken for granted. For example, STS scholars have studied the emergence of transboundary problems, which they define as matters that transcend the 'geographical borders of political organization' (Lidskog et al. 2010)(p.114). In their work on the regulation of trans-boundary environmental issues, Lidskog et al. (2010)[12] show the importance of frames in problem definition and underscore how the framing process is

[11] Latour (1990) describes the invention of the printing press as enabling the mobilization of maps or other scientific inscriptions in their immutable state, preserving the translation without corrupting it (p.28). His account focuses on "optical consistency" (p.27) as an essential feature of why diagrams and other scientific inscriptions carry so much force among scientists.

[12] This work combines STS insights with regulation theory and discourse theory to analyze trans-boundary environmental issues: oil protection in the Baltic Sea, mobile phones and radiation protection, climate change adaptation and genetically modified crops.

social and ongoing (p.119). An important insight from their work is that frames that accompany transboundary problems 'do not travel on their own but need supporter, carriers and social arrangements in order to be distributed to society' (Lidskog et al. 2010)(p.121). In a similar vein, scholars in the sociology of science have also acknowledged the role that external influences in shaping the boundaries and content of science (Granqvist and Laurila 2011). An important locus is policy for STI, which includes the various processes of 'political accommodation among science, society and the state" (Jasanoff 1990)(p.250). It is within policy for STI that scholars have identified the uptake of several powerful ideas, buzzwords, and models (Bensaude-Vincent 2014; Flink and Kaldewey 2018; Flink and Peter 2018; Godin 2006, 2017) that signal convergence across distinct national contexts (Lemola 2002). The recurrence of particular models, frameworks, concepts[13], or ideas highlights the importance of focusing on policy for STI to better understand its dynamics. Flink and Kaldewey (2018) also show that constructs like the linear model of innovation remain 'indispensable for communicating science policy in the twenty-first century' even though they have been discredited in academic circles (p.5). In what follows, I describe three main approaches found in the STS tradition to make sense of the relationship between global and local ideas in policy for STI. The first describes sociotechnical imaginaries, the second buzzwords found in policy for STI, and the last explains the notion of travelling concepts which provide homogenizing pressures across contexts.

Scholars in the STS tradition have been interested in the divergent ways in which countries imagine their futures through technologies. Jasanoff and Kim developed the concept of 'sociotechnical imaginaries'[14] (Jasanoff and Kim 2009, 2013, 2015; Kim 2018) to emphasize national action, performance and materialization through technology. Imaginaries describe attainable futures as well as prescribe what the future ought to be in nations. They rely on particular narratives that serve particular purposes in policy for STI. Scholars who draw on this approach find that they 'provide an entry point for a constructivist, locally grounded theory of innovation policy while still recognizing innovation's global reference points and entanglements' (Pfotenhauer and Jasanoff 2017)(p.801). Imaginaries 'project visions of what is good and worth attaining' (Sovacool and Hess 2017)(p.719). The concept inspired a questioning of which collective imaginations are inserted in policy for STI and how these get operationalized. In one relevant article Pfotenhauer and Jasanoff (2017) draw on the concept to evaluate the best practice mantra in innovation narratives. They approach this by looking at the adoption of the 'MIT model' across three different national settings. The MIT model provides homogenizing pressures across contexts, not in the sense of being the same everywhere but by

[13] There is a growing literature on conceptual history within the history of science (e.g., Godin 2006, 2017, 2020; Shapin 2012; Kaldewey 2013; Schauz 2014, 2015), which signals a conceptual turn in STS. This scholarship has unveiled the way in which many notions in policy for STI are the result of particular histories. However, 'there is a general reluctance in STS with regard to the semantic aspects of science and science policy' (Schauz and Kaldewey 2018)(p.5). The sociology of promise has also been a fruitful space for understanding the policy framings underlying funding for STI and how they shape particular fields (Brown and Michael 2003; Williams 2019).

[14] Sovacool and Hess (2017)(p.719) explain that compared to policy agendas, sociotechnical imaginaries are less explicit and accountable, and unlike narratives, they more directly serve explanatory purposes; imaginaries instead are instrumental and futuristic.

providing the excuse of adopting a global model to legitimize particular perceived national ailments. The reasons for adopting the MIT model varied in the United Kingdom, Portugal and Singapore, signaling that while they all perceived the cure in similar ways, their diagnosed ailments varied substantially. This work shows that even in examples where the translation of a global model involves transformation at the national level, this transformation stems from radically different perceptions of what needs to be fixed in the places adopting such models.

Scholars in STS also study the emergence of 'buzzwords' in the policy world as artifacts that provide ideological and homogenizing pressures in policy for STI. With the pejorative term 'buzzword,' David Berube (2006) seeks to debunk the 'buzz' about nanotechnology. Analyzing the term 'interdisciplinarity' as a buzzword illuminates a discrepancy between rhetoric at the policy level and academic practice (Stamm 2019). These 'fashionable stereotyped phrases' which Bensaude-Vincent (2014) identified in emerging technologies like genomics or nanotechnology, include 'public engagement in science,' 'responsible innovation,' 'green technology,' or 'personalized medicine' (p.238). Through a case study of 'public understanding of science,' Bensaude-Vincent (2014) reveals the ways in which the term draws on notion of 'upstream' engagement, which reinforces the conventional linear model that has been debunked in academic circles (Godin 2006). Bensaude-Vincent (2014)(p.250) shows that buzzwords shape the technoscientific landscape they emerge from creating 'peaceful collectives of people with competing agendas' and thus becoming a 'trading zone' that allows different stakeholders to communicate. In her account of 'public understanding of science' as a buzzword, Bensaude-Vincent (2014) points out that the phrase which originates in both the United States and in Europe from STI policy bodies, reveals the irony the 'while the signified emphasised the need to break away from top-down communication, the signifier itself travelled from the top down' (p.244). STS scholars in Austria investigated 'diversity' in biomedicine as a buzzword in the public health arena. They show that buzzwords steer governance practices and encourage promissory rhetoric (Penkler et al. 2020)(p.138). The literature on buzzwords connects with broader STS literature on the relationship between global-local ideas by explaining how buzzwords make policy 'doable' (Fujimura 1987). The Austrian study of the adoption of diversity in an obesity prevention program revealed 'the need to translate diversity into a "doable" project with clearly delineated target groups, which promoted a narrow understanding of diversity, one that stands in tension with much more fluid and context-sensitive ways of performing diversity' (Penkler et al. 2020)(p.138-139)[15]. Diversity as a buzzword facilitates standardization in understandings but also limits how diversity can be used in the context of public health. Penkler et al. (2020) also show the multiple situated meanings of diversity and their potentially conflicting normative commitments.

STS work has also developed work on 'travelling concepts' to point at the way in which ideas behind particular notions provide stability and coherence. Some scholars have taken on this task by tracing the conceptual journey of particular global ideas. Flink and Kaldewey (2018) take

[15] The notion of 'doable' science stems from STS work that shows how scientific ideas become standardized in recognizable packages of theory or technologies (Fujimura 1987; Fujimura 1988; Fujimura 1992).

ideas of ‘frontier research,’ ‘grand challenges,’ and ‘responsible research and innovation’ (RRI) as traveling concepts between different contexts. They show how notions of ‘RRI’ in Europe and ‘broader impacts’ in the United States emerged in a policy context (Davis and Laas 2013; Flink and Kaldewey 2018), whereas ‘responsible innovation’ has more academic roots that connect it to the study of ethical, legal and social aspects or implications of emerging technologies (Hilgartner 2018; Swierstra and Rip 2007) These distinctions and the movement of these global ideas between practice and theory infuse them with different concerns[16]. Doezema et al. (2019) analyzed notions of RRI, as ‘an increasingly global concept that is translated and transformed in heterogeneous national contexts’ (p.323). In their comparative work from Australia, the Netherlands, Germany, Brazil, Italy, China and Norway, they analyze the global framework in local contexts. They find that RRI in these national examples reveals peculiarities of local contexts, but also points of overlap across them (p.328). Frahm et al. (2021), on the other hand, focused on the growing popularity of ‘responsible’ or ‘mission-oriented’ innovation frameworks in policy for STI, especially as advocated institutions of global governance[17]. They suggest that these popular frameworks rely on technological solutionism and “fixes” in policy for STI, as shown by other STS scholars (Wynne 1992; Pfotenhauer et al. 2019). The authors describe the emerging ‘social fix’ in policy for STI as ‘the integration of society as a “fix” to problems with innovation policy and its contribution to global economic growth’ (Frahm et al. 2021)(p.30). Godin has taken a similar approach in looking at the ‘linear model of innovation’ (Godin 2006), the ‘National Innovation System’ (Godin 2017) and the notion of ‘technological innovation’ (Godin 2020). In his work, Godin underscores that these global ideas become shared amongst a variety of users, they have the ‘capacity to travel widely across scholars and domains’ (Godin 2015)(p.586). His account challenges descriptions that frame these ideas as boundary concepts (Star and Griesemer 1989; Flink and Kaldewey 2018) because they do not ‘establish boundaries between groups’ (Godin 2015)(p.588), instead offering the notion of ‘transdiscursive’ concepts (Miettinen 2002). Flink and Peter (2018) also show how ideas of ‘excellence’ and ‘frontier research’ have ‘travelled a long way from the United States and have derived from contexts outside of science (and policy)’ (p.431). In this work, Flink and Peter (2018) show how these global ideas offer simplicity, coherence and widespread appeal within policy circles. They show how these global ideas initially ‘conveyed the positive image of individual self-mobilization’ but in their move across the Atlantic and into European policy spaces became ‘“euphemizers” of competition in Europe’ (p.432). Their application of the notion of ‘travelling concepts’ is based on an understanding of these global ideas as empirical objects that take different forms of travel, i.e., between academia-practitioner or across continents.

[16] One common criticism is that notions of ‘broader impact’ in the United States are supposedly too close to ‘what politicians want and what gets funded’ (Davis and Laas 2013)(p.966).

[17] The authors focus on the OECD and the European Commission (Frahm et al. 2021).

2.2 Institutional Approaches

The relationship between global and local ideas is also addressed by institutional theory[18] and new institutional theory. Institutions are a set of (in)formal rules that govern social life. These rules become 'legitimate, routine, and taken-for-granted, and … if not actively disrupted, tend toward persistence and self-reproduction (Berman 2008)(p.836). Institutional theories provide useful ways of conceptualizing social order by focusing on the 'construction and deconstruction of institutions' (Czarniawska and Sevón 1996)(p.3). Processes of institutionalization often focus on stability and persistence. This tradition focuses typically on large-scale patterns, emphasizes 'processes of isomorphism, homology, and standardization in an ever more globalized world' (Boxenbaum and Pedersen 2009)(p.178). These theories emerge from an interest 'in explaining why stability, though never permanent, does exist, and where it comes from' (Berman 2008)(p.839-840). An influential explanation of organizational similarity comes in the form of institutional isomorphism (DiMaggio and Powell 1983)(see also Greenwood and Meyer 2008). Isomorphism 'tends to occur most frequently when organizations encounter environmental uncertainty and ambiguity' (Glazier and Hall 1996)(p.48). DiMaggio and Powell (1983) identify three pressures that lead organizations to look increasingly similar: coercive, mimetic and normative. In general, coercive pressure relates to power and politics; mimetic pressures result from uncertainty; and normative pressures from professionalization (DiMaggio and Powell 1983)(p.150).

Since the 1990s the focus of institutional theory has also shifted to explaining organizational change as a result of institutional pressures (Greenwood et al. 2002; Schneiberg and Clemens 2006; Beckert 2010; Currie 2012). Beckert (2010) argued that the focus on similarity in institutional theory did not do justice to social change because it overlooked insights on divergent institutional development. Currie (2012) added that isomorphic pressures sometimes conflict with change efforts at the organization level in her example of the study of electronic health records in the United Kingdom's National Health Service. Within the study of isomorphic pressure, there has also been pushback in the adoption of foreign models into local contexts. In a study on the England-China Maths Teacher Exchange, Probert (2022) found that 'local contexts must be taken into account for a transnational policy transfer to be successful' (p.317), suggesting that the effectiveness of these programs hinges on their embeddedness. In line with research exploring the isomorphic pressure of rankings in various parts of the world (e.g., Hazelkorn 2007; Sadlak and Liu 2007; Erkkilä and Piironen 2014; Lo 2014; Yudkevich et al.

[18] This dissertation draws particularly on scholarship in the neo-institutionalist tradition, which represents one strand of scholarship in organization studies. Neo-institutionalism theory is used across different fields and can be described as an an approach to the study of institutions focused on constraining and enabling influences of formal and informal rules on individuals and groups. It includes seminal work by Meyer and Rowan (1977), Lynn Zucker (1977) and DiMaggio and Powell (1983). The thesis draws particularly on the work by DiMaggio and Powell (1983). In their work Zucker (1977) and Meyer and Rowan (1977) assumed a shared commitment to rationality as a precondition of the institutionalization of organizational practices. Friedland and Alford (1991) questioned this stand and proposed that practices could rest on a variety of values, which could be in conflict with one another. This was a departure for a different strand of work on institutional logics (Thornton et al. 2012; Thornton and Ocasio 1999, 2008; Thornton 2002; David et al. 2019), which I do not discuss in this dissertation.

2015), Anafinova (2020) finds that national universities in Kazakhstan are pushed toward 'the visionary model of Anglo-American research university' (p.11). Within institutional theories of organization there is also work that attends to sources of variation while also explaining the familiar in institutional life, for example: 'competing logics' (Reay and Hinings 2009), 'institutional bricolage' (Carstensen 2017; Christiansen and Lounsbury 2013), 'institutional entrepreneurs' (Battilana et al. 2009; Garud et al. 2007) and 'organizational hybridity' (Battilana and Dorado 2010).

But what happens to ideas when they move from one context to another? Work in the Scandinavian[19] institutionalist tradition illuminates this process. Specifically, work on the translation of ideas (Czarniawska and Joerges 1996; Sahlin-Andersson 1996; Sahlin and Wedlin 2008) sheds light onto the shared meanings that are developed within organizations, and how ideas and meanings emerge and are collectively shared (Scheuer 2021). This tradition focuses on how ideas are contextualized in local settings (Czarniawska and Sevón 2005; Nielsen et al. 2020; Wedlin and Sahlin 2017; Wæraas and Nielsen 2016). Translation can trace the process through which a foreign management practice travels and gets adopted in a setting that may not have been initially receptive to it (Boxenbaum 2006). The outcomes of translation processes can 'range from nearly identical to the global type, to hybrids or blends, to almost completely new versions that have only a vague family resemblance with the global template' (Meyer 2013)(p.81). While translation may at first glance look like ideas found in other organizations, these ideas are always adjusted to fit the norms and routines of the new organizational context (Sahlin-Andersson 1996). Translation processes can also accumulate over time and influence the development of particular professions (Thøgersen 2022). Scandinavian institutionalists, especially those along the conceptual flow between organizational studies and STS[20], theorize the process of translation as something that 'always involves transformation' (Czarniawska and Sevón 2005)(p.8), is 'subject to re-interpretation and reformulation' (Kim 2018)(p.179), and that has a meaning beyond narrow linguistic interpretations (Czarniawska and Joerges 1996)(p.24). This process has been described as a translation leading to local variations of models (Czarniawska and Sevón 1996; Sahlin-Andersson 1996, 2001) because, through circulation, models change (Czarniawska and Sevón 1996; Sahlin-Andersson and Engwall 2002; Mazza et al. 2005).

As ideas travel, they get interpreted and reformulated within organizations and fields. The study of decoupling (Bromley and Powell 2012; Bromley et al. 2012)[21] within organization theory

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[19] This tradition took inspiration from '…organizational sociologists such as Richard Scott, James G. March and John W. Meyer, and social constructivists such as Peter Berger, Thomas Luckmann, and sociologists of science and technology including Bruno Latour, Michel Callon, and Karin Knorr-Cetina' (Kim 2018)(p.178). See Wæraas and Nielsen (2016) for an account of the travel of translation theory beyond Scandinavian institutionalism.

[20] Inspired by actor network theory (Callon and Latour 1981; Callon 1986; Latour 1986, 1987), scholars posit that translation is the process that 'a practice or an idea undergoes when it is implemented in a new organizational context' (Boxenbaum and Pedersen 2009)(p.190-191).

[21] Decoupling has also been studied in the case of stock repurchase programs in the United States (Westphal and Zajac 2001), implementing the 'triple helix' model in Ukraine (Hladchenko and Pinheiro 2019) and in the context

describes the processes through which organizations separate practice from policies as a result of institutional pressures to conform. In their study of nanotechnology in the United States, Grodal and O'Mahony (2015) showed how initial consensus around grand challenges was decoupled away from the original ends in later phases of field development. They show how grand challenges, albeit offering a joint end to pursue nationally, can suffer from decoupling where the means to achieve originally agreed goals diverge over time. But decoupling can also provide the means to frame job profiles to fit local candidates in ways that ensure organizational certainty, as it was shown in a Danish academic department (Nielsen 2016). Organizations also vary in their responses to organizational pressure; Battard et al. (2017) show that research teams in nanoscience reconfigured their physical (policy and materiality), mental (meaning) and social (identity) spaces in response to these pressures.

One final way to think about global pressures as they are locally appropriated can be found in anthropology through the work of Richard Wilk (1995) who introduced the notion of 'global systems of common difference' to describe the dialectic between the global and local, such that there are not one set of global and local influences within countries but that they are co-constructed. Wilk's work zooms into the micro sociological processes that underlie this co-construction. He suggests that globalizing and localizing pressures are brought together within specific practices and settings, in his case beauty pageants in Belize. Sociologists have also found ways to theorize the relationship between global ideas and their implementation and adaptation locally. 'Glocalization[22],' a concept originally found in sociology (Robertson 1992, 1995), challenges the idea that globalization overrides locality, instead it 'regards globalization and localization as simultaneous processes, as two sides of the same coin' (Meyer 2013)(p.79). Glocalization suggests that universalizing and particularizing tendencies are simultaneously co-present (Robertson 1995). Glocalization is conceptualized as a process through which global ideas and models get translated, transformed and mixed as they move between cultures, spaces, or as a result of the emergence of supra-national institutions (Djelic and Quack 2003). This approach facilitates an understanding of how global ideas acquire 'hybrid forms' within the national context (Pallas and Wedlin 2013)(p.296) and emphasizes the role of actors in these processes (Sahlin-Andersson and Engwall 2002). Engels and Knoll (2013) provide an example of the way in which national negotiations about 'legitimate forms of carbon management' provide the locus and process through which the dominant mode of global environmental governance gets localized (p.356).

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of technology policy where Lim and Ferguson (2020) draw on the idea to explain the unwinding of the economic interdependence between the United States and China especially in high-tech industries.

[22] Although glocalization is often used in the context of the study of business and management practices, it has been applied to the context of policy for STI as 'policy glocalization' (Kim 2007). In his work, Kim (2007)(p.218) described policy glocalization as the meeting of isomorphism and decoupling in an institutional path dependent scenario, which revealed the way in which 'homogenization and heterogenization of policies coexist in Korean R&D policies'.

2.3 Comparison and Areas for further Scrutiny

2.3.1 Disagreements and Agreements

There is a rich literature across STS and institutional traditions on the production, spread, change, and stability of ideas, including the relationship between broader sets of ideas—global ideas—and their local, contextual take. Where STS tends to focus on the micro processual, institutional theorists have focused on the macro aspects of these processes. Institutional isomorphism underscores the need to pay attention to the social and organizational practices through which organizations adapt to pressures to conform. Decoupling highlights the ways in which formal means and processes are circumvented to achieve local ends showing the conditions in which this happens. As institutional theory has evolved, its explanations of macro processes like glocalization have suggested that homogenizing and difference-making pressures co-exist. Berman (2008) argues that where institutional theory aims to identify patterns across projects, STS does not focus on such aims because their accounts were not written with the purpose of generalizing.

Institutional theory focuses on the social construction and stabilizing of ideas, whereas STS tends to emphasize their material aspects, i.e., how ideas and technology are intertwined and mutually co-productive. By studying global ideas within their historical and socio-material context, STS scholars document the growing importance and shifts in understanding particular global ideas in policy for STI. The review reveals that even though buzzwords provide homogenizing pressures in policy for STI, they carry negative connotations. However, sociotechnical imaginaries and travelling concepts provide more 'positive' approaches to studying the emergence and adoption of similar concepts, ideas and programs in policy for STI. STS scholars adopt discourse, historical and semantic approaches to understand the adoption and changes of global ideas over time. But all of these approaches within STS show how global ideas infiltrate policy for STI and the set of values they articulate and refine.

There are also concepts and perspectives that the two traditions share, for example, scholars agree that ideas are not given but are made sense of and translated over time. Institutional theory scholars were previously interested in stability, but have increasingly emphasized change processes, and adopted concepts such as translation that STS have also used. These two traditions acknowledge that ideas not only "travel" and spread but change subtly or radically over time. These understandings underline the importance of the global in local settings and highlight how global ideas move across settings. Both approaches would argue that a focus on the increasing homogeneity found in policy for STI warrants further scrutiny.

2.3.2 Areas for further scrutiny

I argue that certain aspects of the relationship between global ideas and their local adoption and adaptation can be further studied to improve our understanding of their interplay[23]. The spread of policies across contexts suggests that these replicate without evolving, that their diffusion is automatic (DiMaggio and Powell 1991); yet policies also change as they circulate (Sahlin and Wedlin 2008). By studying resistance and calls for embeddedness, institutional scholars appeal for a more dynamic investigation of pressures to conform and pressures to differentiate. This is particularly relevant to explain the emergence and adoption of global ideas in policy for STI across contexts that have such different political and institutional settings. In addition, there is a need to theorize the way in which categories or ideas, at the level of 'inter-institutional system,' recombine and vary by institutional order (Thornton et al. 2012)(p.173). Comparative and historical work can illuminate these dynamics.

STS approaches described here point to the ways in which the relationship between global and local ideas can be explained as process of convergence, stabilization or similarity, which calls for further scrutiny of settled ideas that defy challenge due to their social invisibility. In this way, global ideas can be seen as translating through systems that protect them from corruption along the way[24]. These insights call for deeper understanding of how global ideas, recognizable in Europe, Asia and the Americas, come to be understood and co-produced in these contexts. The imaginaries of innovation described by Pfotenhauer and Jasanoff (2017) show particular narratives (or global ideas) gaining traction and crossing scales. The authors reveal the influence that global models have in a national context, while also demonstrating the very contextual nature of their adoption. What looks the same from afar, may be made of very particular reasonings, suggesting that these global ideas must be imagined and translated locally (Irwin et al. 2021). This puzzle shapes the co-production (Jasanoff 2004) of policy for STI and deserves scholarly attention.

The review highlights the increasing interest by policymakers in STI on global ideas that legitimate particular approaches, while also revealing the need for better understandings of the manner in which these concerns become co-produced locally and how they also inform global understandings. This literature review reminds us that while these global ideas may appear as giving way to new visions of progress, they require closer study of the local context in which they come to be imagined. Doezema et al. (2019) show that the national implementation of RRI can enrich the global idea, while also emphasizes hierarchical relations between policy discourses in a European center and its global periphery (Flink and Kaldewey 2018; Macnaghten et al. 2014).

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[23] Instead of focusing on identifying a 'gap' in the literature which assumes that knowledge is bounded, I focus on areas that provide fertile ground for further exploration. For inspiration on this approach see *The Craft of Writing Effectively* (from 1:08:45) (University of Chicago 2014).

[24] Future work could conceptualize global ideas as immutable mobiles—as 'centers of calculation' (Latour 1990)(p.59) that capitalize on compatible inscriptions.

The literature on the relationship between global-local ideas within and outside STI-policy could attend more to the interplay of standardizing and diversifying dynamics, i.e., the remarkable standardization in policy for STI and the patterns of change that emerge from the travel of these global ideas across contexts. Scholarship that explains existing or needed changes in policy for STI does not pay enough attention to the ways in which global ideas, often assumed to be stable across countries, vary and how they often reproduce long-standing ways of working under the veil of novelty. This dissertation seeks to contribute to this line of work by studying specific global ideas within and across national contexts.

Finally, the review suggests that the relationship between global ideas and their adoption within national contexts is better conceived as one of mutual constitution and interplay rather than a one-way of adoption from the global to the local. It illustrates a point made by Schauz and Kaldewey (2018):

> 'The history of global science policy is the history of concepts traveling through time and between cultural contexts, followed by a period of conceptual synchronization. Yet, while the concepts of basic research and applied research finally prevailed in most national science policies, their meaning and use still vary between different cultures and national settings.' (p.2)

While there has been work seeking to understand global ideas in policy settings, they do not necessarily interrogate the commitments these ideas bring with them. What seems to be missing is a more symmetrical reflection on how seemingly new ideas reproduce old understandings (Schauz and Kaldewey 2018)(p.6) along with a more embedded study of how the local context influences these global ideas, avoiding absolute accounts of global adoption.

3. CONCEPTUAL CONSIDERATIONS AND RESEARCH METHOD

To help pursue the question of how global ideas in policy for STI come to be understood within specific contexts, I employ the conceptual lens of 'isomorphic difference' to guide a 'multi-sited' empirical analysis. Here, I first present the isomorphic difference approach and then the way I designed the empirical analysis.

3.1 The *Isomorphic Difference* Conceptual Lens

3.1.1 Its departure in STS and institutional theory

The conceptual lens of *isomorphic difference* (Irwin et al. 2021) draws on complementary, though different, scholarly traditions and perspectives. It incorporates insights from STS and institutional theory to study the pressures within global ideas in policy for STI. STS facilitates a focus on the contextual nature of policy for STI that emphasizes specific socio-technical interactions, while the literature on institutional theory enables consideration of elements that bring stability and meaning to policy contexts. The isomorphic account directs our attention to large-scale patterns from institutional processes whereas STS focuses on the contextual and local. 'Isomorphism' in this conceptual lens refers to patterns of cross-national convergence in

policy for STI. 'Difference' relates to national or local STI traditions, actors and capabilities. There is much that these two traditions can contribute to the understanding of global ideas in policy for STI. Taken together, the conceptual lens provides ways to study how global ideas become widely shared and adopted in policy for STI, but also how they are translated and vary across contexts. The overarching argument is that this combined approach enables an understanding of global ideas in policy for STI and how their local adaptations come to be expressed in globally recognizable language.

The interdisciplinary tradition of STS has sought to address questions of similarity and distinctiveness by exploring the relationship between science, technology and society. Bijker et al. (1989) argued that the development of science and society is intricately connected to culture and political ideas. Similarly, technological possibilities inform visions of society and scientific progress (Daston and Galison 2018). The STS tradition centers around 'the necessity of "opening up the black box" in order to demystify science and technology, i.e., to analyze the process of production as well as the product' (Star 1995)(p.6)(see also Latour 1987). The STS tradition is a more contextual interpretative tradition that takes a qualitative and empirical approach to studying the micro-processes of policy formation, for example (Brickman et al. 1985; Frahm et al. 2021; Guston 1999; Jasanoff 1990, 2004; Slayton 2013; Magro et al. 2014; Pfotenhauer and Jasanoff 2017; Vogel 1986). Berman (2008) argues that STS sees stability in socio-technical systems as temporary, being mostly interested in the 'fluidity and movement that always underlie it' (p.840). STS scholars have also explored the 'plurality of science–policy interface(s), each shaped by national socio-technical imaginaries, development priorities, and local social orders' (Meehan et al. 2018)(p.760). Work in this tradition 'situate[s] the social meanings of sociotechnical projects…in their historical and cultural contexts—to understand the co-existence of divergent social meanings…rather than to explain how to achieve the "objective" goals of those projects'(Jasanoff and Simmet 2021)(p.3). Applying an STS approach to isomorphic difference can reframe the study of global ideas from asking not how they are achieved or evaluating their success or failure, but rather how understandings of the meanings evolve and the context in which they emerge.

Institutional isomorphism (DiMaggio and Powell 1983) illuminates how uncertainty leads to homogenization within or across countries. While institutional isomorphism emphasizes imitation, it does not attend well enough to how diffusion happens portraying organizations as 'passive entities which simply react and adapt to latest trends' (Sahlin-Andersson 1996)(p.69). Institutional isomorphism has not been applied to the context of national policies for STI. Irwin et al. (2021) make an initial conceptual case for why these insights are valuable to understand how different institutional forms, ideas and practices in national policies for STI end up looking the same. These authors explain, for example, how the three pressures identified by DiMaggio and Powell can be found in national STI policies (Irwin et al. 2021)(p.2). The transfer of policies for STI across context can be construed as a normative process of sharing best practice (Monios 2017) or a mimetic process to secure legitimacy (DiMaggio and Powell 1983). These authors allude to isomorphism as way to make policy doable (Irwin et al. 2021)(p.3), which makes particular models in policy for STI relevant—e.g., the 'National Innovation System' (Freeman

1995; Godin 2017) or the 'triple helix' (Etzkowitz and Leydesdorff 1995)—considering that they have provided strong policy narratives that have diffused across countries.

3.1.2 Analytical dimensions/concepts

Isomorphic difference brings together the macro-focus of institutional theories that facilitate an identification of trends within and across countries, along with an interest from STS in understanding how these global trends emerge and are domesticated within specific contexts. The seminal work of Wilk (1995) has been inspirational to the isomorphic difference approach suggesting that globalizing and localizing forces in policy for STI are brought together within specific practices and settings. Isomorphic difference guides attention to how in practice people weave together what might be different focusing on the ways in which individuals, organizations and countries come to make the world by inter-connecting or co-constructing the two pressures at once. It explores these two pressures together, symmetrically, without undue focus on either one.

Like a photo mosaic, the conceptual lens reveals the relationship between distinct elements that are present in something that we observe—e.g., global ideas of curiosity, market or mission—and that replicates. It facilitates the zooming in to see the granularity of elements present in what looks like a global trend at a high-level. The conceptual lens builds on the work by Pfotenhauer and Jasanoff (2017) to point at the ways in which what we take as a unitary form of innovation must be construed as a 'a plurality of imaginaries of innovation' (p.801). In the case of policy for STI, this means that isomorphic difference must attend to the ways in which global ideas relate to local conceptions and justifications for their adoption.

Irwin et al. (2021) defined 'isomorphic difference' as an analytical concept relevant to the analysis of policy for STI. When applying the conceptual lens, policy for STI is not a passive recipient of global pressures but an area of social, political and organizational life where actors and processes interact to dynamically influence it. The conceptual lens, as originally introduced, includes three themes that facilitate the empirical identification of isomorphic difference (Irwin et al. 2021)(p.7):

- What is the relationship between national or regional policies and practices, and globalized policy frameworks?
- What social and organizational processes underpin and facilitate this relationship?
- How do actors make sense of and explain this relationship?

The first theme describes the kind of relationship that will be explored (e.g., national or regional and global), while the second and third themes provide richness about the relationship in question. The first theme underscores the co-production of policy for STI (Jasanoff 2004), which implies that the ways we know and represent the world are inseparable from how we choose to live in it. This understanding calls for attention to the social dimensions of policy commitments and understandings in STI, while at the same time underscoring the epistemic and material underpinnings of these very social formations. This approach resonates with work that

advances the notion that technology, work, and organizations should be conceptualized together (Orlikowski and Scott 2008). The need for methodological symmetry (explained further in Section 3.1.3) implied in the first theme requests equal attention to the local and the global, while also underscoring that as a relationship: it is the interplay between them that is brought forward by the conceptual lens. The second theme about social and organizational processes addresses the specific contexts in which global ideas come to enacted. This includes processes of closure or stabilization that may be in place in particular settings. The third and last theme highlights sensemaking and explanatory ways in which stories of isomorphic difference get inserted in national policy for STI. The adoption of global trends within and beyond national borders offers a glimpse into the sense-making and sense-giving processes (Smerek 2011) necessary to embrace and adapt them. The national focus of the third theme has consequences for the ways in which familiarity and distinctiveness comes to be enacted in policy documents. Irwin et al. (2021) show how in the Danish context this reveals an awareness by Danish policymakers of their existence in a global STI playing field, even though the challenges they identifyor face are not uniquely Danish (p.7). In sum, the themes in the original framework connect the theoretical underpinnings of this conceptual lens to its application.

Isomorphic difference draws on local-global dimensions to explore how in specific settings the global and local come together in particular ways. Probing its explanatory power through empirical studies to understand local strategies in the face of national pressures remains an open area (Irwin et al. 2021)(p.8). Extending the concept through comparative analysis can also reveal how ideas emerge in different contexts and whether certain countries have a better ability to absorb global ideas or trends than others (Horst and Irwin 2015; Irwin et al. 2021). The conceptual lens operates at the level of ideas, policies, and practices as they are diffused and adapted, but remains open to the understanding of those changes as viewed through practice in policy for STI.

The conceptual lens, while novel, joins scholars who have been interested in the interplay between local and global pressures across the STS and institutional tradition: debates on ‘glocalization’ that postulate a ‘fusing of the local and the global’ (Gray and Purdy 2018)(p.14) (see also Drori et al. 2014; Robertson 1995); research that aims to explain why and how organizations vary when drawing on standard practice or globally recognized models (Bromley et al. 2012; Mazza et al. 2005); work interested in the duality between idiosyncrasy and isomorphism in organizational fields (Álvarez et al. 2005); research suggesting a more open questioning of homogeneity and heterogeneity in institutions (Beckert 2010); work on the imaginaries of innovation as contextually understood models (Pfotenhauer and Jasanoff 2017); and research describing ‘global systems of common difference’ (Wilk 1995) that draw attention to contextualized forms of meaning-making and institutional practice. This underscores the relevance of the conceptual lens to broader scholarly debates.

Drawing on insights from STS and institutional theory, the conceptual lens casts policy for STI as co-produced and embedded. These insights uncover how taken-for-granted global ideas in policy for STI come to reflect particular understandings or assumptions about the social world within and across countries. But also, how in the pursuit of difference nations end up adopting

similar policy solutions given the current state of global competition and tensions. Isomorphic difference untangles 'how these perspectives (on similarity and difference) can be brought into more productive, and more symmetrical, engagement' (Irwin et al. 2021)(p.5). I draw on these authors many contributions but extend them in ways more attentive to the dynamics within and between domestic contexts.

3.1.3 Its methodological guidelines

Isomorphic difference underscores how the local and the global are co-constructed within particular settings. This means that exploring these dynamics is best done symmetrically, drawing on the longstanding STS principle that requires the researcher to use the same explanatory tools to account for both sides in a scientific controversy (Bloor 1976; Law 2017; Callon 1986; Latour 1987; Sismondo 2010). This conceptual lens calls for attentiveness to the ways in which interpretive flexibility is handled by actors, without presuming to know before the argument reaches closure whose arguments are the right ones, epistemically or normatively. Extrapolating to the STI policy realm, symmetry means that both science and policy must be seen as historically situated, culturally embedded practice while also ensuring that they are treated as mutually reinforcing and sometimes competing forms of institutionalized pressure.

Isomorphic difference considers homogenizing and difference-making pressures as relational, i.e., emerging interactively as social outcomes. This means that these elements 'are not pre-configured but open to flexible and shifting interpretations' (Irwin et al. 2021)(p.5). This approach resembles Orlikowski (2009) who suggests that 'a perspective that renounces the categorical presumption of separateness is likely to offer a more useful conceptual lens with which to think about the temporally emergent sociomaterial realities that form and perform contemporary organisations' (p.137). The conceptual lens draws on the following proposition: 'what looks the same can be very different when viewed in context' (Irwin et al. 2021)(p.1), which suggests that the converse must also be true, what appears to be distinctive may upon further scrutiny be a variation on a standard idea or practice. Isomorphic difference brings these propositions together, i.e., it takes a high-level view that facilitates the identification of isomorphic elements and pressures, while symmetrically looking at institutional work and meaning making required to mediate and translate both globalizing and localizing processes. The conceptual lens enables an investigation of such countervailing processes in ways that throw light and shade into the understanding of dynamics within policymaking for STI.

In summary, this dissertation applies and extends the conceptual lens of isomorphic difference to gain a fuller understanding of how global ideas in policy for STI come to be understood in specific contexts.

3.2 Research Method

The dissertation adopts a methodological approach combining two elements. First, detailed empirical analysis of particular policy settings, e.g., the NNI in the United States and national comparisons with China and Denmark. Second, the development and application of a comparative framework, which investigates and compares national policy statements within and

across countries[25]. The two-tier exploration unfolds not only within the individual articles but also across them.

3.2.1 A comparative multi-level approach: pursuing global-local ideas

The multi-level approach in this dissertation required first the identification of a policy setting(s) in which it could be explored. Therefore, the selection of countries constituted an important decision in this process of pursuing global ideas in national contexts. The United States[26] has been a major player in and model for policy for STI worldwide; hence, this context (i.e., its history and inclinations) offered a crucial first setting for making sense of the global ideas that inform policy for STI. For example, models stemming from the United States, like the MBA (Mazza et al. 2005) or nanotechnology programs (Shapira and Youtie 2011), have made their way across the globe. Yet it remains an open question how American models come to adapt in this process. The prioritization of future research 'winners' like nanotechnology in the United States offered the potential to understand how global ideas in policy for STI get localized within the context of high national policy commitment. The *National Nanotechnology Initiative* (NNI) was established in 2001 to coordinate federal policies and activities in this emerging area and to advance a world-class and 'responsible' R&D program. The cumulative NNI investment since fiscal year 2001 totals almost $40.7 billion (NSCT-CoT-NSET 2023)(p.vi). At an event in 2023, the NNI was described by a participant as a 'multiagency and concerted effort (that) propelled the (nanotechnology) field forward and led to many technological developments and a deeper understanding of how our world works'[27]. Major institutions across the decentralized and diverse policy system in the United States provide advice in the development of this national program, including the National Academies of Sciences, Engineering and Medicine; the National Science and Technology Council; and the President's Council of Advisors for Science and Technology. The NNI serves as a particular illustrative means of identifying larger patterns in the United States that can speak about the changing character of policy for STI in the United States.

In operationalizing the comparative approach of policy settings, it became crucial to identify countries for comparison. China has been major investor in STI (Benner 2018a) and its rise makes it an important player in the future direction of global policy for STI. China's transformation has been well documented in United States' national strategies (NASEM 2007; National Science Board 2020) and by relevant policymakers (Lucas 2023). Comparisons between the United States and China also abound in the academic literature, especially in nanotechnology (Dong et al. 2016; Gao et al. 2016; Kostoff 2012; Liu and Guan 2016; Tang and Shapira 2011; Wu et al. 2019). But the rising role of China in science and innovation globally

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[25] One major development marked the research project since its inception. The COVID-19 pandemic significantly affected my travel plans to do field work in the United States. In response, I focused on intensive analysis of key policy documents in China, Denmark and the United States.

[26] I take the position that "American" or the United States policy should not be treated 'as so exceptional as to require separate images, explanations, and approaches' (Amenta et al. 2001)(p.213).

[27] Comment at Nano4Earth workshop (2023, January 24). (https://www.nano.gov/nano4EARTHWorkshop). Raw transcript provided by TV Worldwide (https://tvworldwide.com/events/nanotech/230124/).

and the geopolitical tensions between the United States and China since the late 2010's (Tang et al. 2021; Allison et al. 2022) call for cross-national work that compares their approaches to STI. Denmark, on the other hand, represents a small member of the European Union, but one with rising public investment in STI, as noticed in United States' reports (Task Force on American Innovation 2019)(p.13). The Nordic country offers a valuable example of a country with a strong state betting on large-scale projects to improve its global standing.

Next, the multi-level approach needed a comparative framework to answer the research question and to direct data analysis. The approach relates to the identification of regularities (i.e., curiosity, market and mission rationales) across diverse settings and how they are differentially translated and developed at the national level. The comparative frameworks developed in the articles aim to tease out the global pressures and local contextuality found within and across countries.

The three themes presented in sub-section 3.1.2 provided concrete aspects to follow through empirically, i.e., the what and the how. I test this approach through a series of empirical cases. I divide the cases into two types: within a national context and across countries. Within the national context of the United States, I explore the use of 'diversity,' as well as work on the 'valley of death' within the NNI (Articles 1 and 2 respectively). The two comparative cases include work between the United States and China based on innovation policy instruments to imagine innovation-based futures (Article 3), and a cross-national comparison of ideational familiarities and distinctions in China, Denmark, and the United States (Article 4). These four empirical cases were selected iteratively from questions and insights gained from previous work. Taken together, they provide a rich variety of empirical cases across three countries.

3.2.2 Document studies

The dissertation draws on a primary method of analysis of policy documents looking for patterns across them. I treat policy documents as windows to the way society thinks about global ideas and how policy for STI or nanotechnology can be influenced by global and local processes. Policy documents can be defined as the outcome of a political process in national contexts that can provide a window into what becomes politically acceptable at points in time. Scholars have suggested that documents are not simply written materials, they 'should be brought into the research frame solely as "informants"'(Prior 2008)(p.823). In this sense, 'the study of documents in their social setting—more specifically on how documents are manufactured and how they function rather than simply on what they contain' (Prior 2003)(p.5). Documents also circulate within organizations, creating vertical and horizontal lines of communication. If documents help to create organizations, their work does not stop there: we can also analyze what documents do within organizations, consider where they do (or do not) go, and how they do (or do not) get taken up. The policy document, thus, brings organizations into existence, they crystallize global ideas in policy for STI. In approaching global ideas as empirical objects within policy documents, STS encourages seeing them and their associated social processes and practices, together, as ways of ordering society (Law 2017).

To answer the main research question of how global ideas in policy for STI are understood within specific contexts, I drew mainly on content analysis of specific global ideas, 'diversity' (Article 1), the 'valley of death' (Article 2), 'innovation-based futures' (Article 3), and 'market,' 'curiosity,' and 'mission' rationales in policy for STI (Article 4). The dissertation focuses on the US NNI to unpack local and national dynamics through two in-depth analyses of the United States NNI (Articles 1-2). It also analyzes national policies for STI across countries through comparison between the United States and China (Article 3) and the United States, China, ans Denmark (Article 4). The dissertation calls for ways to operationalize global ideas and their meanings embedded in policy documents within and across countries.

In order to trace ideas within policy for STI, I drew on the empirical themes identified by the seminal paper by Irwin et al. (2021) discussed in Section 3.1.2. The themes provide an analytical entry into the policy documents where I extract emerging relationships and trends in an iterative manner. Content analysis and documentary review are also commonly accepted approaches within the policy studies community (John 2018). I examined 40 main policy documents for Articles 1 and 2 (i.e., NNI annual budgets, strategies, and reviews) and five national strategies for Articles 3 and 4 (i.e., policy documents published by national actors seen as central or significant for the national STI policies)[28]. The period of study is from 1999 to 2023. A 20-year period allowed for comparison of policy for STI over consecutive administrations in the United States, China and Denmark, which enabled a long-term perspective of policymaking. I faced two concerns in choosing the length to study: sampling for maximum variation and ensuring sufficient analytical depth. The chosen period enables to gather enough data for a rich coding process within countries and to achieve a limited comparison across countries.

For Articles 1 and 2, content analysis meant identifying keywords (i.e., diversity[29] valley of death, commercialization, technology transfer, etc.) and tracing them in the corpus, and then extracting the data to analyze the context in which they appear. Article 1 initially applied a deductive approach to understand the meanings of diversity in the NNI. Once the deductive coding was completed, an inductive logic was applied to understand the frames that emerged from the data. Article 2 applied an inductive approach to the corpus to let the textual data guide what the emerging meanings associated with the 'valley of death' were[30].

The difficulty of comparing across countries in policy for STI led to the development of a novel analytical framework in Article 4. The framework, in line with the institutional logics inductive

[28] All policy documents were analyzed in English. For documents from China and Denmark, co-authors who are native speakers or fluent in Mandarin or Danish provided translations of the original documents. Any doubts about the meanings in an English translation, native speakers in our research team would review the original documents to confirm the translation was accurate.

[29] I take a broad approach to 'diversity' in Article 1 and searched for text in the policy documents that described activities that brought together multiple elements for example, interdisciplinarity, transdiciplinarity, convergence, interagency, cross-sectoral, multisectoral, to get a sense of areas in nanotechnology policy where multiple elements were described in the development of nanotechnology.

[30] Article 2 focuses on the meanings around the 'valley of death,' common in the commercialization of nanotechnology and technology transfer literatures. To prepare all corpus to be examined, the phrase 'valley of death' was searched and identified where it was mentioned in the policy documents.

approach (Thornton et al. 2012), identifies three distinct rationales: a curiosity rationale, a market rationale, and a mission rationale. A set of categories around which the rationales differ was also developed. Article 3 builds on this exercise and focuses on further analysis of the corpus identified under the market rationale. Articles 3 and 4 focused on the similarities and differences across countries within each rationale and instrument family, respectively. In Article 3, a typology of policy instruments was developed (drawn from Borrás and Edquist 2019b), which distinguishes between three instrument families. The corpus was analyzed using Thematic Analysis (Nowell et al. 2017) to actively identify, organize, and describe themes found within a data set (Braun and Clarke 2006). A core challenge within the coding process for both articles was to keep rationales and instrument families separate. In both cases, I analyzed the data qualitatively to map and identify the policy elements, core arguments and linguistic tropes characterizing the rationales (Article 4) and instrument families in each country (Article 3).

For all articles, the concept of intercoder reliability was key for completion of data analysis (O'Connor and Joffe 2020) using NVIVO qualitative software. To ensure inter-coder reliability, two different coders separately coded each text. The articles employ a similar coding protocol by taking policy documents to be uploaded into NVIVO. General findings from all articles were presented to key informants from each country to test and corroborate the overall patterns.

3.2.3 Interviewing

I also conducted semi-structured individual interviews in the United States that helped me gain insights into the motivations and the assessments of the actors involved in the NNI and in broader policy for STI in the United States over the 20-year period studied. They provided opportunities for testing the interpretive flexibility of global ideas in nanotechnology policy and 'of what counts…, under what circumstances and in view of what kind of audiences' (Simakova 2012)(p.605).

For the interviews, I developed a list of key questions relating to policy for nanotechnology and national policy for STI. I adjusted the order of topics and questions according to the participant (Bernard 2006; Leech 2002). This flexibility enabled me to follow up on remarks and statements while keeping a series of themes in mind. A total of 25 semi-structured interviews were completed with science advisors in the United States. Interviews took place between 2021-2023. Eighty percent of the interviews (20 in total) were conducted with advisors pertaining to at least one of the three science advisory groups designated by the United States Congress in 2003 to evaluate the NNI over the studied period[31]. The remaining five interviews were with science advisors in other national science advisory bodies in the United States. Selection of the

[31] Eight participants were active advisors in the NNI, and 12 participants were not active at the time of the interview. This blend allowed for an understanding of enduring and emerging ideas and dynamics in the advisory groups.

participants originated from a database[32] of participating advisors I created from the policy documents, which enabled the identification of a selected pool of individuals in the three NNI advisory groups. Additional criteria for interviews included balance for gender and across advisory group. Snowball sampling provided an additional way to identify and recruit more participants. Each interview lasts between 40 to 90 minutes and was partially transcribed for analysis. Following common practices for how to conduct and analyze interviews, all identities of interview participants are kept confidential, and the perspectives of participants were not connected in the analysis or publications to any identifiable personal information.

The data from interviews was relevant for Articles 1 and 2 to enrich the analysis, and in Articles 3 and 4 was used to triangulate the analysis from documents. For all the Articles, they supported identifying global ideas to analyze or their meanings. They also enabled me to get a sense of how the strategies for the NNI or the budget documents that were analyzed came to be written. In line with the content analysis strategy for documents, I extracted text from interviews for 'diversity' and the 'valley of death.' Following this, for Article 1, I deductively analyzed extracts from the transcripts according to the diversity typology developed. In Article 2, I inductively analyzed excerpts related to the 'valley of death' and related terms. Analyzing this data underscored the value of understanding the world as experienced by the participants (Justesen and Mik-Meyer 2012)(p.23). The interviews provided insights and confirmation of the patterns identified in the documents.

3.2.4 Participant Observation

Participant observation provided an alternative method away from the policy documents or individual interviews that enabled me to understand how national policy for STI and nanotechnology were negotiated in real time. The 12 events I observed online from 2019-2022 and the four events I was able to experience in person in 2022-2023 enabled a deeper understanding of national policy for nanotechnology and STI in the United States. During the research period the NNI developed its newest research strategy, and it began the process of refreshing the environmental health and safety (EHS) strategy, which meant that the online events provided a window into how particular ideas get inserted, stay or are negotiated into/out of the policy documents. Events included meetings of the President's Council of Advisors for Science and Technology (PCAST) discussing the NNI and matters relating to American science; workshops to launch quadrennial reviews and to develop strategies on the NNI; and symposiums on the future of American science organized by the United States' National Academies of

[32] I developed a database of science advisors in the NNI from publicly available data in policy documents. The groups involved included those mentioned in sub-section 3.2.1 of this dissertation. The database includes 1,430 entries that describe the position of advisors within a group (e.g., member or leader), the number of years that each member had been part of the advisory group, the organization they represent, and whether they had been listed in one or more NNI reports within their group or were part of another group's report. This database is something that did not exist at the project's outset and something that based on the interview participants does not exist elsewhere. While I did not exploit the possibilities of this database in this dissertation, future research can benefit from it to evaluate, for example, how the advisory groups have changed or evolved over time and their interactions within and across advisory groups.

Sciences, Engineering and Medicine (NASEM). The events also provided different entry points to observe the way policy for STI gets discussed in the context of the United States.

Online versus in-person participant observation had ramifications for the ways in which I gathered and used the data. Online events, which made up the majority of observations, were often live and recorded, which meant I could go back to re-watch them. These events sometimes allowed for questions and answers at the end, which gave a glimpse into less orchestrated aspects of events. The online events proved very useful to get a better sense of the nanotechnology field, to test initial findings and to identify global ideas further. For the multi-day in-person events I attended in 2022-2023, I recorded thoughts on the phone after the event that I then transcribed and used to follow up with attendees during the next day. Something like this was not possible for online events.

3.2.5 Strengths, weaknesses, difficulties, surprises

Strengths: One of the strengths of the isomorphic difference approach is that it reminds me to be sensitive simultaneously to the specific circumstances within which global ideas are worked and how they "sum up" to broader patterns. Isomorphic difference does not artificially separate global ideas within policy from STI from the cultural context in which they take place, hence avoiding essentializing either policy for STI or the national context. The lens does not determine a priori what kind of relationship exists or where the relational dynamics stem from, e.g., the global or the local; the isomorphic or the distinctive. This approach enabled me to consider them as co-evolving, what policy for STI is and the social, political and economic orders in which it is brought to bear.

Interviews and participant observation supported the identification of salient ideas to explore in the policy documents. They also provided opportunities for seeing how advisors and participants in events make sense of global ideas in their local context. The iterative process between the different methods strengthened the analysis and my understanding of how isomorphic difference is enacted.

Weaknesses/Limitations: Despite the data gathered, there are limitations to the analysis. For example, the types of data collected. While historical documentary data can provide accurate information on general trends in policy for nanotechnology and STI, qualitative data in the form of participant observations in live events or meetings would have supplemented more detailed data on the ways that global ideas are negotiated. For example, I was able to observe a number of public discussions about strategies, especially in the context of the NNI, but I did not get access to writing sessions where the strategies were finalized. Unfortunately, the meetings of two of the advisory groups writing policy for nanotechnology are closed for the public and researchers are not welcome. Attendance requests and appeals to access meeting minutes were categorically rejected by the organizers. Therefore, I got a glimpse into the policy room discussions through the content that got discussed publicly and compared that against what made it or not into the policy documents.

Second, the qualitative analysis of policy documents, while rich in detail to trace the global ideas and how they get contextualized nationally, makes it difficult to generalize because they

are nested in a national context. The comparative multi-level approach of this dissertation enabled the tracing of global ideas across national contexts which helped extend beyond specific contexts. Additionally, I did not set up to determine a cause-and-effect relationship or to historically trace the evolution of a particular global idea, which limits the conclusions that can be drawn from the analysis.

Finally, a limitation of the research process and a loss for this particular analysis is that the material collected in the interviews was not used as fully as it could have. The collection of interview data was a time- and resource-intensive process for me as a researcher. As explained in Section 3.2.3, I identified text in the transcriptions that related to the global ideas in Articles 1 and 2, which meant that there was interview data that was not analyzed. This limitation of the current study becomes an opportunity because analyzing that data can ensure that I can get as large a return as possible from such efforts.

I am aware of the methodological limitations of this dissertation and have made my best effort to minimize their influence throughout the research process. I believe that the chosen methods are valid and appropriate to answer the research question of this dissertation.

Difficulties: The pandemic inserted some drawbacks in the research design. For example, it limited the travel and participant observation that was possible during the research process. This change drove me to concentrate on document analysis as a main method. The deductive approach taken in the analysis of Articles 1, 3 and 4 made it difficult to keep categories derived from the literature separate in the empirical material. This initially suggested that existing theories did not fully capture the phenomena in the empirical material. The challenge was compounded by finding empirical material that appeared to belong to more than one category. This was the case in Articles 1, 3 and 4 with the different types of diversity, instruments and rationales. However, these instances where material could be coded in more than one category enabled greater understanding and offered a possibility to clarify what each category meant for further coding and subsequent analysis.

Surprises: While analyzing the data, I questioned whether the study of isomorphic difference in policy for STI could be best observed through document analysis alone, which led to adding supporting methods to enrich the analysis. However, the analysis provided a rich way to see how nations enact isomorphic difference in policy for STI. The documentary analysis method was useful in teasing out elements of global ideas stemming from the literature, but also in revealing new elements in specific national contexts and across countries. For example, in Article 3 soft instruments appeared in the empirical material in ways that revealed how instruments of similar substance travel across instrument families but serve different purposes in policy for STI in the United States, as well as the relevance of normative appeals in both countries. The development of typologies from the literature in Articles 1, 3 and 4 facilitated this process. Nonetheless, the inductive analysis of the policy documents in Article 2 also enabled the tracing of isomorphic difference in the context of policy for nanotechnology. These new elements underscore the value of isomorphic difference as a conceptual lens and its influence on the analysis. Being that isomorphic difference is a novel conceptual lens, these were welcome surprises.

The interviews with science advisors who write policy for nanotechnology and STI at the highest level of the United States governance were surprising. I thought that advisors would perceive people without experience in the particular science as less reputable, making it difficult to gain their respect during interviewing (Brinkmann and Kvale, 2015) [33]. Not being a physical or biological scientist or having a background in nanotechnology made it sometimes difficult to challenge the statements of the interviewees and provoke them in a way that could perhaps lead to new insights. However, my professional background and experience in the US policy landscape and my knowledge of the policy process provided legitimacy during the interviews. In listening to interviews I could notice that the answers from science advisors were very open and direct, and the interviews often extended beyond the planned length, which suggests that the asymmetry between interviewer and interviewee seemed to matter less.

In conclusion, the research method reflects core conceptual concerns about standardizing and contextualizing elements within global ideas in policy for STI and accommodates the analytical focus on the relational nature between these elements in policymaking which derived from the conceptual lens. The comparative multi-level approach to data collection and analysis proved critical in the process of bringing empirics and theory into conversation.

Part II of the dissertation presents the four articles that apply this methodology.

[33] Brinkmann and Kvale (2015) underline that the interviewer should be "knowledgeable about the topic of concern and master the technical language" (p. 171).

PART II. ARTICLES

Article 1 – Framing 'Diversity' in Policy: Isomorphic Difference in the United States National Nanotechnology

Framing 'Diversity' in Policy:

Isomorphic Difference in the United States National Nanotechnology Initiative

Aixa Y. Alemán-Díaz

Abstract

As diversity becomes increasingly relevant for policymakers, it is often framed as a significant way to improve policy for science, technology and innovation (STI). What is meant by diversity, however, varies. At times, debates about diversity suggest that countries or regions are unable to increase their competitiveness, address grand challenges, or close the 'innovation gap' because societies, institutions, or scientific activities are not sufficiently diverse. Other debates suggest that countries must do more to reap the benefits of the diversity that already exists. In observing this general pattern, it is important to question what the global idea of 'diversity' does when it travels within policy for STI and into specific contexts. This article explores how 'diversity' is imagined in the National Nanotechnology Initiative (NNI) in the United States of America (USA). I trace the use of diversity and its various meanings in policy for STI drawing on strategic documents, interviews, and participant observation. I employ the conceptual lens of *isomorphic difference* to explore the interplay between diversity as a global construct and its localized expression(s) in the USA. Using three original frames of diversity - as *add on*, as *change agent* and as *transformation-,* this paper explores diversity as a situated object within a national context. This work raises important questions about the contingency of ideas and national commitments when enacted in policy for STI. This analysis offers new understandings of the translation and interpretation of national and global policy goals into specific technology areas and their implications across STEM fields.

Keywords: diversity; isomorphic difference; policy for STI; National Nanotechnology Initiative; United States of America (USA)

1. Introduction

'Diversity' is becoming an increasingly relevant topic of interest and relevancy for policymakers. It is framed as a significant way to improve the quality of policy for science, technology and innovation (STI). The United Nations (UN) defined diversity in the context of sustainable development as '[t]he extent to which policy encourages diverse forms of STI in order to avoid dependency on a narrow resource base, foster continuous innovation, avoid lock-in to unsustainable pathways, and enhance resilience' (UNCTAD 2019) (p.21). In Europe, the diversity of regions has been highlighted by European Commissioner Elisa Ferreira to make the case for differential investment in the region (Ferreira 2023). In the United States of America (USA), diversity has been pitched as the 'smart' national investment that can restore its lead in the STI world (Jilani 2021); an appeal that depends on increasing 'the number and diversity of Americans engaged in innovation' (Council on Competitiveness 2022). At times, these debates about diversity suggest that countries or regions are unable to increase their competitiveness, address grand challenges, or close the 'innovation gap' because societies, institutions, or scientific activities are not sufficiently diverse. At others, these debates suggest that countries must do more to reap the benefits of the diversity that already exists. In observing this general pattern, it is important to question what the global idea of 'diversity' does when it travels within policy for STI and into specific contexts.

Contemporary debates about the form and direction of policy for STI (Schot and Steinmueller 2018; Stilgoe et al. 2013; Doezema et al. 2019) place an emphasis on diversity by stressing the number of actors, opinions, or 'varieties of cooperation' needed to address societal challenges (Kuhlmann and Rip 2018)(p.449). The growing STI policy literature focusing on diversity employs it as an analytic category to understand teams or innovation capacity (see e.g., Huo et al. 2019; Brunetta et al. 2019; Lo and Li 2018; Østergaard et al. 2011; Milliken and Martins 1996). Very often, these studies use firm-level analysis or patent data and adopt an economics-based reasoning (Berman 2022) that shape their perspective on the topic. Scholars in Science and Technology Studies (STS) have investigated how traveling ideas in STI like 'excellence' and 'frontier research,' and buzzwords like 'public understanding of science' offer simplicity, coherence and widespread appeal within and across countries (Flink and Peter 2018; Bensaude-Vincent 2014). Others within STS have shown that by studying popular models we can gain substantial insight into how countries imagine the purpose of innovation (Pfotenhauer and

Jasanoff 2017). Importantly, these travelling ideas or models shape public discourse, restrict policy options, and legitimize major institutional interventions (Pfotenhauer et al. 2019).

This paper explores the global idea of diversity within the specific context of the National Nanotechnology Initiative (NNI). The NNI was set up in 1999 to organize federal efforts around nanotechnology, investing to date almost 40 billion USD. In keeping with global discussions around diversity, this national program has been described as 'a nexus for the nanotechnology community, convening stakeholders across sectors, scientific disciplines, and application areas to advance nanotechnology R&D for the benefit of the American people' (nano.gov 2023). The NNI offers valuable case to understand how diversity gets constructed and understood in policy for STI and within a particular context.

In line with research on national imaginaries of innovation (Pfotenhauer and Jasanoff 2017), I argue that while diversity is often invoked in policy for nanotechnology, there are multiple understandings of why diversity is needed, what diversity could address, and which social and institutional changes are required to achieve it. An application of the conceptual lens of isomorphic difference (Irwin et al. 2021) shows how of ideas, policies, and practices that travel globally become co-produced in particular settings. This focus draws from an STS tradition of exploring the tensions when knowledge, problems and solutions are portrayed as universal in character as opposed to being local and situated (Irwin et al. 2021; Bowker and Star 2000; Haraway 1988; Jasanoff 2012; Tsing 2005). This paper also adds to the growing body of research that analyzes travelling concepts in policy for STI (Flink and Kaldewey 2018; Flink and Peter 2018), how global ideas and models come to be understood in local contexts (Pfotenhauer and Jasanoff 2017), and the interplay between global and local meanings and enactments (Irwin et al. 2021; Wilk 1995).

The article begins with an introduction to travelling concepts and "diversity" in policy for STI (Section 2), followed by a discussion of isomorphic difference (Section 3) and the methods employed in this analysis (Section 4). The empirical case of the NNI is presented (Section 5) and three frames of diversity are applied to examine what diversity means within the NNI (Section 6). This article concludes with a discussion (Section 7) and outline of the empirical, theoretical and policy implications of this analysis (section 8).

2. Travelling Concepts and Diversity in Policy for STI

2a. Travelling Concepts in Policy for STI

The recurrence of diversity in policies for STI across contexts suggests the emergence of a cross-national pattern and movement of ideas. Scholars have considered this phenomenon through the study of ideas such as 'excellence' and 'frontier research' as *travelling concepts* (Flink and Peter 2018). In his work on the 'linear model of innovation' (Godin 2006) and the 'National Innovation System' (Godin 2017), Godin underscores how these models become shared amongst a variety of users which gives them the 'capacity to travel widely across scholars and domains' (Godin 2015)(p.586). But an idea does not travel by itself: 'it moves because of human curiosity and interest in new things, and it moves by the way of the energy produced by each translation' (Czarniawska 2014) (p.111). Work on trans-boundary environmental issues in STS shows the importance of framing as these problems are defined and underscores how framing is a social and ongoing process (Lidskog et al. 2010)(p.119). Seminal work by Star and Griesemer (1989) explored how material objects (i.e., boundary objects) translated between actors, which emphasized their movements between discreet communities of meaning. Flink and Kaldewey (2018) connected the notion of boundary objects to travelling concepts found in policy for STI given their interpretive flexibility across contexts. Therefore, it is critical to identify how ideas are translated and interpreted in the policy process[1].

Buzzwords have also been shown to provide ideological and homogenizing pressures in policy for STI. These 'fashionable stereotyped phrases' include 'responsible innovation,' 'green technology,' and 'personalized medicine' (Bensaude-Vincent 2014)(p.238). Buzzwords shape the technoscientific landscape by creating 'peaceful collectives of people with competing agendas' and thus becoming a 'trading zone' that allows different stakeholders to communicate (Bensaude-Vincent 2014)(p.250). STS researchers in Austria investigated the concept of 'diversity' in biomedicine as a buzzword in the public health arena. They show that buzzwords steer governance practices and encourage a promissory rhetoric (Penkler et al. 2020)(p.138). Penkler et al.'s study of the adoption of diversity in an obesity prevention program revealed 'the

[1] For example, Berman (2022) studied the emergence and stabilization of what she terms 'economic-style' reasoning in policy circles in the USA. She shows how the institutionalization of this type of argumentation in the USA made it much harder for competing claims to gain political power (Berman 2022)(p.19).

need to translate diversity into a "doable" [2] project with clearly delineated target groups, which promoted a narrow understanding of diversity, one that stands in tension with much more fluid and context-sensitive ways of performing diversity' (Penkler et al. 2020)(p.138-139). Penkler et al. (2020) also show the multiple situated meanings of diversity and their potentially conflicting normative commitments. Buzzwords appear as pejorative[3] elements in policy for STI, which at times also indicate a discrepancy between rhetoric at the policy level and academic practice (Stamm 2019).

Nanotechnology policy has provided a fertile ground for studying how specific ideas become embedded and understood in policy for STI. Simakova (2012), for example, finds that collaboration 'becomes both a measurable entity and a measure in itself providing flow of expectations and resources' in the NNI (p.200). In the context of 'societal concerns,' Fisher (2019) describes how the integration of societal considerations in policy for nanotechnology resulted from lawmakers in the USA trying to govern the uncertainty arising from the potential interaction between 'public attitudes, research directions, and technological trajectories' (p.1138). Anderson and Slade (2013)(p.461), meanwhile, find that legislation to organize nanotechnology across the federal government in the USA served to make the discourse around societal concerns less ambiguous over time[4].

2b. Diversity in policy

Diversity in STI has been conceptualized as facilitating exposure to different perspectives (Milliken and Martins 1996), often focusing on gender, race or ethnic origin differences in teams. A common assumption, when considering diversity in this way, is that diversity also implies heterogeneity in information, knowledge and cognitive approaches (Hong and Page 2001; Alesina and La Ferrara 2005; Alesina et al. 2016). Yet STI scholars in Germany found that only combinations 'associated with differences in cognitive approaches and knowledge' matter for innovation (Brixy et al. 2020)(p.10). Smith-Doerr et al. (2017)(p.139) argue that by

[2] The notion of 'doable' science stems from STS work that shows how scientific ideas become standardized in recognizable packages of theory or technologies (see Fujimura 1987; Fujimura 1988; Fujimura 1992).
[3] For example, David Berube (2006) set out to debunk the nanotechnology 'buzz' in policy circles. Also, in her account of 'public understanding of science,' Bensaude-Vincent (2014)(p.244) points out that the phrase originates in the United States and in Europe from STI policy bodies, revealing the irony the that 'while the signified emphasised the need to break away from top-down communication, the signifier itself travelled from the top down'.
[4] They find that after the 2003 Act the discourse about societal concerns in nanotechnology narrowed and focused on specific concerns, primarily 'social justice and responsibility, scientific progress and knowledge advancement, medicine and public health, and economic competitiveness and commerce' (Anderson and Slade 2013)(p.459).

making the distinction between representational diversity and full integration of 'minority' scientists[5], they were able to identify the conditions under which diversity leads to innovation, i.e., 'conditions of equitable and integrated work environments'.

The STS and feminist traditions provide a particularly useful entry point to this discussion given their mutual interest in contextualized forms of meaning-making and institutional practices (Pfotenhauer and Jasanoff 2017). STS scholars have shown how ideas of diversity are deeply situated but also how ideas travel between contexts. A study of representations of ethnicity and diversity in human genome projects by Burton (2018) found that in Iran and Turkey these schemes adopted logics of international genome projects (e.g., the USA Human Genome Project) to justify their local research. However, in these countries the 'assumptions about and representations of ethnicity and diversity are deeply inflected by local histories of scientific development and nationalist politics' (Burton 2018)(p.762). These national and cross-national understandings of diversity can also be shaped by particular technologies and those who develop them[6]. Fujimura and Rajagopalan (2011) show how 'new technologies provide opportunities to change some of our institutional and cultural forms and frames around notions of difference and similarity' (Fujimura and Rajagopalan 2011)(p.5). Scholars in the feminist traditions have also offered powerful critiques of the language of diversity in policy (Ahmed 2007a). For example, research in the United Kingdom investigated how the Race Relations Amendment Act of 2000 led to a situation where '…documents are taken up as signs of good performance, as expressions of commitment and as descriptions of organizations as "being" diverse' (Ahmed 2007a)(p.590). Gushke (2023)(p.94) has shown that all universities in Denmark officially commit to the ideal of diversity, but that such work is rendered non-performative, meaning that their commitment provides a distraction from 'actual' diversity work.

Finally, turning explicitly to the relationship between diversity and nanotechnology, Savath and Brainard (2013) studied scientists at federally funded nanotechnology facilities in the USA finding gender differences in how they considered down-stream risks of their work[7]. A separate study of how different disciplinary approaches come together underscored the impact of 'federal policies, university cultures and local organizational structures' on the practice of

[5] The authors refer to women and people of color (Smith-Doerr et al. 2017)(p.140).
[6] It also serves as reminder that the positionality of individual researchers/technologists shape their questions, theories and methods they develop and use (Haraway 1988; Harding 1986; Schiebinger 2001, 2021).
[7] The scientists were located at centers affiliated with the United States' National Nanotechnology Infrastructure Network (NNIN).

interdisciplinarity (Ku and Zehr 2022)(p.765). This work highlights the need for infrastructural support to bridge collaborative tensions amongst disciplines in the conduct of nanotechnology.

3. Isomorphic Difference

The conceptual lens of isomorphic difference (Irwin et al. 2021) provides a way of showing how different constructs of diversity are enacted and how to situate them within specific contexts. This approach draws upon Wilk's (1995) 'global systems of common difference,' which posits that global phenomena must be made into a local practice, while local practice becomes increasingly uniform. Consequently, it is important to focus on the interplay between a global idea and its local meanings. In this study, the application of isomorphic difference allows one to analyze the dialectic or the tensions between familiarity and difference-making elements present in policy for STI (Kirkegaard et al. Under Review)(p.8). Isomorphic difference disentangles how what looks global may often reflect deep-rooted traditions and local interpretations (Flink and Kaldewey 2018; Flink and Peter 2018; Godin 2017; Pfotenhauer and Jasanoff 2017), but also the manner in which 'local' perspectives can be bound up with larger global discussions. This conceptual lens approaches the coproduction of diversity, as a situated object of research that unfolds in specific settings. This co-productionist perspective (Jasanoff 2004) enables the consideration of how diversity emerges in specific contexts and co-evolves with the social, political and economic orders in which it is developed and enacted.

4. Research methods

To explore how diversity comes to be understood and enacted in the NNI, this paper adopts a two-step research design: (1) the deductive coding of diversity based on a defined framework and (2) the inductive analysis of coded data to understand how diversity come to be framed in practice. The analysis draws on qualitative research applying discourse (Fairclough 2013) and interpretive policy analysis (Fischer and Forester 1993; Yanow 2007 and 2000).

A typology of diversity was developed combining insights from the management and STI literatures (Harrison and Klein 2007; Stirling 2007) – (see online supplement 1)[8]. An inductive

[8] This coding framework draws upon three global constructs for defining diversity: variety, separation, and disparity. These constructs describe differences in kind, position, and resources within organizations, respectively. Stirling (2007) shares two constructs with Harrison and Klein (2007), i.e., variety and disparity. Stirling's diversity typology in STI includes an additional construct of balance defined as 'how much of each type of thing do we have?' (Stirling 2007)(p.709). The construct of balance as defined by Stirling suggests quantification of diversity elements seldom found in policy documents. Therefore, in the typology developed for this research balance was not included.

analytical step was taken next to explore the corpus from policy documents for nanotechnology in the USA using thematic analysis (Nowell et al. 2017). This step enabled the development of three frames of diversity - *add-on*, *change agent*, and *transformation*- that emerged from this data (discussed in Section 6).

Document analysis was employed in conjunction with semi-structured interviews and participant observations. Text that directly addressed diversity was extracted from policy documents and transcriptions from interviews and events. Additionally, texts that referred to elements of diversity in the NNI, such as multiple sectors, scientific disciplines and application areas were also identified and extracted. The dataset was analyzed using NVivo 1.6.

Publicly available policy documents issued as part of the 21st Century Nanotechnology Research and Development Act (Public Law 108-153)(US Congress 2003)(herein 'the 2003 Act') were analyzed. Data consists of 40 policy documents produced between 1999-2023. The documents include the 2003 Act, eight strategies, 20 budget documents, and 12 program reviews (see online supplement 2). These policy documents have been used by the NNI to modify the initiative for the past 20 years, as established by the 2003 Act.

A total of 20 semi-structured interviews were conducted with policymakers linked to the NNI who authored the analyzed policy documents. Of the interviewees, eight participants were active in the NNI and 12 were no longer part of the NNI. Interviews were conducted in English on Zoom, given the COVID pandemic. This data includes both audio recordings and videos. The audio was partially transcribed.

Data collection for participant observation began in August 2019 with a hybrid public workshop on the future of the NNI. The workshop focused on gathering stakeholder perspectives on the key elements required for a thriving nanotechnology enterprise in the USA 'in the next 15 years' (nano.gov 2019). Data were collected during 12 public workshops and meetings on the NNI (see online supplement 3) lasting between one and seven hours, mostly virtual events or archived webcasts.

5. The National Nanotechnology Initiative (NNI)

The NNI was set up to bring together multiple actors, technologies, scientific disciplines, sectors and industries to develop nanotechnology in the USA. For further academic accounts of the development of NNI see for example (Roco 2003a, 2011; McCray 2005; Grodal 2007;

Motoyama et al. 2011; Stinnett 2012; Simakova 2012; Savath and Brainard 2013; Jung and Lee 2014; Dong et al. 2016; Merzbacher 2020).

Anticipating an economic and technological bounty from previous USA-sponsored research at the nano-level, President Clinton announced the formation of the NNI in 2000 (Lane and Kalil, 2005; Huang et al. 2005; McCray 2005; Roco 2011)[9]. The American[10] government was an early mover in promoting 'the nanotechnology label' (Grodal 2007). A confluence of long-term research and planning across the federal government, an emerging international definition of nanotechnology, and the promise of commercial reward stimulated the emergence of the NNI (IWGNET 1999; Roco 2011). The NNI's first program evaluation (NASEM 2002) led to the NNI being enshrined into law in 2003. Roco (2011)(p.428) claims that 'over 60 countries established programs at a national level between 2001 and 2004'[11]. The breadth of sectors, missions, and actors involved in the development of nanotechnology required periodic evaluation, organized investing, and coordination across the federal government by special advisory groups in the 2003 Act[12]. The NNI's most recent annual budget request was almost $2 billion alone (NSTC-CoT-NSET 2023).

The NNI marked an unprecedented effort in the USA to coordinate and invest collectively in a specific technological area (Merzbacher, 2020)[13]. As established in the 2003 Act, the initiative determines and periodically reviews program goals that guide the NNI's work (see online

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[9] Participants confirmed this during interviews conducted December 1-2, 2021; January 26, 2022; and February 17, 2023.

[10] 'American' refers to the people or institutions of the USA.

[11] The NNI's establishment led to many countries adopting similar programs, including 'Japan (April 2001), Korea (July 2001), the European Community (March 2002), Germany (May 2002), China (2002), and Taiwan (September 2002)' (Roco 2011)(p.428). Roco insists that these programs were partially inspired or motivated by the NNI. See also Shapira and Wang (2010).

[12] Strategies and budget documents were produced by the Nanoscale Science, Engineering, and Technology Subcommittee, a subcommittee of the National Science and Technology Council. The President's Council of Advisors for Science and Technology (PCAST) became the 'National Nanotechnology Advisory Panel' in 2004 (Bush 2004) and it produced six NNI reviews. Another PCAST review is expected in 2023. It should be noted that Biden's PCAST has been described as the 'most diverse' in the history of the United States (PCAST Briefing Room 2021). The National Academies of Sciences, Engineering and Medicine produced six reviews on the NNI. These American advisory groups include NNI participating agencies within the federal government, a group of 'outside' STI experts that advice the President of the United States, and an ad hoc committee of experts in nanotechnology, respectively.

[13] Some have argued that the Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act of 2022 ('the CHIPS Act' from herein) marked another watershed moment in the United States policy for STI. The CHIPS Act has been described as 'industrial strategy' (whitehouse.gov 2022a) with about $52 billion in subsidies allocated to support chip manufacturing. Scholars have documented the aversion of policymakers in the United States to call industrial policy (Diebold 2019; Motoyama et al. 2011) what scholars like Mazzucato (2015) identify as state-led interventions in STI. One reason for their aversion is that 'such goal-driven industrial policies are supposed to be the stuff of Soviet five-year plans, not market-based democracies' (Sarewitz 2016)(p.11).

supplement 4). The NNI goals include a commitment to advance fundamental research, investigate the societal implications, develop relevant workforce and infrastructure, and invest in technology transfer of nanotechnology (Bennet and Sarewitz 2006; Roco 2011). The initiative brings together a nanotechnology community that includes 'diverse actors, including government laboratories, universities and other nonprofit research institutions, large businesses, and small startups…also an array of venture capitalists and other intermediaries that has emerged to help facilitate capital and knowledge flows among these actors' (Ouellette 2015)(p.179). This emphasis on a diversity of elements has been a crucial feature of the NNI. The NNI has been distinctive because of its explicit mission to integrate societal concerns into nanotechnology research and development (R&D) and encouragement of citizen input, drawing on experiences from the Human Genome Project in the USA (Shapira et al. 2010; Hilgartner 2018).

The pressure on policymakers in the USA to ensure leadership in the global technological race has led the country to also utilize diversity as a way to ensure equal opportunity to participate, contribute and benefit from STI for all 'Americans' (whitehouse.gov 2021)(min.14:06-43). The Executive Office of the USA President organized a national challenge[14] in October 2021 to gather ideas, insights, and recommendations from the public in this area (NSTC-CoT-NSET 2023)(p.61). This line of reasoning makes diversity necessary to produce the best science, claims that without it is impossible to compete with countries like China[15], and aims to redress structural inequities that have kept many from joining the STEMM[16] enterprise (whitehouse.gov 2022b). These efforts encountered a setback in 2023 when the USA Supreme Court issued a ruling to restrict affirmative action at colleges and universities. The National Academies of Sciences, Engineering and Medicine (NASEM) responded to the ruling by strongly endorsing the national narrative about need and benefits of diversity for science and innovation (NASEM 2023a). It is within this context that the NNI becomes a valuable case to explore how a national STI program adopts and adapts diversity.

[14] Advancing Equity in Science and Technology Ideation Challenge – see: https://www.challenge.gov/?challenge=ostp-time-is-now&tab=rules

[15] Policymakers in the United States frame the discussion about competition with China as a numbers game (based on stark population differences) – i.e., without engaging every American to consider the STI enterprise, there will not be any chance at getting ahead. Scholars have pointed, however, that China's population has peaked and it is rapidly aging (Allison et al. 2022)(p.40).

[16] STEMM refers to the disciplines of for science, technology, engineering, math and medicine.

6. Framing Diversity in USA Nanotechnology Policy

This study applies three frames to the investigation of diversity in the NNI. The first frame -*add-on*- poses that diversity materializes as an assemblage of necessary ingredients or listed elements, like an inventory. A second frame defines diversity as a *change agent* expected to blur boundaries between the multiple disciplines and sectors necessary to develop nanotechnology's promise. The third frame considers diversity in policy for nanotechnology as *transformation* to suggest that it is necessary to achieve programmatic goals in the NNI especially around responsible development and a diverse workforce. Table 1 summarizes the three frames of diversity in the NNI.

Table 1. Proposed Frames found in the NNI Policy Documents

Frames	**Definition**	**Illustrative Example**
Add-on	Listed elements are assumed to provide necessary diversity	NNI Programmatic requirements Expert advice
Change Agent	Anticipates positive organizational outcomes from expected diversity	Multidisciplinarity Convergence
Transformation	Elicits change as part of a larger process of social and technological transformation	Workforce participation Responsible development

6.1 Diversity as an *Add-on*

Diversity as an *add-on* occurs when different elements are listed in policy documents to showcase the kind of diversity deemed desirable. Examples of these elements catalogue specific programmatic approaches and expert advisors in the NNI. Diversity as an *add-on* serves to highlight elements that in the local setting are perceived as legitimate.

From the early days of the NNI, policy documents employed the term 'diversity' when referring to the variety 'of talent and approaches' needed to do nanotechnology (IWGNET 1999)(p.54). The need for work across sectors, agencies and disciplines also appeared among the requirements established by the 2003 Act. The requirements included different forms of collaborative activities that point to the diversity necessary in the NNI: interagency, interdisciplinary, and cross-sectoral work. For example, the 2003 Act required 'interagency'

budgets, coordination and projects; 'interdisciplinary' research and development; as well as 'management and coordination across agencies…disciplines' and sectors, specifically 'academic, industry, State and local government (including State and regional nanotechnology programs), and other appropriate groups' (US Congress 2003). These program requirements appear as listed elements in the formation of the NNI, which suggests diversity as *add-ons* that must be included to achieve the promise of nanotechnology. The list identifies the ingredients necessary to develop an intersectoral initiative, like the NNI, without further commentary on their enactment or practice.

The NNI strategic plans of 2007, 2011, and 2014 (NSTC-CoT-NSET 2007a, 2011a, 2014) illustrate another area where diversity emerges as an *add-on* in nanotechnology policy in the expert groups that advice the NNI. The following statement, an exemplar of what can be found in these documents, shows the value that the NNI places on this advice to keep the program running over time:

> 'Review by outside advisory groups is vital to keeping NNI efforts focused and balanced…the NNI has benefited from their diverse inputs into the planning and evaluation process. The resulting recommendations have led to specific actions and focused attention in areas that were highlighted by both groups...'(NSTC-CoT-NSET 2007b)(p.38-39).

The advisory groups issue reviews and reports on the program, and within these texts they describe themselves in ways that highlight their 'diverse' membership. Diversity becomes an *add-on* to the group's value, a self-defined attribute that can be found across the analyzed documents. For example, this statement appears, with slight changes in wording, in every one of the NASEM reports (NASEM 2002, 2006, 2009, 2013, 2016, and 2020)

> 'This report has been reviewed by individuals chosen for their diverse perspectives and technical expertise.'

In general, the NNI documents do not reflect on the diversity that these advisory groups feature beyond these words, which suggests that their proclaimed diversity is taken for granted. However, the NASEM's internal policy defines 'diversity,' as consideration of:

> 'the committee membership with respect to, for example, race and ethnic origin, gender, sexual orientation, age, employment sector experience, and geographic location. The membership of the committee should reflect the diversity of the communities of scientists, engineers, health professionals and other experts from which the committee members are drawn, and of the communities that have a stake in the outcome of the committee's work' (NASEM 2021)(p.2).

In this case the NASEM makes explicit claims about the list of elements - race and ethnic origin, gender, sexual orientation, age, employment sector experience, geographic location- that should be taken into account in its membership. But in the NNI documents this type of detail does not feature as an explanation of the advisory groups' claimed diversity.

Diversity in these examples features as variety in the vital ingredients necessary in programmatic nanotechnology policy. This variety is simply stated in policy documents and listed as inventory, either in existence or assumed. These examples show that when the frame of diversity as an *add-on* is applied, diversity serves as a closure mechanism (Bijker et al. 1989). This interpretation suggests that diversity in the NNI documents establishes an attribute in policy for nanotechnology without further specifying what diversity means or the kind of diversity that for example, NNI advisors bring to the table.

6.2 'Diversity' as a *Change Agent*

This study finds that NNI policy documents also describe diversity as a *change agent*, which assigns positive outcomes to diversity that reflect local values. Multidisciplinarity and convergence will be developed as two examples of this framing next.

The description of the National Nanotechnology Coordination Office's (NNCO) official crest (Figure 1), which features on the initiative's website, shows the particular emphasis placed upon the variety that makes up the NNI. For instance, Figure 1 includes 'twenty billets (that) symbolize the various elements, disciplines, ideas and Federal agencies that converge and are coordinated by the National Nanotechnology Coordination Office' (nano.gov 2023). This representation offers diversity as being core to the NNI, also apparent in the accompanying banner in Figure 1: 'CONVENING, CONVERGING, CONNECTING.' These words assume that engineers and scientists involved in the NNI will navigate an interdisciplinary, multisectoral landscape when conducting nanotechnology research (see e.g., Nicolau 2004; Islam and Miyazaki 2009, 2010). In this sense, the frame of diversity as a *change agent* offers diversity as catalyst for change in the NNI.

Figure 1. Seal of the National Nanotechnology Coordination Office (NNCO)[17]

'*The NNI serves as a nexus for the nanotechnology community, convening stakeholders across sectors, scientific disciplines, and application areas to advance nanotechnology R&D for the benefit of the American people. The points converging in the center of the logo conceptually represent the tools that enable nanotechnology research and development, and symbolize the power of the NNI to bring together diverse communities in pursuit of shared goals and priorities.* (nano.gov 2023)

Documents underscore that nanoscience spans 'the boundaries of traditional disciplines, and facilitating collaboration across these boundaries is essential' (NSTC-CoT-NSET 2021)(p.1). Diversity becomes a positive attribute that needs nurturing in the local context. The NNI budget mentions specific disciplines in this blend:

> 'Nanotechnology is a multidisciplinary field, requiring the engagement of scientists in disciplines as diverse as materials science, physics, biology, chemistry, engineering, toxicology, clinical practice, social science, and risk assessment, as well as leaders in industry, public health advocacy, healthcare, and the general public.' (NSTC-CoT-NSET 2011b)(p.xiv)

The multidisciplinarity mentioned in the NNI documents becomes a defining attribute of nanotechnology. But early policy documents noted that 'although NSF explicitly included societal implications in its NNI solicitations, nothing came of those efforts' despite the 'compelling reasons for including this kind of work within NNI' (NASEM 2002)(p.34). These observations challenge the inclusion of 'social science projects focused on nano-related societal implications' (NASEM 2002)(p.34) against the claimed multidisciplinarity that the NNI promotes. Multidisciplinarity within the NNI was also dispelled in 2023 when an NNI advisor stated:

> 'Within NSF we have a lot of multi and interdisciplinary programs, and siloed programs which also are a little bit at odds with that…When I get proposals at least, I encourage my reviewers to think about making sure that that PI is thinking holistically across, but that's difficult if you're not trained that way.'[18]

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[17] Source for Figure 1: (nano.gov 2023)

[18] Session: An Integrated Approach. In Public Meeting: Refreshing the NNI's Environmental, Health, and Safety Research Strategy nano.gov (June 1, 2023). [Unofficial Transcript].

These accounts are at odds with a view of nanotechnology as involving numerous disciplines collaborating or blurring with each other. They also suggest that the NNI is pushing against the organization of policy for STI, not just at universities or research centers. Accordingly, this type of diversity in NNI policy documents is interpreted as a *change agent* that facilitates the blurring of boundaries across diverse disciplines and sectors, even in the presence of obstacles.

Furthermore, diversity can also be a *change agent* that can 'break down barriers between the lab and the marketplace', an understanding presented as a 'real' benefit for participants as shown in the following quote:

> 'Collaborative nanotechnology research at our institute unites faculty members from 32 departments across four schools at Northwestern [University]. This diversity of training and perspective does more than broaden the scope of our research. It enables us to identify, understand and address big problems—and it helps us break down barriers between the lab and the marketplace' (Mirkin 2021).

In addition, early NNI implementation documents demonstrate an interest in 'funding of complementary/synergistic fields of research that are critical for the advancement of the nanoscience and engineering field' (NSTC-CoT-NSET 2000)(p.34). The documents often state the existence of these complementary fields, but fail to list which disciplines are involved, for example:

> 'The NNI has also created interdisciplinary linkages that otherwise are likely not to have formed. These new interconnections between fields and between individual scientists and engineers from a diverse range of fields will be a lasting legacy of the initiative. (NASEM 2006)(p.6)

This diversity of disciplines, that is claimed to be so central to the NNI, relies on notions of "convergence research," a type of research advocated by long-time NNI advisors –see e.g., Roco 2003a-b, 2008, 2020; Bainbridge and Roco 2016). Interdisciplinary and convergent research appear as foundational to the frame of diversity as a *change-agent* because they assume that the combined effect of these disciplines will be greater than the sum of their separate contributions in the research enterprise. The 2021 NNI strategy expands upon this point:

> 'The concepts of interdisciplinarity and convergence were novel in the early days of the NNI. The natural focus of nanoscience across the boundaries of disciplines necessitated different fields working together, leading to the vibrant interdisciplinary nanotechnology community that exists today, sometimes referred to as the NNI's "superpower."' (NSTC-CoT-NSET 2021)(p.4)

This statement illustrates a core separation between disciplines that impedes the development of nanotechnology. Nonetheless, when the frame of diversity as a *change agent* is applied, it

underscores the blurring of organizational boundaries, across disciplines and sectors, despite evidence to the contrary.

6.3 Diversity as *Transformation*

Diversity as *transformation* imagines change in policy for nanotechnology as part of a larger process of social and technological transformation. In the NNI, this frame appears in the context of a diverse workforce and responsible development.

In 2021, an NNI strategy defined diversity as stemming from 'differences in race, ethnicity, geographic location, gender, culture, sexual orientation, disability status, socioeconomic status, religion, and other factors' (NSTC-CoT-NSET 2021)(p.5). When the NNI defines diversity in this way, it accounts for demographic differences in its people that initially suggest a variety of elements, yet explicitly includes elements that indicate disparity amongst them. In particular, the 2021 strategy connects diversity and workforce:

> 'Only when the STEM workforce reflects the diversity of the country will the United States benefit from the full breadth of ideas across America' (NSTC-CoT-NSET 2021)(p.5).

Accompanying this quote is a relative new photo of the 2019 cohort of students in the National Nanotechnology Coordinated Infrastructure (NNCI)[19] Research Experiences for Undergraduates (NNCI-REU)[20]. In recent years, similar photos, like the one described, are found in budget and strategy documents. These photos can be interpreted to showcase the growing presence of diverse groups like women, race-ethnic "minorities" and others that now make up the nanotechnology space. In this paper, the photos and their ties to diverse groups of people in nanotechnology point to the aspired social changes, or what I call diversity as *transformation,* in nanotechnology policy.

Diversity in policy for nanotechnology echoes national policy commitments described in Section 4 that point to 'the fair representation of all different aspects of human characteristics, identities, and perspectives in the composition of a group' (NASEM 2023b)(p. AppD2). A

[19] The NNCI was launched in 2015 and is the latest of a series of programs led by the United States National Science Foundation, which has supported a network of user facilities in nanotechnology for the past forty years. Website: https://nnci.net/about-nnci

[20] The NNCI REU program typically consist of an intensive 10 week summer research experience at a university. The NNCI does not offer a network-wide REU program, but many of the NNCI sites conduct their own separate programs. Website: https://nnci.net/research-experience-undergraduates

participant echoed the framing of diversity as *transformation* by noting that 'in more recent decades, much more attention (has been) given, I think, to diversity, inclusiveness…leaving out of important parts of society, women, minorities, various kind of United States'[21]. A review of the NNI pointed specifically to a lack of gender and ethnic diversity in STI as the driver of worker deficits in the USA:

> 'Finding 4.4: Low diversity [by gender and ethnicity] across many NNI–relevant disciplines results in yet fewer STEM–educated workers than would otherwise be present in the United States.' (NASEM 2020)(p.104)

In the context of global competition, and specifically for the NNI, another participant who has been a long-time advisor in policy for STI in the USA expressed that 'if you're going to compete with a country with over a billion in population, well, you need every, the capabilities of every person. And we are failing to develop the capabilities of a large fraction of the population'[22]. A different participant who has been linked to the NNI since its early days expressed how diversity comes to be necessary for the future of science, not because it addresses a diagnosed disparity but because that is the only way it can get public funding and support:

> 'science and technology cannot expect to be funded significantly by the public, unless it connects intimately with the society. So the reason you want diversity is not because of some fairness, unfairness, you can argue about all of that, but rather you must address all of society'[23]

These understandings of diversity draw on identifying individuals who have been systematically excluded and aim to facilitate the participation of society at large as part of a larger process of social and technological *transformation* in the USA. In this sense, the term diversity is not only a matter of increasing the variety of people that enter and stay in the federal workforce, but for agencies like the Environmental Protection Agency (EPA), diversity can also address disparities in the impact of environmental policies. At a meeting of the President's Council of Advisors (PCAST) discussing the NNI, a representative from the EPA made the following statement:

> 'Rodan commented that the Biden administration's emphasis on increasing workforce diversity will help EPA do a better job of engaging with the most environmentally impacted communities, including disadvantaged and disenfranchised communities, and supporting environmental justice…' (PCAST 2021)(p.10)

[21] Interview 2 Dec 2021; 15:35.
[22] Interview 3 March 2022; 46:03-42.
[23] Interview 21 January 2022; 19:37.

This statement highlights diversity as *transformation* given the structural changes expected from the changing makeup of the federal workforce and what this means as these workers are called upon for environmental justice calls and redress for those most negatively impacted from it.

Furthermore, diversity as *transformation* also appears in the context of making nanotechnology accountable to society. This expectation for science to impact society was 'rendered equivalent to engaging multiple agencies who could take innovation out from universities and make it work for the public good' (Simakova and Coenen 2013)(p.249). In nanotechnology, this is coined under the banner of the responsible development (i.e., Goal 5 of 2021 NNI Strategy). The NNI narrative regarding the responsible development of nanotechnology points to 'a variety of publics, stakeholders, and researchers' needed to be responsive to societal values and concerns (Radatz et al. 2019)(p.853). The 2021 NNI Strategy further states:

> 'Just as scientific understanding of nanomaterials has deepened and matured, the understanding of responsible development also has evolved…Responsible development further includes consideration of ethical, legal, and societal implications (ELSI) as well as a new emphasis on inclusion, diversity, equity, and access (IDEA) and the responsible conduct of research.' (NSTC-CoT-NSET 2021)(p.4)

The responsible conduct of nanotechnology experienced an expansion of its mandate, that can also be found in the NNI Budget request issued in Fiscal Year 2022:

> 'This PCA [program component area] includes ethical, legal, and societal implications, issues of research integrity and security, and embraces an emphasis on inclusion, diversity, equity, and access (IDEA) and the responsible conduct of research.' (NSTC-CoT-NSET 2023)(p.4)

The extension of responsible development, namely to include diversity, increased the NNI programmatic commitments in this area. The inclusion of diversity in this context contributes to the understanding of diversity as *transformation* because it furthers the societal and technological aspirations placed on the responsible development of nanotechnology. But responsible development in the NNI already included ELSI and environmental health and safety (EHS) (NSTC-CoT-NSET 2022)(p.18). The budget for this program area represented only about 3% of the 2021 federal investments in nanotechnology (NSTC-CoT-NSET 2023)(p.4). This contrasts also to data on the early years of the NNI that indicated significant activity around the societal implications of nanotechnology (Bennett and Sarewitz 2006) and suggested that their inclusion was considered groundbreaking (Fisher 2019; Hilgartner 2018; Anderson and Slade 2013). These competing claims signal a significant rupture within the responsible development

of nanotechnology, to the disadvantage of the newly integrated diversity concerns. In the words of a senior NNI advisor, this drift happened over time:

> '…[there] was a kind of separation maybe, in time, between nano ELSI main[ly] by NSF and NIH and nano EHS done by regulatory [agencies]… And I like to underline that now [i.e., under the efforts to update of the 2011 EHS strategy] it's a time to bring together the nano EHS and nano ELSI…'[24]

In 2023, when the NNI met again, to update its environmental, health and safety (EHS) strategy, which 'aims to ensure the responsible development of nanotechnology' (NSTC-CoT-NSET 2011b), diversity was only incidentally discussed. While the frame of diversity as *transformation* appears strongly in the context of the responsible development of nanotechnology, in current discussions diversity has taken a back seat, signaling a break between NNI narratives and practice around diversity that threaten its ability to deliver on the expected promises.

7. Discussion

The conceptual lens of *isomorphic difference* enabled the tracing of the global construct of diversity in policy for STI in the USA, specifically in the NNI. The previous sections showed diversity as a travelling concept (Flink and Peter 2018) in the NNI, one that moves between distinct contexts layering multiple understandings of what diversity can do for nanotechnology in the USA. The three frames presented as original contributions –*add-on, change agent, and transformation*- show how a global idea of diversity gets operationalized in the NNI. The first frame shows diversity akin to an inventory that is assumed to exist. The second frame assigns positive organizational outcomes to diversity. Hence, the frame of diversity as *change agent* challenges existing institutional arrangements at a research level, but also in policy and in the development nanotechnology. Lastly, the third frame suggests that diversity is part of a larger social and technological transformation in STI. The frame of diversity as *transformation* directs attention to the diverse federal workforce and the responsible development of nanotechnology to benefit society. These frames align with understandings of diversity in the management (Harrison and Klein 2007) and STI (Stirling 2007) literatures, which suggests that isomorphic understandings of diversity can also be found in policy for nanotechnology in the USA.

[24] Session: Risk Assessment and Risk Management Methods, and Informatics and Modeling Research Areas. In Public Meeting: Refreshing the NNI's Environmental, Health, and Safety Research Strategy nano.gov (May 31, 2023). [Unofficial Transcript].

The coexistence and layering of the frames of diversity features as another main finding from this study. It was clear that all these meanings co-exist and that one frame does not replace the other. Layering describes the introduction of new elements to pre-existing ones (Schickler 2001; Thelen 2003; Mahoney and Thelen 2010; Kern and Howlett 2009; Rayner et al. 2017), suggesting a process of institutional change. This work aligns with STS scholarship that portrays framing of transnational issues as social and ongoing processes (Lidskog et al. 2010). The way in which the NNI develops its budgets, reviews and strategies facilitates these social processes in the USA and amongst groups and organizations interested in nanotechnology policy. The frames of diversity found in the NNI do not build on each other, rather they appear as new levels on top of pre-existing understandings of diversity and what it can achieve. For example, the first frame -diversity as *add-on*- can be found throughout the studied period and gets repeated in NNI budget documents, strategies, and reviews. Whereas the third frame -diversity as *transformation*- appears only recently in NNI budget reviews. This frame grows over time in line with institutional changes advanced by the Biden Administration. Diversity gets formally inserted in the 2021 NNI strategy, and if enacted, it can lead to substantial changes in the conduct of nanotechnology and policy. Unlike the first frame, which assumes diversity as a constant in policy for nanotechnology, the third frame takes an approach of 'gradual layering' that introduces it over time and supposes an institutional ability to adapt. This strategy found in the NNI aligns with research in Denmark that explains changes over time in the public research funding system (Aagaard 2017)(p.274). The frames identified in the NNI suggest are not in contradiction with each other or imply incoherence in policy for nanotechnology in the USA. Instead, the use of the three frames points to how layering emphasizes a renegotiation of global understandings of diversity, while certain institutional elements remain intact. Overall, the use of the three frames expands how to understand the global idea of diversity in policy for STI.

The analysis also demonstrates that the global idea of diversity gets localized in nanotechnology policy to promote the 'cross-fertilization between the different disciplines' (Bensaude-Vincent and Simon 2019)(p.8) and to imply a blurring across distinct subjects and sectors – the 'NNI's "superpower"' (NSTC-CoT-NSET 2021)(p.4). The blurring challenges the current institutional setup of separate, independent disciplines at universities and research centers. The analysis shows that this contextual understanding also stands against the existing organization of key research agencies in the federal government. Elements of convergence and synergy (Bainbridge and Roco 2016; Roco 2003a-b) facilitate a framing of diversity as the *change agent* necessary

for nanotechnology's development. Yet research on nanotechnology groups in the European Research Area has shown that collaborative diversity, though assumed and encouraged in the context of nanotechnology, requires institutional and managerial capabilities to realize the benefits of collaborative research (Pandza et al. 2011). Bringing together diverse perspectives, approaches, and scientific paradigms effectively requires intentional practices across domains of expertise (Bruns 2013). Therefore, supportive institutional environments that facilitate this type of convergence, even amongst disciplines or sectors that may work well together, are necessary (Roco and Bainbridge 2013). Equally, we need a better understanding of how the integration of various disciplines in nanotechnology can be supported through policies, organizational culture and structures that can enable their co-existence and productive exchange (Ku and Zehr 2022).

Finally, the analysis shows how policymakers frame diversity and materialize it in ways that assume consensus about it (Pfotenhauer et al. 2022). For example, *add-ons* provide closure mechanisms that assume diversity in important expert advisory bodies without questioning it. This frame signals diversity in non-performative ways (Ahmed 2007b; Gushke 2023), meaning that by listing diversity in NNI documents, it distracts from 'actual' diversity work that could show in tangible ways how such diversity is achieved and what it looks like in practice. Whereas diversity as *transformation* bets on workforce diversity and its potential to address the effects of particular policies on marginalized communities. This expectation reveals the unequal burden placed on the shoulders of nanotechnology workers who embody such diversity in the NNI. These findings resonate with work showing how diversity commitments in organizations put an undue load on those who embody that diversity (Ahmed 2009)(p.41). The presumed consensus about diversity that these frames insert in the NNI call for intersectional analyses that can theorize STI in more empowering ways and through 'sociological analyses of power and oppression in the innovation ecosystem' (Mickey and Smith-Doerr 2022)(p.10).

8. Conclusions

While the singular global goal of diversity in policy for STI is offered as a solution to grand societal challenges, as well as to address the innovation gap and sustainable development (Vienni-Baptista et al. 2022; Hofstra et al. 2020; UNCTAD 2019), this article challenges diversity as a taken-for-granted category in policy for STI. The application of isomorphic difference (Irwin et al. 2021) opened up the analysis to explore diversity in ways that describe the interplay between global assumptions as they are framed within national policy settings. The findings contribute to the literature on STI and STS by applying the conceptual lens of

isomorphic difference to a national case. However, this study was limited to the exploration of diversity as it appears in policy for STI in one context. Future research could trace diversity as a distinct "American" phenomenon that travels[25], testing which qualities of diversity are its most isomorphic or most contextual as it moves beyond the USA context. More attention is needed to trace how this idea comes to be understood in other national settings (Bendl et al. 2015). This study presented how the interplay between global ideas and local context matters in policy for STI, which underscores the value of the isomorphic difference conceptual lens. Paying attention to these global-local relationships in policy for STI could speak to the varied and ongoing ways in which global ideas are constructed instead of taking them for granted and simply reproducing them. The increased attention to diversity in policy for STI evidenced here has not been met with an equally strong interest in the STI field to understand how diversity is defined within and what it implies for national STI policies. This study begins to address this gap and underscores how global ideas in policy for STI come to intervene in national social, political, and economic orders.

National policy initiatives, like the NNI, become key mediating institutions (Cozzens and Woodhouse 1995) in realizing the assumed positive outcomes of diversity in policy for STI. They contextualize and operationalize diversity to meet programmatic and national policy objectives. Their translation work, as shown in this analysis, challenges the notion that diversity is some sort of boundary concept (Flink and Kaldewey 2018). Diversity does not 'establish boundaries between groups' (Godin 2015)(p.588), suggesting instead that mediating institutions like the NNI act as a translation machine (Martin et al. 2012) that enable the seamless blend between the global or national. Enacting isomorphic difference in this way means that the NNI facilitates the establishment and adoption of varied definitions of diversity situated in particular contexts. Hence, the specifics of how countries domesticate the term diversity matters. The distinct role of mediating institutions, like national programs, can influence how isomorphic difference happens in policy for STI. In doing so, mediating institutions bring together sectors, disciplines, industries, and peoples, as well as potentially conflicting normative commitments that can sit uncomfortably as they become blueprints in policy for STI across the USA and internationally.

[25] In the public administration, management and organizational literatures, diversity has been described as an "American" phenomenon that got exported (Luthra 2022; Barbosa and Cabral-Cardoso 2013; Boxenbaum 2006) and has resulted in an extensive scholarship (Nkomo et al. 2019)(p.500)(see also Sabharwal et at 2018).

This study pays attention to the multiple ways and locations where meaning is made and how these matter for the use of diversity as a construct in policy for STI. Expert advice, multidisciplinarity and responsible development are not exclusive to the NNI, but the way diversity is framed in these very specific contexts has implications for the assumed values and practices of large national programs. For example, a dominant narrative around convergence, while seductive in nanotechnology policy is also not unique. Across policy for STI, convergence is seen as the remedy for the development of a global science and technology ecosystem. These different understandings of diversity affect the 'design, delivery and effectiveness' of policies to address it (Boston and Callister 2005)(p.35). Nanotechnology is not the only policy area within the USA STI enterprise integrating the global goal of diversity to its lexicon (see e.g., NSTC 2023; Mickey and Smith-Doerr 2022; National Science Board 2020). As a result, the findings from this study are relevant to other emerging technologies and to innovation scholars who want to understand how notions of diversity influence imaginaries of technology or how diversity comes to be understood in policy for STI.

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Online Supplement 1. Coding Framework for Diversity

Construct	Meaning	Examples
variety	differences in kind or category; number of categories into which system elements are apportioned	information, knowledge, or experience among unit members -content expertise, functional background, experience Answer to the question: 'how many types of things do we have?'
separation	differences in position or opinion among unit members	reflect disagreement or opposition — horizontal distance along a single continuum representing dissimilarity in a particular attitude or value -opinions, beliefs, attitudes
disparity	differences in concentration of valued social assets or resources manner and degree in which elements may be distinguished	pay and status among unit members —vertical differences that, at their extreme, privilege a few over many -pay, income, prestige, status, decision-making authority, social power Answer to the question: 'how different from each other are the types of things that we have?'

Source: Adapted by the author from Harrison and Klein (2007)(p.1203) and Stirling (2007)(p.709).

Online Supplement 2. Analyzed Policy Documents on the NNI

Legend: National Academies of Sciences, Engineering and Medicine (NASEM). National Nanotechnology Initiative (NNI). President's Council of Advisors for Science and Technology (PCAST).

Year	Type of Document and Number	Document Title
1999	NNI Strategy 1	Nanotechnology Research Directions: IWGN Workshop Report - Vision for Nanotechnology R&D in the Next Decade
2000	Budget 1	National Nanotechnology Initiative: The Initiative and its Implementation Plan
2002	NASEM Review 1	Small Wonders, Endless Frontiers: A Review of the National Nanotechnology Initiative
2003	2003 Act	21st Century Nanotechnology Research and Development Act (Public Law 108-153), 1923 (2003).
	Budget 2	The National Nanotechnology Initiative; Research and Development Supporting the Next Industrial Revolution, Supplement to President's FY 2004 Budget
2004	NNI Strategy 2	The National Nanotechnology Initiative Strategic Plan
2005	PCAST 1	The National Nanotechnology Initiative at Five Years: Assessment and Recommendations of the National Nanotechnology Advisory Panel
	Budget 3	The National Nanotechnology Initiative Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY 2006 Budget
2006	NASEM Review 2	A Matter of Size: Triennial Review of the National Nanotechnology Initiative
	Budget 4	The National Nanotechnology Initiative Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY 2007 Budget
2007	NNI Strategy 3	The National Nanotechnology Initiative Strategic Plan
	Budget 5	The National Nanotechnology Initiative Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY 2008 Budget
2008	PCAST 2	The National Nanotechnology Initiative: Second Assessment and Recommendations of the National Nanotechnology Advisory Panel

Year	Type of Document and Number	Document Title
	Budget 6	The National Nanotechnology Initiative Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY 2009 Budget
2009	NASEM Review 3	Review of the Federal Strategy to Address Environmental, Health, and Safety Research Needs for Engineered Nanoscale Materials
	Budget 7	The National Nanotechnology Initiative Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY 2010 Budget
2010	PCAST 3	Report to the President and Congress on the Third Assessment of the National Nanotechnology Initiative
	Budget 8	The National Nanotechnology Initiative Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY 2011 Budget
2011	NNI Strategy 4	National Nanotechnology Initiative Environmental, Health, and Safety Research Strategy
	NNI Strategy 5	National Nanotechnology Initiative Strategic Plan
	Budget 9	The National Nanotechnology Initiative Research and Development Leading to a Revolution in Technology and Industry, Supplement to the President's FY 2012 Budget
2012	PCAST 4	Report to the President and Congress on the Fourth Assessment of the National Nanotechnology Initiative
	Budget 10	The National Nanotechnology Initiative, Supplement to the President's 2013 Budget
2013	NASEM Review 4	Triennial Review of the National Nanotechnology Initiative: Phase 1
	Budget 11	The National Nanotechnology Initiative, Supplement to the President's 2014 Budget
2014	PCAST 5	Report to the President and Congress on the Fifth Assessment of the National Nanotechnology Initiative
	NNI Strategy 6	National Nanotechnology Initiative Strategic Plan
	Budget 12	The National Nanotechnology Initiative, Supplement to the President's 2015 Budget
2015	Budget 13	The National Nanotechnology Initiative, Supplement to the President's FY 2016 Budget
2016	NASEM Review 5	Triennial Review of the National Nanotechnology Initiative

Year	Type of Document and Number	Document Title
	NNI Strategy 7	National Nanotechnology Initiative Strategic Plan
	Budget 14	The National Nanotechnology Initiative, Supplement to the President's 2017 Budget
2017	PCAST 6	Letter to the President suggesting the next PCAST report takes place in 2018
	Budget 15	The National Nanotechnology Initiative, Supplement to the President's 2018 Budget
2018	Budget 16	The National Nanotechnology Initiative, Supplement to the President's 2019 Budget
2019	Budget 17 PCAST Meeting	The National Nanotechnology Initiative, Supplement to the President's 2020 Budget *Meeting Agenda – 18 November 2019*
2020	NASEM Review 6	A Quadrennial Review of the National Nanotechnology Initiative: Nanoscience, Applications, and Commercialization
	Budget 18	The National Nanotechnology Initiative—Supplement to the President's 2021 Budget
2021	NNI Strategy 8 PCAST Meeting	National Nanotechnology Initiative Strategic Plan *Meeting Agenda, Video and Readout - 28-29 September 2021*
2022	Budget 19	The National Nanotechnology Initiative—Supplement to the President's 2022 Budget
2023	Budget 20	The National Nanotechnology Initiative—Supplement to the President's 2023 Budget

Online Supplement 3. Events on the NNI for Participant Observation

Type of Event	Date	Hosting organization	Title	Format
Meeting	12 March 2010	The White House	PCAST Meeting: PCAST Review of the National Nanotechnology Initiative (NNI) Program Report	Transcript and archived webcast
Meeting	11 July 2014	The White House	PCAST Meeting: National Nanotechnology Review Discussion	Transcript and archived webcast
Meeting	18 November 2016	The White House	PCAST Meeting: 2016 NRC Review of the NNI	Archived webcast
Meeting	6 January 2017	The White House	PCAST Meeting: NNI Update	Transcript and archived webcast
Workshop	1 August 2019	National Nanotechnology Coordination Office	The Future of the NNI: A Stakeholder Workshop (nano.gov, 2019)	Hybrid (in person and virtual)
Report launch	9 June 2020	National Academies of Sciences, Engineering, and Medicine	Quadrennial Review of the National Nanotechnology Initiative: Report Briefing (NASEM, 2020a)	Virtual
Workshop	11-13 January 2021	National Nanotechnology Coordination Office	2021 NNI Strategic Planning Stakeholder Workshop: Charting the Path Forward (nano.gov, 2021)	Virtual
Meeting	29 November 2021	The White House	PCAST Meeting: Biomanufacturing, the Federal Science and Technology Workforce, and the National Nanotechnology Initiative	Virtual
Public Webinar	28 June 2022	National Nanotechnology Coordination Office	Nanotechnology Commercialization: Perspectives from a Regional Innovation Ecosystem	Virtual
Public Workshop	24-25 January 2023	National Nanotechnology Coordination Office	Nano4Earth	Hybrid (in person and virtual)

Type of Event	Date	Hosting organization	Title	Format
Public Workshop	17-18 May 2023	National Academies of Sciences, Engineering, and Medicine	Beyond Broadening Participation: Research to Progress	Hybrid (in person and virtual)
Public Workshop	31 May-1 June 2023	National Nanotechnology Coordination Office	Refreshing the NNI's Environmental, Health, and Safety Research Strategy	Hybrid (in person and virtual)

Online Supplement 4. NNI Goals

2004 NNI Strategic Plan	2021 NNI Strategic Plan
1. Maintain a world-class research and development program aimed at realizing the full potential of nanotechnology 2. Facilitate transfer of new technologies into products for economic growth, jobs, and other public benefit 3. Develop educational resources, a skilled workforce, and the supporting infrastructure and tools to advance nanotechnology 4. Support responsible development of nanotechnology	1. Ensure that the United States remains a world leader in nanotechnology research and development. 2. Promote commercialization of nanotechnology R&D. 3. Provide the infrastructure to sustainably support nanotechnology research, development, and deployment. 4. Engage the public and expand the nanotechnology workforce. 5. Ensure the responsible development of nanotechnology.

Source: (NSTC-CoT-NSET, 2004, 2021)

Article 2 - Into the 'valley of death': *Isomorphic Difference* in Policy for Nanotechnology in the United States

Into the 'valley of death':

***Isomorphic Difference* in Policy for Nanotechnology in the United States**

Aixa Y. Alemán-Díaz and Alan Irwin

Abstract

Ideas of research commercialization have traveled worldwide, drawing on tropes such as the 'valley of death' to portray the alleged disconnect between basic research and commercial application. At the same time, contextualizations and enactments of this metaphor take different forms across settings. Using the National Nanotechnology Initiative (NNI) as a case, we explore how the valley of death trope has been interpreted and domesticated in the United States of America (USA).

We employ the conceptual lens of *isomorphic difference* to explore how global ideas within science, technology, and innovation (STI) policy take shape locally, providing a multi-faceted interplay between the local and global. On the one hand, the valley of death can be seen as a standard and much-reproduced representation of research-market relations. On the other, we point to its situational enactment and co-production.

Analyzing documents from 1999-2023, along with public events and interviews, we show how the valley of death within the NNI simplifies, persuades and re-orients policy thinking: thus making the policy goal of commercialization in nanotechnology apparently simple and coherent. Our analysis extends Science and Technology Studies (STS) notions of standardization and difference-making by showing how global tropes like the 'valley of death' get caught up in local institutional, social, organizational, and political framings. As a consequence, new questions are raised about the relationship between STS and public policy-making – especially with regard to local strategies in the face of globalizing pressures.

Keywords: isomorphic difference; valley of death; nanotechnology; United States of America (USA); STI policy

Introduction

'Even though I walk through the valley of the shadow of death, I will fear no evil, for you are with me; your rod and your staff, they comfort me' (Psalm 23:4).

'Into the valley of death, rode the six hundred' (Tennyson 1854)

'As I walk through the valley of the shadow of death
I take a look at my life and realize there's nothin' left' Gangsta's Paradise (Rasheed et al. 1995)

As the opening quotations suggest, 'the valley of the shadow of death' has become a repeated trope within popular culture. Tennyson's epic poem, The Charge of the Light Brigade, describes a group of cavalrymen ordered to charge the Russian guns during the Crimean War – to ride into 'the valley of death'. As Tennyson has it, 'Then they rode back, but not / Not the six hundred.'

However, it is not just within religious and popular culture that the 'valley of death' has found a place. Within global discussions of science, technology, and innovation (STI) policy, the valley of death has been defined as 'the gap between the technical invention or market recognition of an idea and the efforts to commercialize it' (Markham 2002)(p.31). The valley of death both dramatically portrays the risks of failure in commercialization and reinforces the linear assumption that scientific breakthroughs can (at least in principle if not always in practice) lead to successful innovation. At the same time, it is a call for urgent action – by industrial bodies, policymakers and other actors - if research-based ideas are not to be (like the glorious but ill-fated Light Brigade) killed off by hostile forces.

Over the last thirty years the valley of death has been the subject of academic and policy inquiry from a number of perspectives[1] and across numerous national settings (Al Natsheh et al. 2021; Auerswald and Branscomb 2003; McIntyre 2014; Takata et al. 2020). Within Europe, scholars have mapped the valley of death through survey data (Islam 2017), examined the interaction between actors traversing the valley of death (Hudson and Khazragui 2013), and analyzed policy discourses that portray scientists as knowledge hoarders accumulating their valuable results in the valley of death (Hellström and Jacob 2005). In China, the valley of death has been portrayed as the result of limited funding for bringing products to market (Zhu, Wittmann, and Peng 2012) and has stimulated work identifying management practices to bridge it (An and

[1] For example, economics (Randolph Beard et al. 2009), education (Stoten 2022; Ramírez et al. 2021; Barr et al 2009), innovation (Balch et al. 2021; Upadhyayula et al. 2018), organizational change (Elrod and Tippett 2002), project management (Midler 2019; Osawa and Miyazaki 2006; Hansen et al. 2021), technology transfer (Frank et al. 1996); and public policy (Frisch and Kelly 2010; Bozeman 2000; Youtie et al. 2016) to name a few.

Zhang 2021). In Latin America, the valley of death has been portrayed as the barren space where potentially life-saving vaccines go to die (Homma, Da Silva Freire, and Possas 2020) and as the missing link between universities and knowledge being put to good use (Arciénaga Morales et al. 2018). In Nigeria, scholars have analyzed the role of commercialization in helping academics traverse the valley of death (Abereijo 2015). In the United States, scholars have examined the role of Congressional allocations in bridging the valley of death (Frisch and Kelly 2010), considered the impact of financial valuations on the likelihood of companies moving across the valley of death (Truebel and Thurston 2020) and argued the need for a 'translational bridge' across the valley of death to improve medical care (Gamo et al. 2017; Baumann and Overgaard 2016; Balch et al. 2021).

As we have already suggested, the valley of death provides a particular framework for the relationship between STI. In previous research, Flink and Kaldewey (2018) and Flink and Peter (2018) have described 'travelling concepts' and the power of certain models and metaphors in STI to move across settings. Godin has extensively explored the social history of models of innovation noting in particular their restricted construction of reality (for example, Godin 2017). Meanwhile, Deuten and Rip (2000) have explored the role of what they term 'narrative infrastructure' in innovation. Our focus in this paper will be on the ways in which the valley of death offers both a standardized account and one which is flexible across settings.

The conceptual lens of *isomorphic difference* (Irwin et al. 2021) will be employed as a means of exploring both the valley of death as a global idea within STI policy and its local interpretation and contextualization. An analysis drawing on isomorphic difference makes explicit the dynamics within shared global trends while also revealing the unique aspects expressed within them. The underlying rationale is that, although it is important to explore how models, metaphors and imaginaries operate at a global and standardized level, it is also important to consider how localized understandings, institutions, and innovation cultures (Pfotenhauer et al. 2023) enact and give shape to these isomorphic influences – and may indeed influence global developments. This paper will draw upon one particular empirical case: the National Nanotechnology Initiative (NNI), a federal initiative bringing together over 26 Federal agencies in the USA.

Next, we illustrate how Science and Technology Studies (STS) have studied metaphors and models in STI. We then describe the NNI before moving on to consider the valley of death in this context.

Travelling concepts in Policy for STI and Isomorphic Difference

As previously noted, Flink and Kaldewey (2018) have presented ideas of 'grand challenges,' and 'responsible research and innovation' (RRI) as traveling concepts that move between practice and theory[2]. Flink and Peter (2018)(p.431) also show how ideas of 'excellence' and 'frontier research' have 'travelled a long way from the USA and have derived from contexts outside of science (and policy)'. They suggest these ideas offer simplicity, coherence and widespread appeal within policy circles. Relatedly, Doezema et al. (2019)(p.323) have analyzed notions of RRI, as 'an increasingly global concept that is translated and transformed in heterogeneous national contexts'. Frahm et al. (2021), meanwhile, have focused on the growing popularity of 'responsible' or 'mission-oriented' innovation frameworks in policy for STI, especially as advocated by institutions of global governance[3]. Their work implies that these recurrent frameworks rely on technological solutionism and "fixes" in policy for STI (see also Wynne 1992; Pfotenhauer et al. 2019). These framings travel through 'supporters, carriers and social entanglements' (Lidskog et al. 2010)(p.121).

In a significant body of scholarship, Godin has extensively explored the social history of models of innovation – including the 'linear model of innovation' (Godin 2006), the 'National Innovation System' (Godin 2017) and the very notion of 'technological innovation' (Godin 2020a). As Pfotenhauer and Jasanoff (2017) have considered with regard to the 'MIT model' and its implementation in the UK, Portugal and Singapore, models of innovation are not implemented in the same manner across contexts but are co-produced within specific locations and in accordance with the local interpretation of the challenges faced. In his work, Godin underscored that these ideas become shared amongst a variety of users. They have the 'capacity to travel widely across scholars and domains' (Godin 2015)(p.586).

Deuten and Rip have additionally explored the role of what they term 'narrative infrastructure' in innovation. Stories are needed to make sense of product creation processes, and in so doing complexity and uncertainty are reduced (Deuten and Rip 2000). Building on these discussions, van Lente (2021) has presented a typology of imaginaries of innovation: including narratives, pictures, graphs and symbols. For van Lente (2021)(p.23), imaginaries in this context relate to 'collectively available symbolic meanings and values'. As he argues, such imaginaries should

[3] The authors focus on the OECD and the European Commission (Frahm et al. 2021).

not be seen as mere side effects, operating apart from the 'real' dynamics of innovation, but as an intrinsic element within any innovation: '[i]maginaries point to viable directions, help actors to make decisions, affect the credibility of innovation projects, and afford sense making in public deliberations on innovation at large. Imaginaries, therefore, are crucial for the shape, the speed and the direction of innovation' (van Lente 2021)(p.34).

Taken together, these accounts suggest that models, metaphors and narratives can play a crucial role within innovation processes. On the one hand, they offer a way of understanding and interpreting the sometimes-complex interactions involved. On the other, they help construct socio-technical processes in a particular, and necessarily restricted, fashion.

The conceptual lens of *isomorphic difference* (Irwin et al. 2021) incorporates insights from STS and institutional theory to study the counter-vailing pressures within policy thinking and enactment. STS facilitates a focus on the contextual nature of policy for STI that emphasizes specific socio-technical interactions. Meanwhile, the literature on institutional theory enables consideration of elements that bring stability and meaning to policy contexts. 'Isomorphism' refers to patterns of cross-national convergence in policy for STI. 'Difference' relates to national or local STI traditions, actors and capabilities. Brought together, the isomorphic difference perspective provides ways to study how ideas, models, metaphors and narratives become widely shared and adopted in policy for STI, but also how they are translated across contexts.

Methods

In order to explore the emergence and implementation of the valley of death within the NNI, we first identified policy documents tracing the initiative's evolution from 1999 until 2023. Such documents included annual federal budgets, strategy statements, and mandated reviews[4]. In addition, a total of 20 semi-structured interviews were completed between 2021-2023 with advisors linked to at least one of the three science advisory groups designated in 2003 to

[4] Three advisory groups in the federal research landscape of the USA produced these documents. The groups were appointed by law to coordinate, assess and suggest changes to the NNI program (US Congress 2003). They include: the Nanoscale Science, Engineering, and Technology Subcommittee of the National Science and Technology Council (NSET); the National Academies of Sciences, Engineering and Medicine (NASEM); and the President's Council of Advisors for Science and Technology (PCAST). Unlike the other two groups, the NSET is composed solely of Federal civil servants with a remit for science and technology across the USA government. These groups are introduced separately in the analysis section based on the material extracted from the corpus.

evaluate the NNI[5]. Observation of 12 online events from 2019-2022 and four 'in-person' events in 2022-2023 was also conducted. We extracted data relating explicitly to the valley of death, commercialization and technology transfer. This data was then inductively analyzed to interpret the contexts in which the valley of death emerged in the USA.

The National Nanotechnology Initiative

Policy for STI in the USA can be traced back at least to the post-war era under the auspices of Vannevar Bush[6] (Bush 1945; Dennis 2004, Mowery 1998; Neal et al. 2008). The objective at the time was to 'harness together the complete set of players necessary to ensure the USA would have all the technologies needed to win the Cold War' (Sarewitz 2016)(p.8-9)[7]. Consistent investment in basic research led the USA to become a leader in the global technological race. However, over time the USA government has been reducing its stake in funding the national STI enterprise, opening the space for an increasingly active private sector investment in its research enterprise (National Science Board 2022) and the commercialization of science (McCray 2005).

The NNI, introduced by President Clinton in 2000 (Lane and Kalil 2005) and enshrined into law in 2003 (US Congress 2003) ('the 2003 Act' from herein), is a collaborative endeavor across the federal government involving 'cross-disciplinary research, multi-agency programs, technology transfer, and societal implications' (US House of Representatives 2003)(p.20). The initiative has had a cumulative investment of over $40 billion[8] since its inception. The NNI aimed to 'fill major gaps in fundamental knowledge of matter and to pursue the novel and economic applications anticipated for nanotechnology' (Roco 2011)(p.428).

The explicit inclusion of technology transfer in the 2003 Act (US Congress 2003) and as a specific program goal in subsequent strategy statements revealed high hopes for the

[5] Eight participants were active advisors in the NNI, and 12 participants were not active at the time of the interview. This blend allowed for an understanding of enduring and emerging ideas and dynamics in the advisory groups.

[6] In the USA, Vannevar Bush is a mythical figure in policy for Science, often connected to the linear model of innovation, even though 'models of innovation' emerge in a later era (Godin 2015). Additionally Bush did not propose a 'linear model' explicitly nor did he pioneer the conceptualization of innovation in a linear way (Pfotenhauer and Juhl 2017)(p.90).

[7] The symbiotic relationship between STI and the military in the USA has been described extensively (Slayton 2013; Oreskes 2021; Connor 2022) and some argue the foundations built 'during the Cold War continue to support the American economy' (Sarewitz 2016)(p.10).

[8] For FY 2023 the estimated request was of almost $2 billion.

commercialization of nano research (Roco 2011). At a workshop on the future of the NNI a speaker from the White House Office of Science and Technology Policy (OSTP) stressed that 'commercialization is key to the NNI'[9]. Scholars have described the NNI as a 'policy intervention that targets the commercialization of technology and a focused research direction to promote national economic growth' (Jung and Lee 2014)(p.74). This connection between the commercialization of nanotechnology and national economic growth is most evident in the NNI goals (Table 1).

Table 1. Commercialization in the NNI

Year of NNI Strategic Plan	**Relevant NNI Program Goal**
2004	2. Facilitate transfer of new technologies into products for economic growth, jobs, and other public benefit.
2007 **2011** **2014** **2016**	2. Foster the transfer of new technologies into products for commercial and public benefit.
2021	2. Promote commercialization of nanotechnology R&D.

Source: (NSTC-CoT-NSET 2004; 2007a; 2011a; 2014; 2016; 2021) Notes: Format changes to text (i.e., underline**)** added by authors.

Technology transfer features as number two out of four (or sometimes five) goals in the NNI strategies. It has retained its status over the life of the NNI, second only to the goal of basic research in nanoscience. Furthermore, and as Table 1 shows, while the goal of commercialization within the NNI has remained consistent over time, the verbs used to describe it have evolved in ways that signal increased intentionality: from 'facilitate' through 'foster' to 'promote'.

The next section explores how the USA has adopted the valley of death in its efforts to support the commercialization of nanotechnology. We begin with the Valley in recognizably standard - or isomorphic - terms.

[9] Comment made by Chloe Kontos (2019, August 1). The Future of the NNI: a stakeholder workshop 1-2 August (Unofficial transcript). https://www.youtube.com/watch?v=w6QD2xKGqXU.

Into the Valley of Death - Isomorphic elements

As we will discuss in this section, the valley of death in this context combines two globally-recognizable elements: a *case for government intervention* and the assumption that there is a *point of no return*.

The case for government intervention: An interview with a senior advisor at the NNI revealed that, while the early focus within the initiative was on basic research, quickly 'the focus began to be heavily on commercialization'[10]. The NNI is a novel program that '…makes it possible to support technology transfer in ways that typical research programs cannot' (NASEM 2013)(p.96-97). The evolution of the program coincided with larger political changes in the US that allowed recognition of the importance of central intervention in order not to lag behind (NASEM 2013)(p.106).

This new mandate for government involvement emerged in the NNI within the area of nano manufacturing where the President's Council of Advisors on Science and Technology (PCAST) identified a clear role:

> 'While each agency considers areas of nanotechnology interest according to its mission, the challenges in manufacturing are likely to impede commercializing advanced nanomaterials, nanomedicine, and other nanotechnologies unless the Federal Government addresses the 'valley of death', which involves the need for nanofabrication facilities to create high volumes of nanotechnology product.' (PCAST 2014)(p. 48)

The valley of death appears bigger than any one department in the USA government can address. The NNI arrangement means that '...each agency invests in projects that support its own mission and retains control over how it will allocate resources against its NNI proposals based on the availability of funding…' (NASEM 2002)(p.12). Traversing the valley of death provides a powerful justification for the bespoke programs across the federal government that have sprouted to assist 'companies, in particular small start-ups, to cross the significant gap between technology development and product commercialization' (NASEM 2006)(p.66). At the Nano4Earth workshop[11], Dr. Asmeret Berhe, Director of the Office of Science in the U.S. Department of Energy (DoE) stated that:

> '…for the entrepreneurs who want to launch their own companies based on innovations and patents, DoE has a robust small research program that provides opportunities to

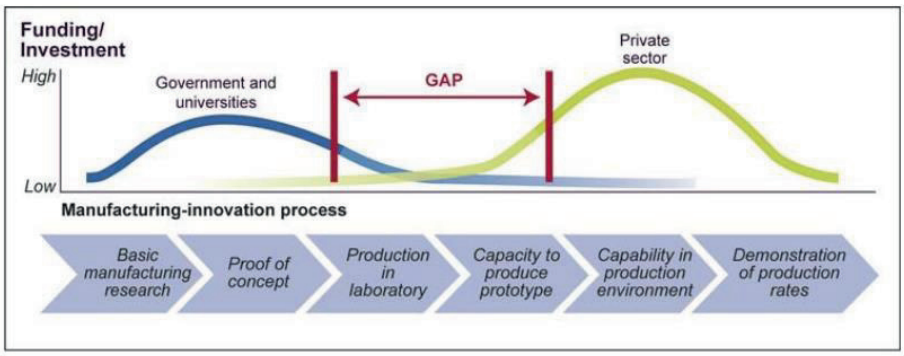
[10] Interview 9 May 2022, 16:50.

[11] For details on the agenda and speakers of this workshop visit (nano.gov 2023).

> support the next phase in commercialization of your ideas...You have your great ideas, now if you're ready for the next steps, we're here to help.'[12]

Federal interventions in the NNI included requirements for reporting and assessment. As it relates to the NNI's second goal (see Table 1), this means a legal obligation to track technology transfer efforts across the participating agencies. The Nanoscale Science, Engineering, and Technology (NSET) must submit an annual report to Congress on 'how the Program will move results out of the laboratory and into application for the benefit of society' (US Congress 2003)(p.1925). Meanwhile, the National Academies of Science, Engineering and Medicine (NASEM) evaluates the NNI's efforts to transfer technologies to the private sector (US Congress 2003)(p.1928). NASEM was the first to introduce the valley of death notion into the NNI as a means of presenting the different federal programs (NASEM 2006). However, PCAST, which also has a mandate to review the program, introduced the first visual representation of the valley of death (Figure 1) to draw attention to the USA's apparent lag in commercialization of nanotechnology (PCAST 2014).

Figure 1 The valley of death



Source: (PCAST 2014)(p.46)

The accompanying text invoked a path which must be taken in order to make the leap between idea and commercial products. Figure 1 also makes explicit that the government has a role to play in the innovation process, especially at its beginning. It also presents universities and the private sector as (at least potentially) significant actors.

[12] Comment by Asmeret Berhe. (2023, January 24). Nano4Earth workshop (https://www.nano.gov/nano4EARTHWorkshop)(Raw transcript). Provided by TV Worldwide (https://tvworldwide.com/events/nanotech/230124/).

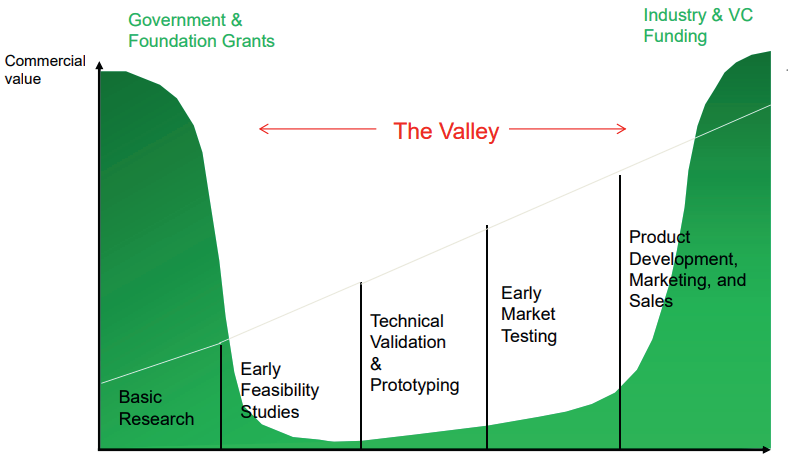
The point of no return: The valley of death represented in Figure 1 appears as a gap in the manufacturing innovation process caused by the lack of financial resources for the translation of ideas into commercial products. The PCAST states that:

> 'The major impediment in this commercial translation typically occurs in the 'valley of death' or the 'Missing Middle,' the stage where infrastructure is needed between Government-backed research and select privately-funded technology scale ups…Early stage technology development is typically supported by grants to academic investigators, and late stage private sector investments are made to select technologies with significant potential, leaving a gap in the middle' (PCAST 2014)(p.47)

In this, the valley of death emerges as a familiar metaphor that constructs a particular version of reality in the NNI. It draws upon classical 'linear' notions of the innovation process. Figure 1 suggests that to bridge the valley, policy for nanotechnology in the USA should focus on increasing 'interaction among those who are performing R&D and those who manufacture and sell goods and services' (NSTC-CoT-NSET 2004)(p.5).

Figure 2, presented by an invited speaker at a meeting of the NASEM, offers an even more dramatic view of valley of death. It suggests that the actors involved can also be foundations as well as the venture capital (VC) sector. The representation in Figure 2 draws on the same linear notions of innovation found in Figure 1. However, in Figure 2 the y-axis measures the commercial value of activity that fails to materialize, as opposed to funding or investments shown in Figure 1. In this way the image may stay the same, but the meanings inscribed in it change.

Figure 2 The valley of death revisited



Source: (Herskowitz 2019)(p.3) Legend: VC-venture capital

The valley of death representations in Figures 1 and 2 must also be reconciled with narratives in the policy documents that allude to the need for 'a sustained investment over many years from industry and government … to realize major economic benefit and to stay internationally competitive' (NASEM 2006)(p.67). NASEM acknowledges that 'in general the timescales from research-based discovery to commercialization of technologies are long, often 20 years or more, and as an enabling technology, nanotechnology in particular is still in its infancy' (NASEM 2006)(p.62). But it is not only time that can make the valley a point of no return. As stated by NASEM in its 2013 report:

> 'The diversity of processes and agreements used by agencies, federal laboratories, and universities—and in some cases lack of flexibility—can be a barrier to transitioning research results to practical and commercial use, particularly by small companies and start-ups.' (NASEM 2013)(p.115)

The actors invoked in Figures 1 and 2 have ways of working practices that can also make the valley of death a point of no return for many research ideas. The experience of scientists' highlights the disrupted way in which funding disbursement can contribute to the valley of death. At the Nano4Earth workshop in Washington, D.C., Dr. Sally Benson from the OSTP commented:

> '…I am going to speak through the lens of the academic research community who is highly engaged in innovation in this area and had been for 20 years. The typical experiences that you get funded by the government, you do a project and you have really good results ….The next thing is you need to find a funding source or maybe get industry to support this, but there is a hiatus, so it takes a long time. Maybe the funding

> that you can get is …sort of adjacent of where you want to head so you want to continue…'[13]

Dr. Benson's comments highlight the intertwined nature of the obstacles (e.g., time and varied practices) to bridging the valley of death. Yet, as suggested by Sam Brower, an online participant at the same event, there are other hurdles to overcome: '…one of the roadblocks that maybe didn't get discussed as much for the commercialization of nanotechnology was the discussion of how to find a first customer'[14]. Brower's question was answered by Dr. Cynthia Friend, President of the Kavli Foundation[15] and keynote speaker:

> 'I want to come back to a point that was just made and that is that the defense industry often has been the first customer. There's a great example about Silicon Valley and the growth of microelectronic devices. In that case, without defense Department investment we wouldn't have all the devices we have today. The key is to find someone, and maybe this is the role of people who have wealth, too …. to be able to pay a premium for a new technology, for the promise of that. If you don't have government spending … then I think it becomes very challenging.'[16]

Dr. Friend reminds us that the valley of death can be very challenging for researchers or startup companies who, unable to secure funding, come to die there. She underscores the role of the government not only as a funder but also as a first customer in the process of the commercialization of nanotechnology. These roles emphasize the *basis for government intervention*, but also open up the space for other actors, like venture capitalists and the private sector, to intervene.

Into the Valley of Death – Elements of Difference

Having presented two of the intrinsic and recurrent elements within the valley of death trope, we now address two contextual and difference-making elements found in this specific case. In this

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[13] Comment made by Sally Benson. 2023 (January 24). Nano4Earth workshop (https://www.nano.gov/nano4EARTHWorkshop)(Raw transcript). Provided by TV Worldwide (https://tvworldwide.com/events/nanotech/230124/).

[14] Discussion between Sam Brower and Cynthia Friend. 2023 (January 25). Nano4Earth workshop (https://www.nano.gov/nano4EARTHWorkshop)(Raw transcript). Provided by TV Worldwide (https://tvworldwide.com/events/nanotech/230124/).

[15] Kavli is private foundation in California that 'stimulate basic research in the fields of astrophysics, nanoscience, neuroscience, and theoretical physics; strengthen the relationship between science and society; and honor scientific discoveries' (Kavli Foundation 2023).

[16] Discussion between Sam Brower and Cynthia Friend. 2023 (January 25). Nano4Earth workshop (https://www.nano.gov/nano4EARTHWorkshop)(Raw transcript). Provided by TV Worldwide (https://tvworldwide.com/events/nanotech/230124/).

section, the domestication of the valley of death model is presented in the form of a *quilt of logics* and the *practicing of metrics*.

A quilt of logics: The multisectoral nature of the NNI provides a foundation for partnerships beyond the federal government to maximize the commercialization of nanotechnology. Policy documents suggest that 'the NNI agencies could work together to partner with industry consortia to identify and address long-term research needs of sectors that have potential for high economic impact' (NASEM 2013)(p.115). There are at least 26 such agencies working in the NNI, each inserting their own local needs and understandings of the process of commercialization.

Early in the NNI, documents allude to nanoscience as needing 'help to accelerate the commercialization of NNI developments' (NASEM 2002)(p.48). They refer to venture investors and firms providing the necessary capital for entrepreneurs in this area, with the acknowledgement that:

> 'While such private capital investment is rarely being channeled into basic research and is not building infrastructure, it does fund new tools, applications, and innovations that utilize elements of nanoscale science and technology and it does contribute to the expanding fabric of nanoscale science and technology as a core industrial competence in the United States.' (NASEM 2002)(p.25)

At a meeting on the NNI, the Columbia University Nano Initiative reported that at least '16 emerging start-up companies' and 'over 280 inventions' have emerged from their work (Herskowitz 2019). The Northwestern University International Institute for Nanotechnology estimated that '23 companies' were launched from its efforts bringing to market over '2,000 commercial products' and attracting over '1 billion USD (in) venture capital' (Mirkin 2019)(p.4). Universities and research centers fund the production knowledge for commercialization - as envisioned in Figures 1 and 2. The centers bring together industry–government–university partnerships that 'combine interests and expertise to create the science and technology needed to successfully commercialize new products and create new jobs within the United States' (NSTC-CoT-NSET 2011b)(p.25). Beyond the private sector and universities, private foundations are also seen to be important. At the Nano4Earth workshop, Dr. Cynthia Friend, remarked that:

> 'Philanthropy can do things that you could not readily do in a federal funding environment or perhaps in business…In my view, a fundamental innovation landscape

> includes philanthropy as a complement to federal funding and also commercial investment, so I think that's something that can be fostered more.'[17]

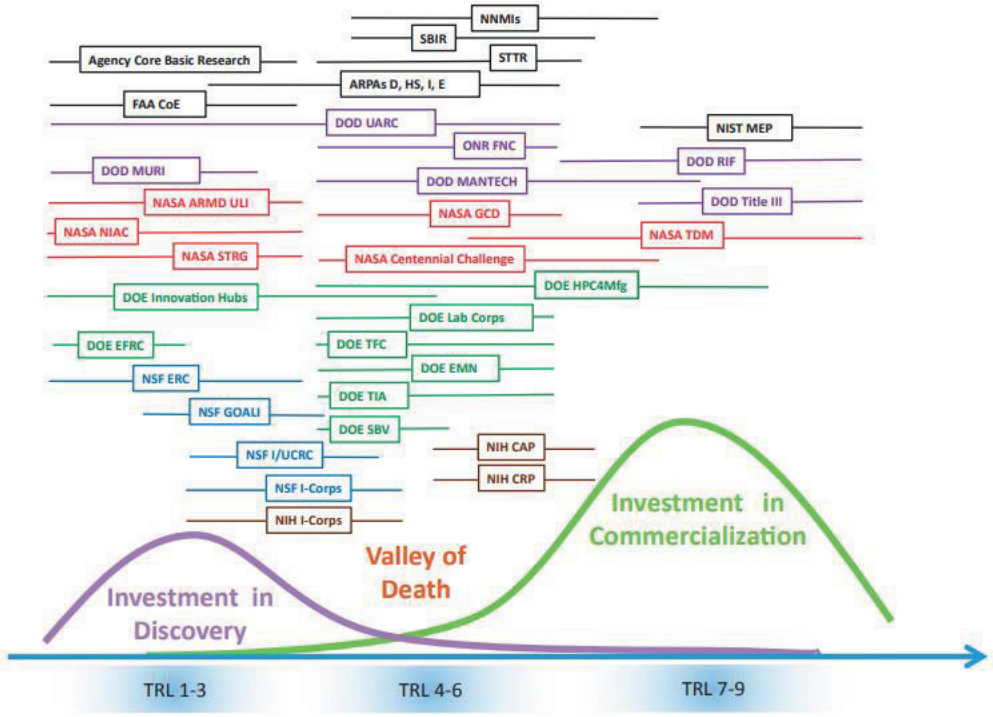
How these partnerships negotiate in practice the quilt of logics they bring together remains to be seen; the valley of death metaphor does not attend to this matter.

Nano-specific elements further complicate commercialization efforts within the NNI: for example, due to nanotechnology's 'novelty and …the existence of little in the way of standards and regulatory certainty' (NASEM 2013)(p.96). The tension between the national and global logics was laid out in the most recent NASEM review where countries like Japan, Malaysia, China, and regions like Europe were used to showcase commercialization programs unlike the NNI (NASEM 2020). But the NNI has not just been waiting to learn from the rest of the world as it develops its nanotechnology program. For the NNI, the 'development of common terminology and internationally recognized standards will play a critical role in the successful commercialization of nanotechnology' (NSTC-CoT-NSET 2007b)(p.25).

The 'alphabet soup' of federal programs to address the valley of death, as described by Dr. Berhe, is represented clearly in Figure 3 (NASEM 2016)(p.27). This image repeats the 'valley of death' trope, but now with the addition of individual agency contributions to overcoming it. Figure 3 suggests how the valley of death is co-produced in the particular USA setting. The unique programs listed signal a collective response to bridging the discovery-commercialization divide. The number of these programs suggests substantial levels of activity in the valley – thus challenging the assumption of a funding dearth (as presented in Figures 1 and 2) but also many statements within the academic literature.

[17] Comment by Cynthia Friend. 2023 (January 25). Nano4Earth workshop (https://www.nano.gov/nano4EARTHWorkshop)(Raw transcript). Provided by TV Worldwide (https://tvworldwide.com/events/nanotech/230124/).

Figure 3. The valley of death domesticated



Source: (NASEM 2016)(p.27)

Legend from original image: Blue: National Science Foundation; Red: National Aeronautics and Space Agency; purple: Department of Defense; green: Department of Energy; black: others)

As just one part of Figure 3, the Small Business Innovation Research (SBIR) program involves many agencies, many interests, and many agendas. This funding is granted through agencies across the federal government. As Dr. Berhe mentioned, the DoE has its own version of the program, but so do 10 other federal agencies, each with different budgets and funding per phase (sbir.gov 2023). This suggests that Figure 3 represents an extremely crowded and complex space within this specific USA setting.

Practicing metrics: In policy for nanotechnology in the USA, impact has become synonymous with the development and application of metrics. From the start of the NNI, there was an interest in measuring its activities, even though

> '[t]he timescales over which the cumulative benefits of nanoscale R&D will become apparent will vary, depending on the nature of individual industries and products and the kinds of developmental research and testing required, such as clinical trials' (NASEM 2006)(p.62).

The NNI acknowledges that '[t]here is no common method or system across the NNI participating agencies for measuring and tracking progress toward achieving the four NNI goals' (NASEM 2013)(p.153). Nevertheless, NASEM encouraged '…individual agencies to establish

NNI priorities, budgets, and metrics for evaluating various research activities.' (NASEM 2002)(p.12). The USA has been a strong proponent of program evaluation in R&D long before the NNI (see e.g., Berman 2022 or Neal et al. 2008). This positivistic tradition in American policymaking emerges strongly in NNI documents. In 2013, the NASEM report stated that '[m]etrics are necessary for evaluation, rational decision-making, and appropriate allocation of resources.' (NASEM 2013)(p.154). They go on to identify specific metrics '- 'for inputs, outputs, and outcomes' (NASEM 2013)(p.154)- necessary to measure commercialization activity in the NNI. But NASEM's push for metrics in the NNI began much earlier when it envisioned that

> 'As the NNI grows in magnitude and complexity, it is imperative that the nation be able to evaluate its investments in nanotechnology and analyze how the return on those investments aligns with national goals, including those goals defined in the strategic plan for nanoscale S&T' (NASEM 2006)(p.61)

NASEM argues that efforts to measure impact have been 'hindered by a lack of metrics and lack of a comprehensive empirical framework' (NASEM 2013)(p.154). Certainly, the NNI has been undeterred from pushing towards practicing metrics to address the valley of death. The PCAST included a specific recommendation in its 2017 report on this matter:

> Recommendation 7: The Nanoscale Science, Engineering, and Technology Subcommittee, with the Department of Commerce, should execute a process to establish a common set of evaluation metrics to quantify and report the impact on workforce, productivity, and scientific knowledge in nanotechnology for all new research and commercialization programs beginning in FY2016.' (PCAST 2017)(p.6)

These attempts at practicing metrics within the NNI acknowledge that commercialization varies by sector and that they depend on the agency that is leading them. The goal over time has been to identify 'metrics that allow us to understand the synergies and interactions' between the NNI and other programs and policies (NASEM 2013)(p.101). In this vein Figure 3 adopts the notion of technology readiness levels (TRL)[18] to replace the generic manufacturing innovation process found in Figures 1 and 2. This notion, originally developed at NASA, requires 'discipline-specific tailoring' (Héder 2017)(p.2). And while programs like the SBIR emerge as pathways to traversing the valley of death, research has found that the program does 'not necessarily span' the whole valley as determined by the TRL scale (Belz et al. 2021)(p.1482). Nevertheless, these

[18] TRLs have also been subject to use beyond their intended application, e.g., 'people expect them to provide clarity in decision choices and risk assessments, which they can play a part in, but were not meant to accomplish' (Olechowski et al. 2020)(p.404). In the NNI, this extended interpretation gets linked to notions of market readiness, as it was the case in the adoption of TRLs at the European Union (Héder 2017)(p.10).

levels do reinforce the notion of a linear evolution from research to the marketplace (NSTC-CoT-NSET 2012)(p.31).

Quantifying the federal investments and analyzing the impact of the NNI's efforts has intensified over the studied period. The use of these metrics encourages shared national standards across very different contexts and missions. In the NNI, the valley of death simplifies the various pathways to commercialization, while the race for metrics provides a further method to reduce complexity.

Isomorphic Difference and the Valley of Death

This paper has set out to explore how the valley of death trope has been interpreted and domesticated in one specific setting: offering simplicity, coherence, and based on our analysis, a strong appeal within American policy circles oriented towards the commercialization of nanotechnology. This standardized representation illuminates aspects of the innovation process but also shapes and directs it in particular ways.

As we have shown, within this trope it becomes difficult to escape notions of linearity, of a simple and constrained temporal progression, and of one common process applying to all areas of nanotechnology development. Certainly, the proliferation of programs like the NNI raises questions about the ways in which these isomorphic metaphors and travelling concepts come to be adopted and how in their adaptation come to represent cures for perceived ailments in STI systems (Pfotenhauer and Jasanoff 2017). Our analysis expands STS work in this area by highlighting how NNI processes and practices anchor the 'valley of death' metaphor across diverse players and sectors, providing also a ready-made explanation and route map for the challenges involved in the commercialization of science in the USA.

The depiction of the 'valley of death' in Figure 3 provides a vivid illustration of isomorphic difference in action. Figure 3 includes the well-recognized picture of 'the valley of death', and mixes familiar elements with the embedded contextual elements identified in the USA. The trope obscures the complex entanglements that the commercialization of nanotechnology brings with it and 'the plurality of values and norms these discourses entail' (Jotterand 2006)(p.663). The valley of death can be interpreted as providing a necessary simplification of a complex policy process, while at the same time constraining the possibilities attached to the process it aims to represent. Our analysis shows that the challenges associated with the development of new technologies (Fagerberg 2016)(p.10) provide a justification for *government intervention* in

the USA but also create the need for what we have presented as a contextual *quilt of logics* to support research ideas traversing the valley. Nonetheless, Jung and Lee (2014) found that while the NNI's focus on commercialization had increased the knowledge inflows from universities to industry, it had done so at a cost, with less technological breakthroughs and narrower research scopes in the USA. In practice, the metaphor used by the government has been successful in drawing a variety of players into the commercialization sphere, but the outcomes do not appear (at least so far) to have elicited all of the anticipated benefits.

Additionally, the valley of death serves as a mode of persuasion and communication that implicitly makes the case for the state as a central actor while also normalizing relations between the state, research, and the market. Our findings echo work in Sweden that revealed how policy frames are 'used as rhetorical justification for research funding policies that seek to increase business influence and input to university research at the expense of academic autonomy…' (Hellström and Jacob 2005)(p.443). We also suggest that academia and industry play a vital role in the conceptualization of this metaphor within the NNI; they appear as opposing and sometimes complementary influences that give it life and introduce competing logics. Centers, like those at Columbia and Northwestern University, merge a variety of interests and logics that may not always be compatible and where relationships must be negotiated (Fochler 2016; Vedel and Irwin 2017). The valley of death prompts negotiation of these actors' interactions locally suggesting that metaphors in policy for STI have power and influence over the actions of relevant actors but may also be less rigid and top-down than Godin (2017) suggests. As a result, this analysis shows that ideas and metaphors like the valley of death 'do not travel on their own but need supporters, carriers and social arrangements in order to be distributed to society' (Lidskog et al. 2010)(p.121).

Moreover, the analysis shows how normative pressures implicit in the valley of death within the NNI, not least to conform and respond to international competition, bring out unique aspects of the US nanotechnology landscape. Djelic and Sahlin-Anderson (2006)(p.397) posit that the transnational governance fields give an advantage to actors, organizations and networks in the USA because these fields are 'shaped according to institutional principles with which they are in a sense "genetically" familiar'. The 'transboundary' (Lidskog et al. 2010) nature of nanotechnology standards encourages institutional arrangements, like those of the NNI, that bring together such disparate sectors.

Finally, the NNI's encouragement for shared organizing and the adoption of common metrics across the federal government create new pressures within this complex environment: with the adoption of metrics like the TRL one good example here. However, we would suggest that the pressures of the innovation process are situationally enacted and co-produced (Jasanoff 2004). These seemingly contradictory ideas co-exist providing a window into the complexity that inhabits the 'valley of death' and opening up new questions about the relationships that exist within it. The adoption of common metrics also serves to simplify a complex reality. The interplay between these dynamics results in coercive isomorphic pressures to conform with a policy mandate that may result in 'indicators that are easy to find and not easy to interpret negatively…(to) meet the joint criteria of ease and innocuousness' (Bozeman 2000)(p.646). The reliance in STI policy on overarching metrics to measure commercialization poses a challenge to policymakers since it tries to quantify what, based on their own accounts, represents a multi-layered and complex phenomenon.

Conclusion

The 'valley of death' serves as a standard and much-reproduced representation of research-market relations. Application of the isomorphic difference conceptual lens illuminates how this standard metaphor within policy for STI is contextualized and brought into practice in a national setting. The metaphor might stay the same, but its specific meanings can vary substantially and embody localized assumptions. As such, it serves both as one application of a global innovation policy conceptualization (recognizable not least in a Chinese and European context) and as the specific product of a very specific national policy assemblage.

The analysis has shown how the valley of death has been domesticated to accommodate intensifying priorities around the commercialization of nanotechnology in the USA. We demonstrate the role that this metaphor and framework plays in promoting collective action across distinct settings, helping in particular to coalesce shared concerns. The USA domestication of the valley of death illuminates the ways in which global trends in STI emerge and evolve as national projects and how local strategies fare in the face of these globalized tendencies. This application of isomorphic difference helped us look anew at what is otherwise seen as unproblematic, taken-for-granted, or beyond challenge. This work shows the importance of re-examining what is taken for granted within policy for STI. It also introduces nuance to our understanding of shared trends within STI policymaking that take on very distinct forms in national contexts.

This work extends STS notions of difference-making in policy for STI by showing how the 'valley of death' offers a powerful image, but one imbued with strong assumptions about how the innovation process should be understood and the roles of those involved – including those of research, researchers, the state, and industry. Ultimately, this invites us to consider whether alternative understandings of innovation are possible as we consider emerging technologies, while also raising new questions about the relationship between STS and public policy-making – especially with regard to local strategies in the face of apparently globalizing pressures. The 'valley of death' in policy for STI conjures loss and a sense of inevitability: there is only one way forward. Yet its domestication in the USA might also suggest new ways of building – and localizing - technological futures.

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Article 3 – National Variants of Innovation-based Futures in Policy: Varieties of Capitalism and the Frames of Innovation in the United States and China

National Variants of Innovation-based Futures in Policy:

Varieties of Capitalism and the Frames of Innovation in the United States and China

Xuan Li and Aixa Y. Alemán-Díaz

Abstract

Socio-technical futures are mobilized in ways that impact the present. An innovation-based future is a socio-technical future where knowledge-intensive activities serve as a primary engine for economic growth. On the one hand states have to consider their national features in how they envision the future, but on the other hand states also pick up global templates to shape the future. Taking isomorphic difference as the conceptual lens, the paper makes a comparative analysis of the United States and China to elucidate where the national variants of an innovation-based future are positioned in science, technology and innovation (STI) policies between following a global template, as outlined by the Frames of Innovation, and retaining their national features as described by the Varieties of Capitalism (VoC). Methodologically, policy instruments in STI strategies are taken as carriers through which the innovation-based future acts upon the present. The findings reveal that the national variants of innovation-based futures in both countries have been situated closer to their distinct VoC framework than the Frames of Innovation, notably the third frame—the most recent global norm. Lastly, the paper makes a theoretical contribution to the VoC literature in the innovation field and reflects upon its implications.

Keywords: national variants; innovation-based future; varieties of capitalism; frames of innovation; isomorphic difference; policy instruments

1. Introduction

The socio-technical future, understood as a linguistic abstraction, is mobilized as an object of present-day action and agency (Brown & Michael, 2003; Brown & Rappert, 2017). Futures can often be seen as effective mobilizers of the present through policy practices and rhetoric (Hermann et al., 2022; Korsnes, 2016). Innovation-based futures are the socio-technical futures of many countries. The essential idea of an innovation-based future departs from the underlying assumption that high-technology and knowledge-intensive activities will be the primary engine for future economic growth (Clarke, 2001; Gibson & Oden, 2019). On the one hand, states need to consider their distinctive national features in how the socio-technical future adapts to the present's realities; on the other hand, states are readily picking up global isomorphic norms to shape how the socio-technical future looks (Pfotenhauer & Jasanoff, 2017). Granted that both national features and global norms influence the national imaging processes in policy for STI, no known study has cast light on where the balance strikes between these two in 'co-shaping' innovation-based futures. It forms a critical empirical and theoretical project to pinpoint how a common pursuit of innovation-based futures is executed through policy blueprints in different national settings. The central question the paper addresses is: to what extent do states adopting an innovation-based future absorb global frames or retain their national features?

A comparison of Science, Technology, and Innovation (STI) strategies at the national level between the United States (US) and China provides a good vantage point for studying innovation-based futures, as the national STI policy blueprints are the vehicles to envision an innovation-based future. While the US is generally regarded as the world's most innovative nation to fuel its economic growth (Mikler & Harrison, 2012), China has in the past twenty years stepped towards a leading 'innovation economy' closer to that of the US (Hutschenreiter & Zhang, 2007). Through the common pursuit of innovation-based futures, it is empirically

intriguing and theoretically informing to know whether China has chosen similar pathways as it envisions itself closer to the US in the past twenty years.

The conceptual lens of isomorphic difference (Irwin et al., 2021) provides an analytical angle to attend to both national conditions and global norms in co-shaping a common innovation-based future. On the one hand, the Varieties of Capitalism (VoC) framework outlines a set of complementary national institutional characteristics around which national economies are organized (Fligstein, 1996). On the other hand, the Frames of Innovation have emerged as a global evolutionary template of how economies are structured in relation to state intervention on innovation, especially the third frame of innovation –transformative change—which represents the most recent global template (Schot & Steinmueller, 2018). Given that the global innovation models and templates seem to be very prevailing (Etzkowitz, 2013; Fransman, 2014; Pfotenhauer & Jasanoff, 2017), the paper elucidates where the national variants of an innovation-based future in STI policies are positioned between following the global norms based on the Frames of Innovation and retaining their national features in virtue of their VoC.

How can we empirically observe these two dynamics in co-shaping an abstract future? To ground our analysis, we draw on policy instruments in STI strategies as carriers through which the innovation-based future has acted upon the present. Flipping the conventional approach about 'best policy instruments for given policy goals' on its head (Acciai, 2021; Borrás & Edquist, 2013; Duchamp, 2015; Flanagan et al., 2011), we regard policy instruments as socially constructed objects that embody both material practices and underlying normative assumptions through which the future has acted upon the present (Hogan & Howlett, 2015b, 2015a).

The paper is organized as follows. Section 2 theorizes the two dynamics of isomorphic difference—the Frames of Innovation and VoC framework— in co-shaping the innovation-based futures. Section 3 details data sources, selection criteria, the definition of three instrument

families and the following three-step coding procedures. In section 4, we identify policy instruments and move to probe the dominant policy instruments as important carriers through which the innovation-based future has acted upon the present. Section 5 opens up a discussion on how the two dynamics of isomorphic difference co-shape the innovation-based future. Lastly, section 6 concludes the paper by explicating the contributions and pointing toward future research agendas.

2. Two dynamics of *isomorphic difference*

The conceptual lens of isomorphic difference gives equal analytical attention to national and global dynamics in shaping a socio-political archetype (Irwin et al., 2021). The 'isomorphic' elements of the conceptual lens draw on 'isomorphic pressures'(DiMaggio & Powell, 1983) as conceived in the institutionalist tradition, revealing large-scale patterns of convergence towards global norms and standards (Beckert, 2016; Boxenbaum & Jonsson, 2017; DiMaggio & Powell, 1983). The 'difference' element of the conceptual lens draws upon 'co-production' (Irwin & Michael, 2003; Jasanoff, 2004) in the interdisciplinary Science and Technology Studies (STS) tradition, revealing how the global systems are locally interpreted and enacted with national features (Irwin et al., 2021). Isomorphic difference assumes that no global idea gets to be imposed across national contexts, but it must be 'imagined, translated and enacted within specific contexts and assemblages' (Irwin et al., 2021, pp.5). The conceptual lens provides an entry point to studying these global ideas, in our case innovation-based futures, as empirical objects (Flink & Kaldewey, 2018; Godin, 2006). Having introduced the conceptual lens of the analysis, we will present the state of the art on the Frames of Innovation as the global templates and the VoC framework as the national features.

2.1 The Frames of Innovation

The evolutionary frames of innovation historicize the adjustments and readjustments of the normative relationship between innovation systems and the market economy based on three historical periods. These historical accounts describe global isomorphic pressures in STI policies. The first Frame of Innovation (Schot & Steinmueller, 2018)—innovation for growth—began during the post-World War II period, formed around the political consensus that R&D investment can address market failures through the private provision of capital to commercialize and develop new knowledge. This frame of innovation, which is based on a classical supply side-oriented R&D investment strategy, is legitimated by the neoclassical economic assumption of 'perfect markets,' which limits the state intervention to addressing market failure (Kattel & Mazzucato, 2018; Laranja et al., 2008; Mazzucato & Robinson, 2018). According to neoclassical economic theory, classical market failures refer to ownership externalities, public goods externalities, and imperfect information (Bator, 1958; Randall, 1983; Winston, 2006), all of which result in insufficient capital investment in some areas. Examples of the state's action legitimizing the first Frame of Innovation can be in the form of increasing R&D spending in places where the market fails to generate substantial economic resources (Wu, 2017), or securing a 'level playing field' via legal and regulatory frameworks to protect the economic interests of all players equally.

The second frame of innovation is what Schot & Steinmueller (2018) named 'national systems of innovation'. The second frame emerged in the 1980s, during which the global economy witnessed the readjustment of innovation policies toward developing national innovation systems (NIS) (Edquist, 2001; Freeman, 1995). The second frame acknowledges the 'stickiness' of knowledge across different knowledge producers since the knowledge production within a geographic space is path-dependent, cumulative, and often contains important tacit elements to

create entry barriers to new entrants (Schot & Steinmueller, 2018). To address knowledge barrier issues, the state is called to cultivate localized learning and strengthen the networked linkages across different knowledge producers—i.e., private firms, public institutions, and universities—to facilitate knowledge sharing process (Asheim & Herstad, 2005; Etzkowitz & Leydesdorff, 2000; Lundvall, 2007; Vertova, 2014). The state measures on this frame include the fostering of networked linkages, the cultivation of learning capacities, and the harmonization of the relationship between knowledge producers and across different levels. The related concept of the 'triple helix' of university-industry-government interactions in the knowledge society also emerged during this period (Etzkowitz & Leydesdorff, 2000).

Lastly, the third frame of innovation by Schot and Steinmueller (2018) is known as 'transformative change', which gradually gained traction in the 2000s. Schot and Steinmueller stated that the attempt to organize the economy around addressing societal and environmental challenges rather than maximizing profits would inevitably entail transformative changes in the pre-existing socio-technical and socio-political system. From this transformative perspective, addressing societal challenges is a means for firms and national economies to enhance economic competitiveness on the global market insofar as the normative rules of the market economy have shifted towards social responsibility (Acciai, 2021; Borrás, 2009; Gassler et al., 2008; Hicks, 2016). This requires the greater role of the state as a 'market shaper' instead of a 'market fixer' (Mazzucato & Robinson, 2018; Stirling, 2015). To name a few, the challenges could arise from democratic deficits in innovation processes (Stirling, 2015), public disengagement with science and technology (Irwin, 2006; Tomasso et al., 2021), accountability and transparency issues with emergent technologies (Stilgoe et al., 2013), and climate change with biodiversity losses and deforestation (Mazzucato, 2018a, 2021). To relate the third frame of innovation: transformative change back to the inquiry of the paper, it will be taken as the most recent global template of

how the current economic landscape ought to be organized in relation to innovation. To sum up, Table 1 below outlines the Frames of Innovation on how economies ought to be structured concerning state intervention in innovation at different historical times.

Table 1

The Frames of Innovation in different historical times

Frame	**Historical period**	**Underlying logic**	**Examples of policy measures**
First frame	Post World War-II	Built upon the neoclassical economic assumption of 'perfect markets', which limits the state intervention to addressing market failure	• Scale up R&D spending in places where the market fails. • Level the playing field for businesses through legal and regulatory changes.
Second frame	1980s	Acknowledges the 'stickiness' of knowledge production that creates important barriers to new entrants and obstructs knowledge sharing.	• Foster the networked linkages between different knowledge producers. • Cultivate localized learning capacities. • Harmonize the relationship between different knowledge producers.
Third frame	Since 2000s	Economic outputs should address societal and environmental grand challenges either arising from or assisted by innovation and technology.	• Increase social equality for all social classes. • Allocate capital to green and sustainable sectors. • Engage public opinion in disputable science areas. • Increase transparency and accountability of corporate practices to protect users' data privacy from digitalization.

Source: Authors' own compilation from (Schot & Steinmueller, 2018)

2.2. Varieties of Capitalism

The landmark work by Hall & Soskice (2001) on the VoC framework and its expansion (Allen & Aldred, 2009; Herrmann & Peine, 2011; Nölke et al., 2015, 2019) have categorized the liberal market economy (LME) modeled on the US and the state-permeated market economy (SME) modeled after China. The VoC literature outlines how the political economy of nations plays a

critical role in shaping technological trajectories (Mikler & Harrison, 2012), revealing that LMEs and SMEs approach technological innovation differently. In detail, it argues that Anglo-Saxon LMEs, with greater disposition to competitive market (Hall & Thelen, 2009), are said to better support radical technological change (Block & Keller, 2009; Mikler & Harrison, 2012). The reason why the US-style LME excels at technological breakthroughs is that LME supports entrepreneurial managers to seek for market opportunities and make decisions free from government intervention and broader social responsibilities (Hall & Soskice, 2001; Mikler & Harrison, 2012). However, the US government is by no means hands-off in technological advancement, as evidenced by the longstanding literature on the strong state presence in basic research through DARPA and the Department of Defense (Mazzucato, 2018b). John Mikler & Neil Harrison (2012, pp 188) stressed that "features of a state are not just a matter of whether the state is involved in innovation or not, but the rationale for and mechanism of its involvement". To leverage the competitive advantage of a competitive market, the state involvement in LMEs focuses on standard market relations, free-flowing global production networks through joint ventures or multinational contractors, deregulation measures such as tax breaks, and regulatory measures to safeguard level-playing ground for all competitors (Hall & Soskice, 2001; Hall & Thelen, 2009).

In contrast to LMEs, SMEs focus on 'centrally planned' technological change with an active state role partaking in capital accumulation in selected sectors for technological upgrading (Hung, 2008; Overbeek & Apeldoorn, 2012; Parnell & Robinson, 2012) and its close coalitions with domestic business. These features create a somewhat fragmented yet dynamic state-permeated market economy. Very often, SMEs adopt a dual state approach in the global economy: on the one hand, states manage to limit global actors from accessing the domestic market and thus secure a domestic mass market for domestically made, cost-effective, and low-

end tech production; on the other hand the states are also selective in taking part in the global production networks (Nölke et al., 2015, 2019). Via relatively high tariffs on imports and selective procurement of importing technologies, most SMEs' innovations actively adapt foreign technology into domestic products that sell on domestic markets (Nölke et al., 2019). Last but not least, the VoC claims that SMEs "maintain relatively weak patent rights systems, which facilitate reverse engineering and technological catch-up" (Nölke et al., 2015, pp.545). Table 2 outlines the relevant propositions of the VoC pertaining to the organizing of innovation discussed previously.

Table 2

Varieties of Capitalism pertaining to the innovation field

The innovation field	**LME**	**SME**
Transfer of innovation	Radical innovation Fast adaptation to changing market conditions	Active adaptation of foreign technology through reverse engineering.
Innovation Agencies	Rely on joint ventures or multinational contractors in global production networks	Rely on state-led innovation through selective integration of global production networks
Intellectual Property rights	Strong patent right regime	Weak patent rights regime

Source: Authors' compilation from (Nölke et al., 2015, 2019; Peck & Zhang, 2013)

However, the 'institutional determinism'(Coates, 2002) focus of the VoC framework has been criticized for its rigid compartmentalization of institutional properties of each model into an iron cage, falling into the fallacy of ahistorical and deterministic processes (Crouch, 2005; Peck & Zhang, 2013; Streeck, 2010). At the heart of the framework, it is argued that to attain comparative advantages and gain proximity to the supposedly 'ideal type' of one capitalist economy model (Fligstein, 1996; Howlett, 2018; Howlett & Mukherjee, 2014; Howlett &

Rayner, 2007), LMEs ideally engage in high-end tech industries whereas SMEs ideally engage in low-end tech industries (Herrmann & Peine, 2011; Schmid & Kwon, 2020; Schneider & Paunescu, 2012). However, Schneider & Paunescu (2012) argued that institutional complementarities of a defined ideal-typical model are more varied than the VoC framework suggests. One of their findings shows that economies that moved towards the LME model have also specialized more strongly in high-tech over time, indicating that countries might travel across different capitalist models at different times. As implied in the introduction, given that China has been striving to shift from low value-added production to a more knowledge-intensive production, it is empirically timely and theoretically apt to raise the question of whether China will take a materially and normatively closer pathways to the LME model in this process.

As follows, we will critique the taken-for-granted ahistorical properties of these two models in this unfolding historical juncture where China strives for an economy closer to that of the US in the past twenty years. Hereby in the discussion section 5, the paper seeks to modify Table 2 on the grounds of the empirical findings.

3.Methodology

3.1 Data sources and selection criteria

Since the national policy blueprints are the vehicles through which the innovation-based futures act upon the present, the paper has taken STI strategies at the national level as the units of analysis. These strategies consist of key reforms and milestones at different times in each country. There are three criteria upon which we have selected the national STI policy strategies: first, they have to be in the period of the past twenty years in that for the past twenty years China strategically has begun to shift its position from an ‘innovation emulator’ to an ‘innovation leader’ calling for indigenous innovation and innovation-driven societies; second, the strategies have to be forward-looking, visionary, long-term planning; and third, the issuers of the strategies

have to be key and authoritative national actors mandated with the capacity of projecting the innovation trajectories of the country. Based on these criteria, we have chosen five national policy strategies in China and five in the US. See Appendix 1 for more information.

3.2 Three instrument families and three-step coding strategy

Our coding objective was to capture the meaning of 'innovation-based futures' in the texts of the strategies. To capture the texts of 'innovation-based future', we reiterate the concept of 'innovation-based future', which anchors innovation as the primary engine for 'economic growth'. Therefore, in the first coding round, we extracted the body of texts centered around this meaning. During the first round of extraction, 45% and 44% of the text in the policy strategies of the US and China were extracted.

In the second step, to further categorize the extracted text from the first round, we adopted a deductive logic that assigned specific portions of text to pre-identified instrument families: regulatory instruments, economic and financial instruments, and soft instruments (Borrás & Edquist, 2019). As detailed in the codebook in Appendix 2, regulatory instruments refer to 'legal tools (directives, rules, laws, etc.) for the regulation of social and market interactions'(Borrás & Edquist, 2019, pp. 6-7). Economic and financial instruments provide 'incentives or disincentives to support or discourage actions' in society or the economy (Borrás & Edquist, 2019, pp. 6-7). Soft instruments provide 'recommendations, normative appeals and less hierarchical forms of cooperation between public and private actors based on the mutual exchange of information among actors'. As a result of this step, we identified a total of 321 occurrences of instrument families: 137 occurrences in the US and 184 occurrences in China, accounting for 33% of the extracted text from the US documents and 34% from the China documents.

The third step entailed more complex and reflexive work that involved Thematic Analysis (TA) (Nowell et al., 2017). We used an inductive approach to derive the emerging themes (sub-instruments) from the instrument families. TA requires coders to take an active part in identifying, organizing, and describing sub-instruments found within a data set (Braun & Clarke, 2006). Distinctive sub-instruments were identified and organized within each instrument family. We only developed new sub-instruments if the portions of the text could not be categorized into the formerly established sub-instruments. We stopped developing new sub-instruments when all the meaning structures of the text were organized. In total, we categorized 44 sub-instruments: 22 in China and 22 in the US. The respective sub-instruments within each instrument family will be displayed in section 4.

4. Empirical findings

By probing into the varieties of policy instruments, we get a better sense of how a common innovation-based future has acted differently or similarly upon the present. After the first and second coding rounds, we found that the distribution of policy instrument families displays remarkable similarity across the US and China. To be more specific, regulatory instruments account for 43% of the total instrument families in the US and 39% in China; economic and financial instruments account for 18% in the US and 20% in China, and soft instruments account for 39% in the US and 41% in China. This means that the US, as a representative of LME, and China, as that of SME, execute their innovation-based economy futures through strikingly similar configurations of instrument families. The third coding round enabled us to identify all the sub-instruments, with percentages indicating their shares of words over the total words of their respective instrument family.

In what follows, we have narrowed the analytical focus to the top two dominant sub-instruments to direct our analysis. Our analysis not only attends to what the dominant sub-instruments are in

relation to VoC and the Frames of Innovation, but also attends to the changing meanings attributed to sub-instruments over the past twenty years. It is worth noting that a few exceptions have been made if the percentage (the share of the words) of the 3rd ranked sub-instrument is very close to the percentage of the 2nd one. Under that condition, we will also take the 3rd ranked sub-instrument on board. To be more specific, in the regulatory instrument family, in China *Intellectual Property Right*s (IPR) (16%) is very close to the 2nd ranked *National STI program* (17%), and thus IPR is included in the analysis for both countries. In the soft instrument family, the three top sub-instruments in both countries all fall in this category because the 3rd ranked sub-instruments in both countries score very close to the 2nd ranked sub-instruments (21% and 20% in the US; 22% and 21% in China).

4.1. Findings on regulatory instruments

Regulatory instruments are policy devices through which coercive practices, guidance, directives, laws, and binding regulations attempt to shape the 'rules of the game' in the STI domain. This instrument category reflects the will of policymakers to regulate specific fields. Table 3 displays all the sub-instrument types within the regulatory instrument family in the US and China. Of all the sub-instruments in the regulatory instrument family, the top two dominant sub-instruments in the US are *Measures to optimize the market* (27%) and *Education* (17%) in the US*; while Evaluation and management system* (48%) and *National STI program* (17%) in China. As stated before, *Intellectual property rights (IPR)* also fall into our analysis since its share of coverage (16%) is very close to the 2nd ranked *National STI program* (17%) in China. Very importantly, IPR also constitutes an essential theoretical property of VoC framework for organizing innovation.

Table 3

Sub-instruments identified in the regulatory instrument family

Regulatory instruments			
United States		**China**	
Measures to optimize the market	*27%*	*Evaluation and management system*	*48%*
Education	*17%*	*National STI program*	*17%*
Open government	12%	*Intellectual property rights*	16%
National S&T programs	10%	Central and local government relations	8%
Evaluation and management Systems	9%	Personnel system	6%
Internet/Broadband	8%	Consultation mechanism	2%
Intellectual property rights	5%	Defense science	2%
New government role/body	5%	Pricing mechanism	2%
Harmonization	4%		
Export controls	2%		

Percentages indicate the shares of words by sub-instrument over the total words in the regulatory instrument family.

Italic legend: *sub-instrument* that falls into our analytical subjects.

In the US, Measures *to optimize the market* are found in all the STI policy strategies over the twenty years. It has been heavily used to target areas where the market fails, implying an innovation logic that draws on the first frame of innovation. *Measures to optimize the market* are expressed through different discursive forms, e.g., enforcement of anti-trust laws (2009-08-05)[1], increased supervision of the financial market (2009-08-05 & 2015-11-16), improvement of public goods in areas such as broadband access and infrastructure (2004-04-26 & & 2009-08-05 & 2015-11-16), and support for open capital markets (2009-08-05 & 2015-11-16). It also covers regulatory harmonization in technology transfer (2015-11-16 & 2020-05-15) and net neutrality

[1] We include dates of the year within brackets, e.g. (2009-08-05), to indicate the specific date of the year of a central-level STI policy strategy in which a particular instrument was found.

(2004-04-26 & 2009-08-05 & 2015-11-16) to safeguard the equal interests of both internet service providers and end-users.

Unfolding alongside the underlying principles of 'fixing' the market in executing an innovation-based future, a set of assistive measures are found to be scaffolding the free-flowing human capital market in the data, e.g., the call for improved institutions in high-tech visa applications (2009-08-05) and establishment of a more 'clear, consistent, and predictable' visa system for workers (2020-05-15). In this vein, these assistive measures speak to the fundamentals of the LME model, which thrives on a fluid and obstacle-free global labor market.

Education, as the second dominant sub-instrument in the regulatory family, greatly emphasizes the upstream of tech knowledge supplies in the US. We argue that this should be added as one crucial feature of the LME model regarding innovation systems. *Education* is expressed in other ways through the cultivation of the early development of Science, Technology, Engineering, and Mathematics (STEM) education in young people as well as for teachers (2005-12-28 & 2015-11-16 & 2020-05-15), the reform of public universities to deliver complete and competitive education (2009-08-05) and the cutdown of 'wasteful spending' in student aid programs (2009-08-05). Arguably, *Education* draws on both the first Frame of Innovation regarding education as a public good and the second frame of innovation attempting to address systemic and structural failures in program administration (e.g., time limits on federal aid). In short, two dominant regulatory sub-instruments—*Measures to optimize the market* and *Education*—have risen to prominence as the proximal carrier to execute the present toward the innovation-based future in the US. In other words, the US version of the imaginary innovation-based future thrives on a fluid obstacle-free high-tech labor market and a competitive and efficient provision of STEM education.

However, China reveals noticeable contrasts in the deployment of instruments in this family compared to that of the US. *Evaluation & management system* account for nearly half of the shares (48%) in China and speaks very little to the first frame of innovation revealed by the US. Instead, to pursue an innovation-based future in China, regulatory emphases have been biased towards the state-led research evaluation standards and management practices to steer the STI activities under the national directives.

Evaluation & management system encompasses a range of measures to crystalize and formalize the research and development (R&D) system: 1) to integrate R&D spending and its performance into the evaluation metrics that will be used as a benchmark to secure further state funding (2012-09-23 & 2016-05-19 & 2019-01-08); 2) to disclose expert assessment results of science projects to the public to boost public trust and transparency (2019-01-08); 3) to actively supervise and oversee the use of public funds in national key STI programs and public procurement of imported technology (2006-02-07 & 2012-09-23 & 2016-05-19 & 2019-01-08); and 4) to enhance the research integrity of researchers and STI personnel (2012-09-23). In short, Evaluation *& management system* represents a tremendous institutional effort to optimize the NIS, drawing both on the second Frame of Innovation and the hegemonic SME logic to assert state control in organizing innovation systems.

As the second top salient sub-instrument (17%), the *National STI program* self-evidently mirrored the second frame of innovation, expressed through the examples of the Beijing-Tianjin-Hebei economy circle (2016-05-19), the Yangtze River Economic belt (2016-05-19) and the Guangdong-Hong Kong-Macao Greater Bay Area (2019-01-08). By shifting the organization of innovation systems from focusing on a single research entity to networks of research entities, the instrument is devised to foster technological transfer, facilitate knowledge flows, and reshuffle resources across different entities. Interestingly, as we observed, the second

Frame of Innovation has been coupled with the third in recent years, orienting the economy towards a more socially responsible and greener direction. For instance, the 69 National Field Scientific Observation and Research Stations approved by the Ministry of Science and Technology have gained prominence in recent years to monitor energy safety, prevent natural disasters, and reduce the risk of power grids (2019-01-21).

Lastly, *Intellectual property rights (IPR),* as the third dominant sub-instrument with its share (16%) coming very close to that (17%) of the second one in China, signals that a 'weak patent rights regime' is not necessarily a defining institutional property of the SME model described in the VoC framework. In attempting to achieve an innovation-based future, an IPR regime working on the legal-based transfer of innovation has gained policy attention as China is dreaming closer to the US. Interestingly, the US and China differ in attributing the meaning packages to the instrument due to their different phases of development in the domain of IPR. The US discourse around IPR is cast with outward-looking visions to strengthen the position of American businesses in the global foreign market, e.g., through protecting IPR in overseas trade agreements and greater cooperation on fostering international standards (2009-08-05). While in China, IPR has a more inward-looking lens and emphasizes the regulatory nature of IPR, e.g., emphasizing the establishment of IPR trading system and prevent the abuse of IPR (2006-02-07), the protection of the interests of IPR owners (2006-02-07 & 2012-09-23 & 2016-05-19), optimization of the registration procedures (2019-01-08) and IPR incentive reforms (2019-01-21).

4.2. Findings on economic and financial instruments

The economic and financial instrument family refers to the economic and financial incentives or disincentives to support or discourage actions in society or the economy. The variants of the sub-instruments reflect the varied preferences of policymakers in the deployment of economic

and financial tools. To not overcomplicate the analysis, we insulate the analysis from the further investigation of the volume and scale of these sub-instruments involved over the past twenty years, and therefore their impacts on society are not discussed here. Thus, the shares of each sub-instrument in Table 4 only indicate the policy preferences of each sub-instrument in the imagination of an innovation-based future. Surprisingly, *Direct fiscal funding* topped both in the US and China, signaling its popularity as an economic tool to propel the present towards an innovation-based future. However, this sub-instrument is disproportionately pronounced in the US deployment, accounting for 72% in this family cohort, whereas the six sub-instrument types in China are more evenly distributed. The second top sub-instrument is *Tax relief* (20%) in the US and *Banking and insurance* (22%) in China.

Table 4

Examples of dominant themes in the economic and financial instrument family

Economic and Financial Instruments			
United States		**China**	
Direct fiscal funding	72%	*Direct fiscal funding*	27%
Tax relief	*20%*	*Banking and insurance*	*22%*
Loans	4%	Income distribution policies	15%
Prizes	4%	Tax relief	14%
		Stock/intellectual property trade	14%
		Venture capital funds	9%

Percentages indicate the shares of words by sub-instrument over the total words in the economic and financial instrument family.

Italic legend: *sub-instrument* that falls into our analytical subjects.

As the most dominant sub-instrument in both countries, *Direct fiscal funding* targets specific areas deemed as economically deficient in a local context, with an underlying logic linking to the first frame of innovation to tackle market inefficiency. Unlike the relatively evenly distributed deployment of different kinds of this instrument family in China, the prominence of

this instrument in the US indicates two matters: 1) the federal state is granted legitimacy to direct money to where it is needed; 2) a limited interventionalist powers of the federal apparatus in the US as an active market participant in the process of financialization.

When delving into the meaning packages of the instrument, the US and China also differ in the priority areas they deem important to achieve an innovation-based future. The US centered its direct fiscal funding around the scale-up of federal R&D expenditure (2004-04-26 & 2005-12-28 & 2009-08-05 & 2015-11-16), greater and equal access to broadband infrastructure (2004-04-26 & 2009-08-05 & 2015-11-16), hydrogen technologies (2004-04-26 & 2009-08-05), funds for regional innovation clusters (2009-08-05 & 2015-11-16) and the education sector (2004-04-26 & 2009-08-05 & 2015-11-16). In China, the focus shifted from agriculture sectors (2006-02-07), state-run venture capital investment (2006-02-07 & 2012-09-23), high-tech manufacturing equipment (2012-09-23), small and medium-sized enterprises (SMEs) funds (2012-09-23 & 2019-01-21), to most recently scale-up of basic research (2019-01-21).

Tax relief, as the second top sub-instrument (20 %) in the US, has been underpinned by the same logic of the first frame of innovation, expressed through the Research and Experimentation Tax Credit (2004-04-26 & 2009-08-05 & 2015-11-16), depreciation of capital expenditures (2004-04-26), and the tax elimination on capital gains of small businesses (2009-08-05). Similarly, tax incentives account for 14% of shares in China, exemplified by the pre-tax deduction for corporate R&D expenditure (2006-02-07 & 2012-09-23 & 2019-01-21), the depreciation of high-end equipment for R&D activities (2006-02-07, 2012). However, some unique forms of Tax Relief distinguish China from the US: e.g., a refund of value-added tax on the procurement of advanced scientific laboratory equipment overseas (2006-02-07) and tax benefits on overseas technology transfer activities and technical consultation (2012-09-23). These tax policies highlight the uniqueness of China's SME model in which reverse engineering encourages

product imitation to adapt foreign technology to domestic markets. Equally unique on the US's side is its tax relief on telecommunications infrastructure, namely making the internet tax moratorium permanent (2004-04-26) and making broadband access tax-free (2004-04-26), which is not at all considered by China.

As the second dominant sub-instrument in China, *Banking, and insurance* accounts for 22% of the coverage. This observation reaffirms that the Chinese financial system has long been featured by the dominance of the state-controlled banking sector (Hu et al., 2011). The most significant four banks in the world by asset size are all state-owned Chinese commercial banks – the so-called Big Four, having combined more than $17.32 trillion in assets according to the 2021 annual rankings (S&P Global Market Intelligence, 2018). *Banking and insurance* have been operationalized towards a more abundant provision of credits for tech firms which insurance companies could potentially underwrite in bank lending, such as the establishment of intellectual property credit for light-asset and small and medium-sized companies (2006-02-07), the development of insurance products suitable for different financial stages and conditions of the companies (2012-09-23), and experiments with loan risk compensation pilot projects (2019-01-21).

4.3 Findings on soft instruments

The soft instrument family refers to non-coercive rhetorical devices mobilized by policymakers to achieve particular ends. Given the reasons stated before, we encompass three top instruments in each country as displayed in Table 5: *Education & Training*, *Partnership & collaboration* and *Entrepreneurship in the US* and *Partnership & Collaboration*, *Entrepreneurship* and *Industrial competitiveness & Technical standards* in China (in the descending orders by percentage shares). A similarity between *Education* being ranked second in the regulatory instrument

family in the US and *Education & Training* in China suggests that an instrument of a similar substance can travel across different instrument families.

Table 5

Examples of dominant themes in the soft instrument family

Soft instruments			
United States		**China**	
Education & Training	*22%*	Partnership & Collaboration	35%
Partnership & Collaboration	21%	*Entrepreneurship*	22%
Entrepreneurship	20%	*Industrial competitiveness & Technical standards*	*21%*
Coordination bodies	11%	Personnel and reward system	8%
Focus areas	11%	Regional Innovation	6%
Innovations private sector	7%	Education and training	4%
Improvements public sector	6%	Evaluation reform	4%
Technical guidance	3%	Popularization of science	1%

Percentages indicate the shares of words by sub-instrument over the total words in the soft instrument family.

Italic legend: *sub-instrument* that falls into our analytical subjects.

Education & Training (2004-04-26 & 2005-12-28 & 2009-08-05 & 2015-11-16 & 2020-05-15) emerged as the top soft sub-instrument (22%) in the US with two primary meanings. In the first type, the focus centered on increasing the quality of education (2005), expanding access to higher education (2009), engaging students of all backgrounds (2015), and integrating research-based STEM pedagogy and practices into the classroom (2020). The second type of meaning revolves around the inclusiveness and democratization of entrepreneurship, especially targeting women and minorities, which relates to the third frame of innovation. From this perspective, the economy is organized around the principles of addressing societal challenges and aims to provide entrepreneurs with more personalized training resources (2009-08-05) and non-traditional ways to access training through online courses or boot camps (2015-12-28).

Education & Training, similar to *Education* in the regulatory instruments, validates the US's LME fundamentals underlining the human capital investment and the knowledge workforce in marching towards an innovation-based future. The underlying logic of *Education & Training* stems from the first frame of innovation that confines the role of the state in the public arena. Interestingly, the logic gradually gets to be coupled with the third frame stressing the inclusiveness and democratization of participants in recent years.

On China's side*, Industrial Competitiveness & Technical Standards* emerges as the third dominant soft sub-instrument (21%) in China. Stemming from the logic of the second frame of innovation addressing the systems of the innovation, this sub-instrument seeks to work on the standardization of the industrial actions at key strategic industry levels rather than at individual-firm levels to improve the industrial competitiveness as a whole (2006-02-07 & 2016-05-19 & 2019-01-21) and assert China's position in the global technology standards competition (2016-02-07 & 2019-01-21). China has put technical standards in the contexts of the experimental laboratories (2006-02-07), the technology transfer process (2006-02-07), the industrial upgrading in global value chains (2016-05-19 & 2019-01-08), and most recently, the global acknowledgment of China's technology standards in advanced technology (2019-01-21).

As the shared dominant sub-instrument, *Entrepreneurship* is a common normative appeal in both countries. However, *Entrepreneurship* is endowed with different sets of meanings in each country. In the US, *Entrepreneurship* connects to ideas about open and competitive capital markets, considered one of the greatest strengths of the American liberal economy (2009-08-05), as well as to a fair and predictable immigration system (2015-11-16) and regional innovation ecosystems (2015-11-16) to support entrepreneurship. The focus is on individual entrepreneurs (native or immigrant) in a competitive world, connecting risk-taking entrepreneurs and the power of the company to the foundational 'building blocks' of an innovation-based

future. Therefore, the logic behind these normative appeals in the US resonates with both the first and second frames of innovation that legitimate public intervention to address market and systemic concerns to support entrepreneurship.

In contrast, China centered *Entrepreneurship* around the party-state apparatus to support the development of enterprises (2006-02-07 & 2012-09-23 & 2019-01-21), seeking to elevate them as the key drivers in the pursuit of an innovation-based future. *Entrepreneurship* in China is closely associated with the modernization and corporatization of state-owned enterprises by the installation of corporate structures (2006-02-07) (in line with the mass corporatization and shareholding reforms starting in the mid-1990s (Wang, 2015)), the empowerment of enterprises to undertake national key research projects (2012-09-23), 'going out efforts' to establish R&D center overseas (2006-02-07 & 2016-05-19), and most recently about the cultivation of a professional, market-oriented, and international team of professional managers (2016-05-19) (in line with the reform to detach the state involvement in direct business management (State Council and CCP, 2015)). Entrepreneurship in China is cultivated as a part of the state-regulated capitalist project attempting to cultivate and strengthen the capacity of enterprises, drawing mainly on the second frame of innovation.

Partnership & Collaboration, while a shared theme, also takes on different and similar meanings in the two countries. This sub-instrument in the US changes its embedded meanings over time. Initially, it introduced an outward-facing approach focusing on 'international and interagency partnerships' at the NSF to attract global talent and training opportunities (2005-12-28) to 'partnerships of NSF-funded research with mission agencies, national labs, or industry'. Later on, it adopted an inward-facing strategic planning approach to speed up technology transfer (2020-05-15 by orchestrating different key agencies involved in science and technology. The 2020 STI policy strategy highlights that 'the US faces increased competition from countries

that organize their S&E enterprises much more centrally' (2020-05-15, pp. 5). The more orchestrated response to challenges in recent years speaks to the second frame of innovation due to the concerns about systemic failures that may erode US leadership in the innovation-based future. The response to US challenges also takes the third frame of innovation principle as it calls for 'broadening participation in the US S&E enterprise' (2020-05-15, pp.19).

China, in contrast, consistently prioritizes *Partnership & Collaboration* in the form of the 'national systems of innovation' over the 'ecosystem' described in the US, suggesting a more systemic and less organic way of organizing innovation towards an innovation-based future. The idea of *Partnership and Collaboration* in China comes with a full commitment to fostering a strategic alliance between industries, universities, and public research institutes (2019-01-21). The sub-instrument is expressed through 'establishing new mechanism fostering research institutes and universities to provide services tailored to the innovation needs of companies (2006-02-07, pp.12)'; 'supporting key industrial enterprises, research institutes, and universities to jointly establish R&D sharing platforms (2012-09-23, pp.3); 'encouraging various innovation entities to build professional incubators and strengthen the personnel exchanges of different entities' (2019-01-21, pp 8). Overall, China draws heavily on systemic language to portray the collaborative relationship among different agencies, suggesting an alignment of its SME model with the second frame of innovation.

5. Discussion

We briefly restate the central question of the paper: to what extent do countries adopting an innovation-based future absorb global frames or retain their national features?

As China, an exemplar of the SME model, has been striving for an innovation economy closer to that of the US at this critical historical juncture, we found that the projection of the

innovation-based futures onto the present via policy instruments has largely kept the pathways of China apart from that of the US, even though one can easily assume that the Frames of Innovation will nudge countries to look quite similar in economic governance.

In the US, *Measures to optimize the market* and *Education* (regulatory instrument), *Direct fiscal funding* (economic and financial instrument), and *Education & Training* (soft instruments) confirm the archetypes of an LME model with an alignment to the first frame of innovation. The VoC framework (Hall, 2015; McLaughlin & Wright, 2018) argues that LMEs diffuse and absorb knowledge by leveraging their embedded global production network via joint ventures and multinational contractors as the key innovation strategy. The paper amends the LME model in the innovation field. Working towards an innovation-based future, the LME model found in US STI policies puts emphasis on the provision of an obstacle-free and competitive global labor market, the integration of research-based STEM pedagogy in education and training, fair and predictable visa conditions for global talents, and the fostering of individual entrepreneurship. In this light, the state involvement in the US is very much seen as an effort to overcome market failure that results from increasingly liberal relations in US product and financial markets (Mikler & Harrison, 2012). In relation to the Frames of Innovation, these dominant policy instruments are in line with the underlying principles of the first frame of innovation: the role of the state is restrained in the areas where the market is deemed insufficient, as also evidenced by anti-trust laws, broadband infrastructure, education sector, and one-off budget allocation indicated in the STI policy strategies.

In China, *Evaluation & management system* and *National STI program* (regulatory instruments), *Banking and insurance* (economic and financial instrument), and *Industrial competitiveness & technical standards* (soft instrument) all confirm the archetypes of an SME model aligned with the second frame of innovation. The VoC framework argues that SMEs diffuse and absorb

knowledge through the leverage of their selected integration of global productions and their production imitation through reverse engineering as the key innovation strategy. Likewise, the paper amends the SME model in the innovation field. Working towards an innovation-based future, the SME model we found in Chinese STI policies puts emphasis on the provision of sound and transparent state-led top-down funding evaluation and approval systems, a more robust networked knowledge linkage between industries, public institutions, and universities, the stronger synergies between state-led bank lending market and the insurance market to provide credit support for tech companies, and finally the industrial upgrading and the standardization of industrial behaviors to formulate domestic technical standards. Speaking of the Frames of Innovation, these dominant policy instruments align with the underlying logic of the second frame of innovation, which seeks to tackle 'systemic failures' by enlarging the state's roles.

We also challenge the proposition of the VoC framework that regards weak patent rights regimes as a static feature of the SME model (Hall & Soskice, 2001; Malik, 2017). In fact, this feature turns out to be more fluid than what the VoC suggests, especially at this historical juncture of the past twenty years. As shown below, Table 6 builds upon Table 2 in this paper to specifically include an amendment over *Intellectual property rights* and propose the category of innovation instruments. These amendments to the VoC framework seek to reflect timely, national historical shifts of LME and SME, reduce its over-simplification of reality, and steer the VoC literature in the innovation field toward increased focus on innovation policy instruments.

Table 6

Amendments to the Varieties of Capitalism framework in the innovation field

The innovation field	**LME**	**SME**
Transfer of innovation	Radical innovation Fast adaptation to changing market conditions	Active adaptation of foreign technology through reverse engineering.

The innovation field	LME	SME
Innovation Agencies	Rely on joint ventures or multinational contractors in global production networks	Rely on state-led innovation through selective integration of global production networks
Intellectual Property Rights	Strong patent right regime	Moving towards stronger patent regimes
Innovation instruments	Obstacle-free and competitive global labor market through fair and predictable visa conditions for global talents	A sounding and transparent state-led funding evaluation and approval systems
	Investment in upstream knowledge production through the integration of research-based STEM pedagogy in early education and training	Investment in robust networked knowledge linkages between industries, public institutions, and universities
	Direct fiscal funding and tax reliefs for tech companies	The augmentation of state-led banking and insurance to provide credit and capital support for tech companies
	Direct fiscal funding and tax reliefs for tech companies	The augmentation of state-led banking and insurance to provide credit and capital support for tech companies
	Individual risk-taking entrepreneurship	Industrial upgrading and the standardization of industrial behaviors to formulate domestic technical standard

Undeniably, we acknowledge the role that the Frames of Innovation plays in the imaging of innovation-based futures. While more subtle than the VoC, the influence of the third frame of innovation is revealed through the gradually changing meaning of a specific instrument type nested in the hegemonic VoC models. Put differently, while the different dominant instruments very much reflected in the respective VoC models, the meaning packages of the dominant instruments in each country have been gradually shifting towards the underlying principles of the third frame of innovation over time. For instance, the meaning packages of National STI program in China (a regulatory instrument) are shifting the key STI programs in a ‘greener and more sustainable’ direction. Likewise, the meaning packages of Measures to Optimize the Market (a regulatory instrument) in the US have been moving towards a more inclusive and democratic immigration system which expands its interest to all different social classes.

6. Conclusion

In this paper, we sought to examine the interplay between the taken-for-granted taxonomic distinction between LME and SME and the Frames of Innovation through their national articulation in the form of policy instruments as carriers of how innovation-based futures act upon the present. Overall, the findings show: 1) Both the US and China have been positioned closer to their distinct VoC framework (the national features) than the frames of innovation, particularly the third frame (the most recent global norms) in the imaging process of an innovation-based future; 2) The most recent global template still plays a role in the imaging process of an innovation-based future, but in a less obvious way that is revealed with the changing meaning structures of a certain instrument type nested within the preexisting archetypes of hegemonic VoC models.

Our findings contribute unique empirical and theoretical insights. First, the paper applies the novel conceptual lens of *isomorphic difference* (Irwin et al., 2021) to demonstrate the interplay between two dynamics—the Frames of Innovation and Varieties of Capitalism—that co-shape the innovation-based futures within national contexts. Our analysis provides a methodological advancement through the policy instruments approach to 1) enable the cross-country comparison of STI policies, 2) forecast the trajectories of the abstract-level socio-technical futures, and 3) open up an investigative space for tracing both local and global pressures in STI policies (Flink & Kaldewey, 2018; Godin, 2006). Second, by elucidating how the SME is materially and normatively different and similar to the LME at the historical juncture of pursuing innovation-based futures, the paper theoretically amends and expands the VoC literature pertaining to the innovation field. Finally, the paper broadens the literature on innovation-related policy instruments (Borrás & Edquist, 2019) through the detailed comparative case of China and the

United States. These policy instruments will be of great reference to policymakers in the innovation field.

The paper reveals how the envisioned future that acts upon the present takes considerable references from the national features albeit with the global trend seemingly pushing countries to converge along global frames. In this light, policymakers should take serious consideration of the importation of highly regarded global models and be aware of how the national features consisting of regional cultural expectations and institutional norms can interplay with global practices to achieve the intended outcomes. In addition, the paper calls for future scholarship to explore and unpack other market economy types in the innovation field to further advance and develop the substance of Table 6. This will serve as a new knowledge base for future state and private actors to understand and organize innovative activities in different socio-political contexts.

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Appendix 1

China's STI Policy Strategies

No.	Year	Title	Issuing Body
1	2006-02-07	Medium- to Long-Term Plan for Scientific and Technological Development (2006-2020)	The State Council
2	2012-09-23	Opinions on deepening the reform of the scientific and technological system and accelerating the construction of the national innovation system	Ministry of Science and Technology
3	2016-05-19	Outline of National Innovation-driven Development Strategy	Central Committee of CPC & The State Council
4	2019-01-08	Notice of the General Office of the State Council on Grasping and Implementing the Relevant Documents Conferring Greater Autonomy on Scientific Research Institutions and Staff	The State Council
5	2019-01-21	The guidance to join forces and enter the ranks of innovative countries in Xi Jinping 's new era of socialism with Chinese characteristics	Ministry of Science and Technology

The US STI Policy Strategies

No.	Year	Title	Issuing Body
1	2004-04-26	Promoting Innovation and Competitiveness—A New Generation of American Innovation	The White House
2	2005-12-28	2020 Vision for the National Science Foundation	National Science Board
3	2009-08-05	A Strategy for American Innovation: Driving Towards Sustainable Growth and Quality jobs	Executive of Office of the President & National Economic Council & Office of Science and Technology Policy
4	2015-11-16	A Strategy for American Innovation	Executive of Office of the President & National Economic Council & Office of Science and Technology Policy
5	2020-05-15	National Science Board Vision 2030	National Science Board

Appendix 2

The codebook. Adapted by authors from Borras and Edquist (2019)

Type of instrument	Definition	Examples
Regulatory instruments	The role of the government to define the frameworks of the interactions among different stakeholders.	1. Intellectual property rights. 2. Competition (anti-trust) law. 3. Ethical regulations. 4. Reconfiguration of the structures of entities 5. Foreign visa system. 6. Commercialization efforts for specific technologies. 7. Systems to assess the research capability 8. Mandate to increase revenue for R&D 9. Management systems or regulation of S&T investments. 10. Explicit allowances for research personnel to work in enterprises.
Economic and financial instruments	The instrument family relies on actions that give positive incentives (encouraging or promoting certain activities) or disincentives (discouraging or restraining certain activities) in STI.	11. 'In-block' support of R&D. 12. Competitive funding of R&D. 13. Tax exemptions. 14. Tax reduction in export or import of high value-added products. 15. Public procurement to enhance innovation. 16. Venture capital support from the state. 17. Favorable loans/loan guarantee. 18. Insurance services for high-tech enterprises. 19. Different financing channels for SMEs. 20. Wage increase/ conferment of shares as rewards. 21. Venture capital investment.
Soft instruments	The soft instruments provide recommendations, make normative appeals, or offer voluntary or contractual agreements. The instrument family is characterized by suggesting actions that are voluntary and non-coercive.	22. Voluntary technical standards at the national or international level. 23. Codes of conduct for firms, universities, or public research organizations. 24. Public–private partnerships sharing costs, benefits, and risks in the provision of specific public goods. 25. Popularization of the knowledge to the public. 26. Communication instruments (for example, diffusion of scientific knowledge by using events like “research days” or TV documentaries). 27. Talent retention scheme: provide housing and insurances for overseas researchers.

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Article 4 - Blending Curiosity, Market, and Mission Rationales: Capturing *Isomorphic Differences* in National Science, Technology, and Innovation Policies

Blending Curiosity, Market, and Mission Rationales:

Capturing *Isomorphic Differences* in

National Science, Technology, and Innovation Policies

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Abstract

The existence of numerous accounts of changing science, technology, and innovation (STI) policies raises the question of whether they describe different phenomena or instead offer competing conceptualizations of the same basic pattern of activities. Our paper develops and tests an analytical framework for capturing ideational familiarities and distinctions in STI policies over time. Employing the concept of *isomorphic difference* to investigate overarching patterns and local variations, we inductively outline three basic rationales for the main purpose of research investment: 'curiosity,' 'market,' and 'mission.' Analyzing their presence in selected policy documents from China, Denmark, and the United States during 2003–2020, we find that the three rationales are indeed at play and that national STI strategies take shape as combinations and variations of them. Comparisons of the national blends also reveal important similarities and differences regarding scientific freedom and excellence, forms of competition and collaboration, and technology as a type of mission. We argue that changing STI policies can usefully be understood as ideational blends of the three basic rationales currently united around technology and a quest for novelty.

Keywords: STI policy; policy rationales; isomorphic difference; United States; China; Denmark

1. Introduction

Science, technology, and innovation (STI) policy has become central in advanced economies. At the same time, the ideas informing STI policies and guiding the distribution of public funding for research have evolved, although characterizations of the changes vary in the literature. A classic distinction is between four reasons for the support of scientific research: 'cultural,' 'economic,' 'social,' and 'educational' (Brooks 1971) but there are numerous others. Elzinga and Jamison outline four "policy cultures" giving rise to different approaches in STI policies: bureaucratic, academic, economic, and civic (Elzinga and Jamison 1995). Others identify a development from a 'Mode 1' to a 'Mode 2' knowledge production (Gibbons et al. 1994a; Shinn 2003; Hessels and van Lente 2008) with strong focus on applied science and user-involvement. Some authors notice a development from science policy through technology policy and innovation policy to knowledge policy (Lundvall and Borrás 2009). Others find evidence for a development in public funding toward thematic priorities (Lepori et al. 2007). Elzinga points to three successive phases: from a legitimation period through a period of professionalization to a period of accountability (Elzinga 2012). Most recently, a development from a growth frame to a transformative frame and a "third generation of innovation policy" has been identified (Schot and Steinmueller 2018; Diercks et al. 2019), while others characterize the development as one from a market-fixing approach to a renewed mission-oriented approach (Mazzucato 2018). Finally, Benner identifies four trends in contemporary STI policies: the importance of research for state formation; the growing significance of meta-governance; the alignment of research and economic growth; and the connection to social processes (Benner 2018a).

In addition to general trends, a significant variation across countries and regions has been observed (Lepori et al. 2007). Rather than representing distinct phases or homogeneous frameworks, there might be overlaps and cumulative effects where new policies encompass instruments and rationales from previous periods in a multi-layered and distributed system (Lepori 2011; Diercks et al. 2019; Edqvist 2003). For example, Swedish science policy has been characterized as a system of three superimposed layers: science as a motor of progress; science as a problem solver; and science as a source of strategic opportunity (Edqvist 2003). It is also evident that there are multiple, potentially intersecting conceptualizations. Examples are "national innovation systems" (Lundvall 2010), "knowledge economy" (Powell and Snellman 2004), "triple helix" or "Mode 3" (Etzkowitz and Leydesdorff 2000) and "responsible innovation" (Saille 2015; Stilgoe et al. 2013). This co-existence of accounts and

conceptualizations may reflect that accounts of STI policies intersect with different theoretical models of innovation (Godin 2017). However, Lepori and colleagues argue that there is a lack of systematic comparisons between countries and across time, which makes it difficult to conclude how and to what degree general trends are affecting and reflecting national or regional specificities (Lepori et al. 2007).

This paper focuses on the level of ideas to investigate general and local patterns. Employing the concept of *isomorphic difference*, we pursue the question: *What are the ideational similarities and differences in national STI policies?* To allow comparisons across time and geography, we identify three basic rationales for what research should be driven by – "curiosity," "market," and "mission." We then examine their presence in fourteen national STI strategies in China, Denmark, and the United States (US) in the years 2003–2020, each aiming to set the political direction for national STI policies. Our comparative analysis suggests a shared trend towards what we term a "blending" of the three rationales around a growing emphasis on novelty and technological development. It also uncovers national differences regarding the view on scientific freedom and excellence, competition and collaboration, and types of mission. We discuss how our findings, including the notion of "blends," contribute to the understanding of changing STI polices. We also address the methodological contribution of the *isomorphic difference* approach to capture similarities and differences in such ideational blends.

2. Theoretical approach

Our analysis of ideational changes in STI policies employs the concept *isomorphic difference* (Irwin et al. 2021) to guide the comparison across countries over time. *Isomorphic difference* refers to the way ideas and practices travel, evolve, and become domesticated in various ways. It combines insights from institutional theory and science and technology studies (STS) to illuminate patterns of similarity and distinctiveness in policies as well as underlying dynamics.

Institutional theory views societal institutions as arising from cultural-cognitive, normative and regulative elements that bring stability and meaning to social life (Scott 1995). DiMaggio and Powell point to three types of "isomorphic pressures" that work to homogenize organizations: coercive, mimetic, and normative pressures (DiMaggio and Powell 1983)(p.150). At work is also a range of key societal symbolic systems or rationales that order social life and active beliefs and motives, e.g., market, state, democracy, family, and Christianity. These rationales are each guided by a particular "institutional logic" (Friedland and Alford 1991)(p.232) that can be

distinguished by a set of generic categories, e.g., “root metaphor,” “sources of legitimacy,” “sources of authority,” “informal control mechanisms” and “economic system” (Thornton et al. 2012)(p.76). Thornton and colleagues further theorize an “inter-institutional system” in which institutional logics co-exist and are created, enacted, and recomposed. Although the categories shape individual and organizational preferences and interests, the authors stress that “we know little about how the type and level of cognitive as well as social restraint are likely to vary by institutional order or by recombination of [the categories]” (ibid)(p.58). Accordingly, they encourage historical and comparative studies of institutions to illuminate the dynamics and complexities of institutional systems (ibid) (p.173).

Johansen and Waldorf argue that logics have predominantly been studied “vertically” with a focus on the relationship between ideational elements within a logic, or “inductively”, i.e., identifying empirically the logics at work (Johansen and Waldorff 2017). They also notice a shifting interest within institutional theory towards understanding the sources of variation and change. These contributions include work on: “competing logics” (Reay and Hinings 2009); “institutional entrepreneurs” (Garud et al. 2007; Battilana et al. 2009); “institutional bricolage” (Carstensen 2017; Christiansen and Lounsbury 2013); and “organizational hybridity” (Battilana and Dorado 2010).

The interdisciplinary tradition of science and technology studies (STS) addresses questions of stability and change in terms of relationships between science, technology, and society. A basic argument is that the development of science and technology is intricately connected to cultural and political interests and ideas (Bijker et al. 1989). Likewise, visions of society and scientific progress are informed by technological possibilities (Daston and Galison 2018). Jasanoff and Kim propose the notion of ‘sociotechnical imaginaries’ to understand how this relationship plays out in multiple and changing ways. These are “collectively imagined forms of social life and social order reflected in the design and fulfillment of nation-specific scientific and/or technological projects” (Jasanoff and Kim 2009) (p.120).

Working also in an STS tradition, the “sociology of translation” elaborates how and why innovations develop differently in particular networks. In this conceptualization, a ‘program’ (e.g., a policy idea) emerges and acquires stability by gaining support from actors and materials vis-à-vis other programmatic ideas through ‘problematization,’ ‘interessement,’‘enrollment,’ and ‘mobilization’ (Callon 1986). These steps include subtle or profound translation of the program and hence there is an “interactivity” of ideas with actors and networks (Latour 1991).

Relatedly, Godin reveals how innovation models serve not simply the purpose of representing the reality of innovation but possess a rhetorical function to propagate shifting research agendas and policies: "[m]odels circulate, but the multiplicity of models renders the wide circulation of one particular model almost impossible today, making its life very short" (Godin 2017)(p.220).

These contributions are brought together in the concept of *isomorphic difference*. Combining two seemingly opposite perspectives, it points to overarching ideational patterns and local variation without assuming a particular dynamic or causality between these prior to empirical investigation.

3. Analytical framework

To pursue national similarities and differences in STI ideas, we adopt a research design with two steps: a) an inductive construction of an analytical framework outlining three distinct rationales; and b) a comparative coding and analysis of STI policies in three selected countries on the basis of the analytical framework.

3.1. Identifying three rationales

A core challenge in identifying broader rationales in national STI policies is the multiplicity of concepts and models in both the academic literature and policy documents. To distinguish common ideas across these and in line with the institutional logics inductive approach (Thornton et al. 2012), we examined core academic literature addressing STI policy: what types of basic assumptions regarding the purpose, nature and governance of research recur within the different contributions and communities of thought?

We found that three distinct rationales are at work. We term them: a curiosity rationale, a market rationale, and a mission rationale. We also identified a set of categories around which the rationales differ, e.g., the role of research in society, the nature of research, the role of the state, and the temporality of research. The three rationales and their generic categories are shown in Table 1.

Table 1. Three rationales for the role of research in national STI policies.

	Curiosity rationale	*Market rationale*	*Mission rationale*
Role of research in society	Solve puzzles and enlighten	Deliver knowledge and expertise relevant to economic value creation	Deliver knowledge and expertise relevant to societal challenges
Ideal nature of research	Self-chosen pursuit of knowledge and internal critique	Basic research provides foundation for commercially relevant applied research informing innovation. Natural science and physical sciences are particularly relevant	Directed exploration in basic research provides foundation for applied research targeting societal missions and associated innovation Inter-disciplinary collaboration
Role of state	Funds academic institutions and research grants Promotes scientific values Secures independence of research from other interests	Funds academic institutions and basic R&D Directs research and education towards business and industry Facilitates innovation systems Secures optimal market conditions including open competition	Funds academic institutions, basic and problem-oriented R&D Directs research and education towards societal missions Facilitates innovation systems towards societal missions Creates markets for solutions
Core actors	Scientific community	Scientists, industry/business	State, scientists, industry/business, and civil society
Ultimate decision-maker	The scientists	The market	The state
Quality criteria	Scientifically interesting, scientific excellence, meritocracy	Commercially viable	Societal usefulness
Funding mechanism	State funds, philanthropy	State funds basic and high-risk R&D, industry funds R&D on basis of return-on-investment estimates	State funds basic and R&D targeted societal priorities supplemented with private funds on basis of return-on-investment estimates
Time horizon	Long	Short, except basic R&D	Both short and long

The *curiosity rationale* unites schools of thought sharing the premise that the purpose of research is the curiosity-driven pursuit of knowledge through systematic inquiry and internal debate. Important roots can be found within philosophy and sociology of science. Popper argues that science advances towards "an infinite, yet attainable end; that of discovering new, deeper, and more general problems, and of subjecting our ever tentative answers to ever renewed and ever more rigorous tests" (Popper 1935)(p.281). A similar idea is found in Polanyi's work on scientists "laboring under the common spell of a potential discovery" (Polanyi 1946)(p.19). In his view, scientists balance creative impulses and critical caution, "freely making their own choice of problems and pursuing them in the light of their own personal judgement" (Polanyi 1962) (p.54). This accentuation of scientists' discretion is also present in Kuhn's emphasis on 'puzzle-solving' within scientific paradigms and the 'discontent' with the same paradigms' ability to provide solvable problems that start scientific revolutions (Kuhn 1962).

The freedom of research must be guarded from political and private interests, e.g., Merton's four social norms of science – 'communism,' 'universalism,' 'disinterestedness' and 'organized skepticism' – are to keep "local contagions of anti-intellectualism" and "a frontal assault on the autonomy of science" at bay (Merton 1973)(p.267, 268). Science will progress through a combination of introduction and judgment of novelty by scientists and values and frameworks guaranteeing an open debate and sufficient funding. The "five fundamentals" of Vannevar Bush in *Science the Open Frontier* (1945) offers a good example: "stability of funds" administered by people "understanding the peculiarities of scientific research and education" in "organizations outside Federal Government," "leaving internal control" to these organizations themselves and "assuring complete independence and freedom for the nature, scope and methodology of research" (Bush 1945). Others distinguish the curiosity rationale as "science done for its own sake" (Toulmin 1964), "science as culture" (Brooks 1971), and "Mode 1 knowledge production" (Nowotny et al. 2003). This concern for the 'freedom of research' is typically underpinning academic resistance to management reforms of universities and funding schemes: "preserving what are seen as traditional academic values of autonomy, integrity, objectivity, and control over funding and organization" (Elzinga and Jamison 1995)(p.576). The curiosity rationale favors a hands-off approach – "laissez-innover" (Freeman 1974) – regarding the role of the state in employing scientific knowledge for economic growth.

However, the hands-off approach has also opponents. A longer debate unfolds, for example, in the 1960s and 70s in the journal Minerva regarding what should govern "scientific choice." Two

alternative rationales appear in this debate: a market rationale emphasizing the economic role of science but preserving the "open society" spirit of Polanyi and a mission rationale combining the economic role of science with societal purposes and direction by the state.

The *market rationale* encompasses ideas and models sharing the assumption that research is a vehicle for economic progress by delivering knowledge to inform new products and services on the market. In the Minerva debate, it is argued that science should be directed towards economic growth potentials (Carter 1963) and that basic science should be considered an "overhead charge" on applied science and technology (Weinberg 1964). In subsequent work, Freeman (1974) argues that 'innovation' is not simply the invention of new things, but the commercialization of scientific and technological discoveries. He and others advocate for strengthening national 'systems of innovation' in which economically useful knowledge is produced, circulated, and used among public and private actors (cf. Nelson 1993; Freeman 1995; Lundvall 2010). OECD is one of the institutions that has promoted this idea (Lundvall and Borrás 2009)(p.603-4).

A related idea with an even stronger market-orientation is that advanced economies are "knowledge economies" (Powell and Snellman 2004), where knowledge drives productivity gains and economic growth, and research has an economic value that can be patented and capitalized. This includes the import of principles from market economics into knowledge institutions such as private ownership, open competition, financial incentives, and professional management (Gibbons et al. 1994b). It includes also increased collaboration between universities and industry (Etzkowitz 1983). Research should not be left to the scientists only: "[S]pending more on R&D than any other nation in the world will have little impact on economic growth unless American industry can successfully commercialize the results of that R&D" (Business-Higher Education Forum 1983)(p.6). The role of the state in the market rationale is to facilitate the knowledge economy or innovation system by increasing research and development (R&D) funding, bringing knowledge institutions into close contact with industry and facilitating 'uptake' of knowledge.

Freeman's work on innovation contains also seeds of the *mission rationale*. He argues for coupling research to the needs of the market, but also warns against "implicitly" channeling public funds to support commercialization: "[i]f government subsidies to enterprises are used at all, then thorough public discussion is essential" (Freeman 1974)(p.287). Governments should fund R&D that firms will not pay for themselves, and which is necessary for reaching societal

goals. Bernal had articulated an even more radical stance against the pleas for 'pure science' and 'science for profit.' He suggests a planning approach in which "…scientific development might be used to assist human needs, and […] human needs may lead to the development of science" (Bernal 1939)(p.332). One example is the research requested by "mission-oriented agencies" such as the National Institutes of Health (Toulmin 1964). Another is the Apollo Project in the US and its ambition to strengthen military defense and push the human frontier vis-a vis the Russian frontrunners in space (Kennedy 1961). Such missions involve large-scale collaboration across disciplines and multiple actors: "Innovation is far too important to be left to scientists and technologists. It is also far too important to be left to economists or social scientists" (Freeman 1974)(p.309). Under the pressure of global financial and climate crises, the mission rationale emphasizes the need for tackling broader 'grand challenges' and 'wicked problems' (e.g., Hicks 2016; Larrue 2021; Mazzucato 2018). EU examples of the mission rationale are the Mazzucato Report (Mazzucato 2018) and the Horizon 2020 programs.

3.2. Comparative coding and analysis of selected STI policies in three countries

To investigate whether and how the three rationales appear within actual policy documents, we balanced two concerns: sampling for maximum variation over a given period and ensuring sufficient depth in our analysis.

Selection of countries: As the three rationales adopt quite different views regarding the role of the state, we selected countries that differ regarding economic model and state form. On that basis, we selected China, the United States, and Denmark because of their diversity across central dimensions. The United States and China are leading global players, who have both invested heavily in innovation and represent different societal models; respectively a market economy with limited central state regulation and few overarching policy centers (Benner 2018b)(p.84) and a socialist market economy with strong state planning and centralized yet fragmented policy making (Tong 2008; Lewin et al. 2016). Denmark is a small player in the global economy with a mixed economy, but also strongly integrated with the EU policy center. We expected that the curiosity, market, and mission rationales would not be similarly present in the three countries.

Selection of time period and documents: To enable sufficiently rich coding and comparison across countries, we limited our attention to the two decades from 2000s to 2020s. This period covers global ruptures such as the Financial Crisis in 2008 and the Climate Crisis as specifically

in the 2010s and 2020s. Within each country, we identified four or five main policy documents published by the government or significant national actors and seen by key players as central or significant for the national STI policies (see Appendix). This focus on national STI strategies allowed us to distinguish and compare national ideational characteristics. In China, we selected four national plans and strategies for STI each related to China's five-year plans, plus an additional report issued by the General Office of the State Council. In Denmark we chose the four national research and innovation strategies that were launched in the selected period. In the United States, we selected three presidential strategies for innovation and two vision reports written by the National Science Board (NSB)[1] in a key independent science agency.

Coding of documents: The author team coded the documents using the template presented in Table 1. The documents were uploaded into NVIVO and coded sentence by sentence (occasionally fragments of sentences) as either expressing a curiosity, market, or mission rationale, or none of these in which case the sentence was not coded. To ensure inter-coder reliability, two different coders separately coded each text. In cases of discrepancy, we brought in a third coder. Table 2 displays examples of coded and not-coded sentences.

[1] The selection of the NSB reports reflects the board's function in the establishment of policies for the National Science Foundation government agency and giving advice to the President and Congress. This analysis noted that the curiosity rationale is more prevalent in NSB policy documents than in the Presidential national strategies. Vision documents from other national actors, such as the Department of Defense (DoD), would have similar biases (in the case of DoD towards the mission and market rationales) but also a restricted view to a particular domain of society. To stay clear of particular stakeholder interests, we also excluded, the much-debated 2007 report from the National Academies of Sciences, Engineering and Medicine (NASEM): "*Rising above the Gathering Storm*" (NASEM 2007), which was explicitly produced on request of two Senators asking NAS' view on the role of S&T for US to "successfully compete, prosper and be secured in the global community of the 21st Century."

Table 2. Coding display. Examples of coded and not coded sentences[2].

	Curiosity rationale	*Market rationale*	*Mission rationale*	*Not coded*
United States	"[E]mbrace and champion core values of objectivity, honesty, openness, fairness, accountability, and stewardship" (2009)	"…a prosperous America that is powered by innovations flowing from the latest transformative scientific ideas" (2005). "Support open capital markets that allocate resources to the most promising ideas" (2009)	"[U]rge coordinated public and private sector efforts that will accelerate broader adoption of health information technologies" (2004) "Identifying those areas where focused investment can achieve transformative results to meet the challenges facing our nation and the world" (2015)	"While it is clear that a new foundation for innovation and growth is needed, the appropriate framework for government involvement is still debated" (2009)
China	"Speed up the formulation and promulgation of documents related to the expansion of scientific research autonomy of universities and research institutes" (2019)	"Technological innovation is the ultimate route to enhanced enterprise competitiveness" (2006) "[G]ive full play to the market in the allocation of scientific and technological resources" (2019)	"Establish a national defense S&T innovation system, highlighting the combination of both the defense and civilian needs" (2006) "Use systematic technical solutions and industrialization paths to develop technologies and industries for pollution control and resource recycling" (2016)	"During the past two decades or so since we began to pursue the policy of reforms and opening to the outside world, our country has imported a huge amount of technologies and equipment" (2006)
Denmark	"Allowance has to be made for the need for freedom of research" (2003) "The top level of Danish research must be of a Nobel Prize-level" (2018)	"Government is creating a number of new incentives for interaction available to enterprises, researchers and knowledge institutions" (2003) "Increased commercialisation of research results and especially cooperation between the business community and knowledge institutions" (2012)	"A strategic research programme on dialogue and understanding between different cultures should be established" (2006) "Demand for solutions to specific societal challenges must be given higher priority in the public innovation policy" (2012)	"The Government is approaching the task with humility and respect, because we already have a good research and innovation system" (2018)

A total of 83 percent of the documents were coded, indicating that the three rationales were strongly present in the texts. A core challenge within the coding process was to keep rationales separate, e.g., the United States we found "[b]roadband provides Americans with high-speed

[2] Note that years in parenthesis, e.g. (2019), indicate the publication year of relevant national strategies where the relevant text was taken from – see Appendix.

Internet access connections that improve the Nation's economic productivity and offer life-enhancing applications" (2004), which both expresses a market rationale and a mission rationale. Another challenge was to code elements that could belong to more than one rationale. Here, we took the following decisions: a) statements addressing the importance of research quality and merits were coded as a curiosity rationale (scientific values), whereas statements expressing the need for better research mobility were coded as a market rationale (free movement of knowledge); b) statements addressing the general importance of scientific disciplines such as "STEM" were coded as a market rationale (basic research as a general economic factor), but as a mission rationale if coupled to particular societal missions or problems (directed research); and c) statements that address the need for upgrading public education and skills in general were coded as a market rationale (education as a foundational economic factor), as a mission rationale if coupled to specific societal challenges or missions, and as a curiosity rationale if linked to development of creativity and exploration. In other cases of doubt, we determined the ideational context in which a sentence appears.

Comparative analysis: The coded documents were first analyzed in terms of the quantitative distribution of rationales across the countries and documents. Figure 1 presents the aggregate coding percentage (i.e., total number of words coded for a particular rationale divided by the total number of words). Secondly, the coded documents were analyzed qualitatively to map and identify the policy elements, core arguments and linguistic tropes characterizing the rationales over time in each country. We also analyzed the similarities and differences across country within each rationale (e.g., what are common policy elements, arguments, and tropes across the countries within the market rationale? What are the unique elements within the rationale that differ from one country to the other?) The general findings from the quantitative and qualitative analyses were subsequently presented to key informants from each country (four from Denmark, five from China and five from the United States) to test and corroborate the overall patterns.

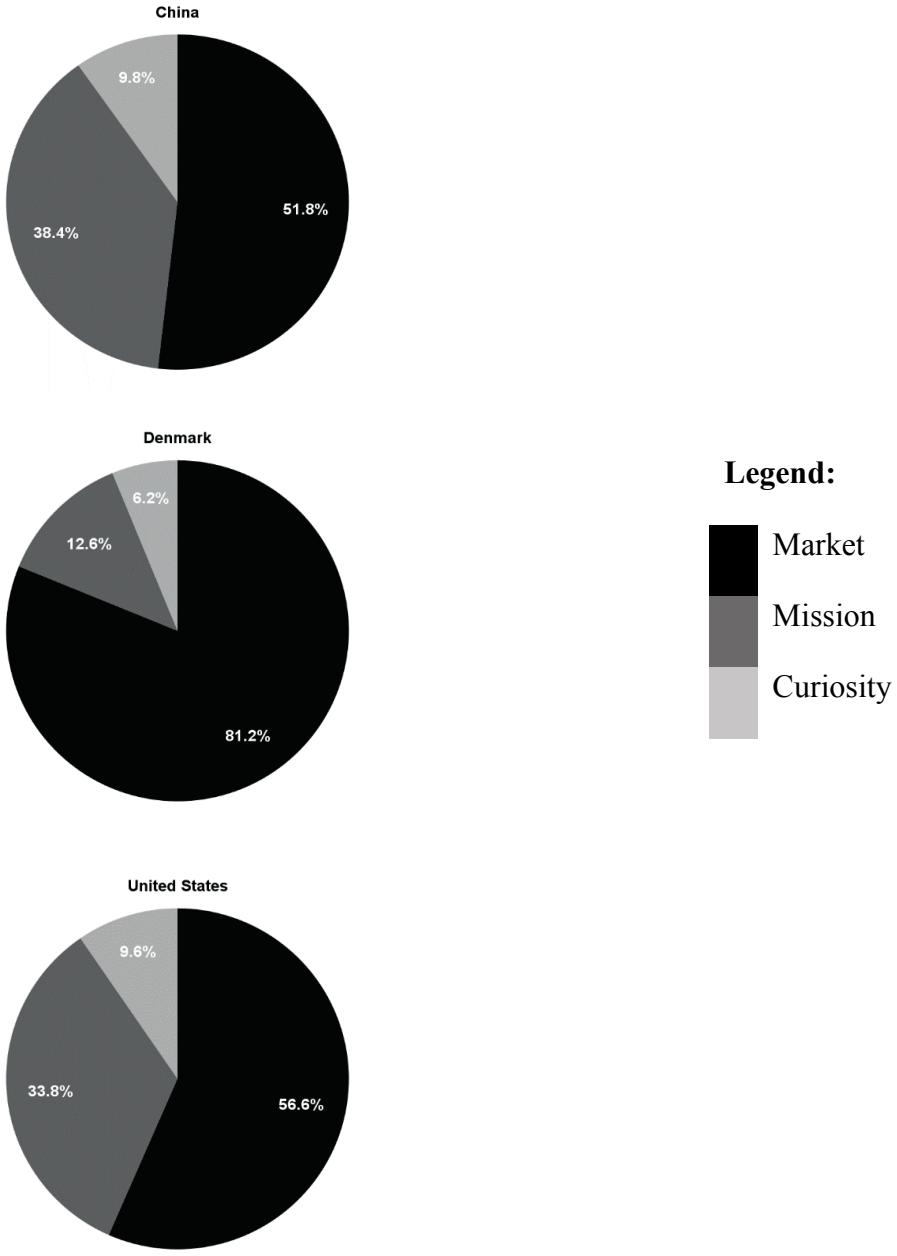
4. Findings

4.1. The general patterns across countries

The curiosity, market, and mission rationales are at play in all three countries, although in various changing constellations (Figure 1). The market and mission rationales are almost equally salient in China and the United States, whereas Denmark is an outlier with the market rationale covering more than three quarters of the national policy documents. The curiosity rationale is

the least dominant in all three countries. Its greatest presence is in the US with only 10.5% of the coded content.

Figure 1. China, Denmark and the United States: distribution of rationales, percentage of all documents 2000–2020



a) China: Sustainable economic growth through state planning, market forces and more curiosity

The mission rationale is strongly represented in the Chinese documents but is closely accompanied by the market rationale. The policy documents revolve around China's long-term mission of the "sustainable development" of China towards a "Harmonious Socialist Society." The missions center on "catchup" in science and technology and industrial upgrading through releasing market forces to overcome the country's "irrational" economic structure. It weighs heavily on strong state planning, including priority objectives such as sixteen "major special projects" (2006) and "key national development and research tasks" (2012) to realize Deng Xiaoping's policy from 1978 towards a "socialist market economy with Chinese characteristics." These state-led missions aim to profoundly reform the Chinese society to achieve economic and environmental development and state security through a strong focus on elevating China's level in science and technology and innovation capacity.

The market rationale is presented as an enabling mechanism integrating and upgrading research and education to accelerate economic development and foster "indigenous innovation." The market elements include private R&D investments and venture capital, IP protection, entrepreneurship, and partnerships between public and private and across industry and research institutions, international talent recruitment, and performance evaluations and incentives. However, these elements are to be part of centrally planned "frontier" science and technology and undergirded with significant state support. The profound entanglement of mission and market elements aims to make China "leapfrog" into the world's most innovative nations: "we will give full play to the role of the government in strategic planning, policies and regulations, standards and supervision and guidance, and the basic role of the market in the allocation of resources to create a good environment and stimulate innovation" (2012).

In the Chinese documents the curiosity rationale focuses on reforming the research environment with a culture of "basic research of free exploration". It grows in strength throughout the period, asserting that the lack of autonomy of research institutions impedes the "force of innovative creativity" (2019). STI activities must be freed from undue interference by party cadres and others and institutions should develop a culture that enables scientific discoveries: "strengthen original innovation, strive to lead the world in scientific research in more fields, and enhance China's contribution to human scientific exploration" (2016).

b) *United States: Bolster market forces with missions and curiosity*

In the United States, the market rationale is the most salient, covering over half of the policy documents. These documents depict a knowledge economy fueled by strong private innovation and entrepreneurship and underpinned by Federal government removing institutional barriers, setting rules, and correcting market asymmetries. A core ambition in the United States is to maintain its global position in science and engineering: "... new knowledge is perhaps the single most important driver of economic growth and the most precious and fully renewable resource available to individuals and societies to advance their material well-being" (2005). Federal investments in research and education should therefore benefit "fundamental research," "technologies of the future, "leading physical infrastructures" and STEM education. At the same time, the economy should be given all the necessary tools for successful innovation and risk-taking through a "conducive regulatory and taxation climate", open capital markets and attraction of foreign talent: "making the S&E ecosystem more nimble" (2020).

The mission rationale is particularly salient in the early documents in the United States (2004, 2005, 2009) which argue: "the recent crisis illustrates that the free market itself does not promote the long-term benefit of society" (2009). A recurrent focus is to combine market investments in R&D with efforts to grow domestic talent and workforce including the recruitment of women and minorities. Furthermore, missions should co-shape markets by identifying "…sectors of exceptional national importance where the market is unlikely to produce the desirable outcomes on its own" (2009) e.g., a cleaner, greener economy and "the grand challenges of the 21st century." Missions include also national space and defense programs.

The curiosity rationale is significantly smaller (although it has the largest presence among the three country cases) and, unsurprisingly, appears primarily in the NSB documents. However, it works to underscore the importance of scientific minds as an invaluable resource in the United States success of moving the "frontiers of knowledge" and leading "paradigm shifts". The conditions for "curiosity-driven research" must be maintained through dedicated grants and through research values like "objectivity, honesty, openness, fairness, accountability, and stewardship" (2020), harness[ing] the spirit of innovation and discovery that has always moved America forward" (2009)(p.8).

c) *Denmark: Promote market principles across society and enhance them with curiosity and missions*

The market rationale dominates the Danish documents and focuses on gearing framework conditions towards knowledge-based growth and innovation "in all areas of society." Better transfer and commercialization of knowledge should strengthen the competitive performance of public and private organizations: "Denmark has unexploited potential for interaction between the business and industry sector and public research" (2003). Increased public investment in research is necessary and "knowledge institutions" should be reformed towards higher quality and relevance for business. This includes modelling university governance after corporations with boards of executives and performance indicators, introducing competition for positions and funding, establishing partnerships and tech transfer institutions across university and business, and enhancing the mobility of talent. Globalization is requiring Denmark to develop its competitive performance across industry and universities, but also providing new opportunities to be exploited. This includes the establishment of Danish "innovation centers" abroad in strategic locations such as Shanghai and Boston, and prioritizing "particularly promising areas" such as data science and technological research: "[m]any of our future solutions are as yet unknown, and answers will be found through new knowledge" (2018).

The mission rationale supplements the emphasis on competition, commercialization, and STEM with a focus on social cohesion and societal challenges such as climate change, migration, and sustainability. These priority areas across the market and mission rationales are combined in five-year national "Research Catalogues" supported by public funding schemes and institutional initiatives. Likewise, while the curiosity rationale mentions the value of "freedom of research" it leans towards the market rationale arguing for the importance of research excellence as a national asset. Accreditation bodies should govern the quality of education as well as and universities should introduce elite programs and foster international exchange: "the top level of Danish research should reach the same echelons of greatness as those at a Nobel-level of achievement. We must work towards seeing more researchers bringing home Nobel prizes to Denmark in the future" (2018).

4.2. Comparing across the three rationales

Comparing the country variations within each rationale, we find both similarities and differences.

a) The curiosity rationale: different interpretations of quality and scientific values

The curiosity rationale appears in all three countries as a minor but distinct voice that has nevertheless grown over the years. It encompasses topics such as research quality, scientific values, and research ethics, although with different accentuation across countries. A shared core focus is on the importance of improving research quality. The United States documents anchor the rationale in the heyday of American science and the establishment of the National Science Foundation. They stress the importance of maintaining the nation's ability to "probe the frontiers of knowledge" (2005), "harness the spirit of innovation and discovery that has always moved America forward" (2009), take a dominant position in "fundamental research" and "lead the evolution of the global practice of science and engineering (2020). To do so, funding should be directed towards foundational questions: "research that has the capacity to revolutionize existing fields" (2003), "lay the foundation for new discoveries" (2009) and "curiosity-driven research" (2020). It is accentuated that "US universities lead the world" (2015) and "are modeling scientific values" (2020).

In Denmark, curiosity is discussed in terms of how Danish research competes internationally. Danish research is depicted as "often of the highest international standards" (2003), "comparable to world top performers" in "world top-level universities" (2006), and "measure up to the global elite" (2018). Funding should be distributed "according to quality" (2006). It should support "basic funding which will advance the quality of Danish research even further" and "future top researchers" (2018). The 2018 document crowns the quality ambitions by encouraging a "Nobel Pact…bringing home Nobel prizes to Denmark". This strong focus on excellence and ranking couples the Danish curiosity rationale closely to the market rationale.

The Chinese documents also focus on international rankings: China should "establish a number of world-class research institutes," "top-notch" with "world-class academic leaders," and "moving into the top five countries" (2006). It adopts the American rhetoric of leading scientific discovery: "make original breakthroughs" (2012), "facing the forefront of science" (2016) and producing "original results" (2019). Funding should be managed "in accordance with the laws of scientific research," and academic environments should "respect scientists' exploratory spirit and pay more attention to the long-term value of sciences" (2006) and "encourage rational skepticism and criticism" (2012). The need for autonomous research institutions is stressed in the 2019 documents: "respect scientific researchers," "promote the implementation of the scientific personnel's decision-making power," and "ensure independent management."

Whereas research ethics is only mentioned once in the Danish documents (2003), it is a designated topic in the United States 2020 document suggesting to "strengthen global acceptance of the core values of open, transparent, and ethical conduct of S&E research," "setting the standard for research ethics and values" and "champion the merits of openness and the highest ethical standards." In China, research ethics appears in 2012, arguing that "research integrity… is weak" and for the importance of "curbing flippancy and unethical practices in scientific research." The subsequent documents continue this focus, advocating to "strengthen research integrity," "abide by academic ethics" (2016) and adopt "punishment of violations and scientific research misconduct" (2019).

b) Market rationale: different varieties of capitalism, but shared focus on STEM, increasing public investments and orienting universities towards business

Across countries we found an emphasis on knowledge and technology-driven innovation as a driver of economic growth. The three countries all focus on increasing investments in R&D, particularly in the STEM area, and improving the interplay of universities, industry and entrepreneurial activity. They differ in how they seek to shape that interplay and approach international collaboration.

The United States market rationale centers on transiting to a new growth paradigm focusing on "innovation flowing from the latest transformative scientific ideas with a workforce among the most scientifically and technically competent on the planet" (2005). Private enterprises should be coupled to knowledge by investing to "educate next generation with 21st Century knowledge" (2009), creating a "STEM talent powerhouse" (2020) and high-tech infrastructures. The means are, for instance, the removal of regulatory boundaries, federal investments "3 pct. in R&D," and R&D tax credit. This includes further opening of capital markets, commercialization of federally funded lab research, partnerships between industry and academia, and strategic planning of S&E "expanding the geography of innovation across states" (2020). In 2005, United States workforce should "live and work globally" and "exchange ideas", but from 2009 the documents adopt a tone of international competition that acknowledges that the "global S&E enterprise is growing faster" and that it will be imperative to "attract foreign talents" to "keep US lead in fundamental research" (2020).

Whereas the "market" is often implicit in the United States rationale, the Chinese version highlights it as a vehicle for improving 'indigenous innovation' and China's economic

development. Like the United States documents, it includes a strong commitment to scientific and technological progress: “market competition is an important driving force behind technological innovation while technological innovation is the ultimate route to enhanced enterprise competitiveness” (2006). Likewise, it entails state investments in and reform of national training and education schemes and introduction of models for university-industry collaboration. The sense of urgency appears more pronounced than in the United States. Repeat phrases are “catching up” and “leapfrogging”, and international collaboration is placed centrally from the outset: “allow multinational companies to place R&D centers” (2006), “become gathering place for high-end innovation and entrepreneurship world-wide”, and “distribute innovation network globally” (2016). A particular focus is to make universities able to “service needs” (2012) and shield them from unwanted party regulation: “Remove all ideological obstacles and institutional barriers that restrict innovation” (2016).

The Danish market rationale encompasses many of the same ideas and reform elements, but with even more stress on commercialization and competition. These principles are put center stage in the “strategic” allocation of public research funding and innovation schemes. The focus begins by “narrowing the gap” between industry and knowledge institutions, “turning science intro business,” and reforming the governance structure of universities (2003). Gradually, it changes towards positioning Denmark better in the international competition through “lifelong learning” and a “Globalization Pool” (2006), reforming the funding system to get “fewer boxes and less overlap” and “stronger competition” (2012), “strengthening technological research,” “landing of EU grants,” and opening “Innovation Centers in world’s leading hubs” (2018). Where the Chinese documents center on bringing international resources and business to China, Denmark’s strategy is to increase its collaboration with selected international “hot spots” and networks including China and the United States.

c) The mission rationale: in between military, welfare and sustainability

In the United States and China, the mission rationale is well-represented from the outset. It is less salient in Denmark and arrives later. In the first two countries defense and space are central missions, but all countries increasingly emphasize climate change and green transition together with digitalization, although in different ways. References to “grand challenges,” “societal challenges” and “societal benefits” are used in all three countries as broader slogans for evaluating and directing science and technology towards societal impact.

In China, the overarching mission is to "rejuvenate the nation through science and education" (2006) and foster "indigenous innovation." In this way, STI policy itself can be seen as a core mission with nationally prioritized key areas and technologies, supplemented with several other missions related to the development and security of China. The most salient mission is the upgrading of defense, space, and security technology; topics mentioned multiple times across the Chinese documents. The second most salient theme are missions related to a more sustainable and greener economy, e.g., ecological and environmental protection, energy systems, transportation, agriculture and food supply. Finally, missions dedicated to "rural revitalization" and regional development are also salient (2019).

The United States mission rationale is closely coupled to the market rationale through its foregrounding of "technologies and industries of the future," e.g., for the space sector, healthcare sector and energy sector (such as hydrogen fuel technology and health information technology in 2004; high-speed rail, battery, and electric drive in 2009; and precision medicine in 2015). Defense and military are only mentioned twice in the United States mission rationale, one of them being a reference to the past success of Defense Advanced Research Projects Agency (DARPA). However, cybersecurity is highlighted as an important societal mission together with social innovation tied to the "potential of underrepresented minorities, women and persons with disabilities" (2005). Like in China, although less markedly, the selected areas are allocated specific funding and supported with instruments such as tax credits and loan guarantees to steer supply and demand in the wanted direction.

The Danish mission rationale is virtually absent in the 2003 document and enters the policy arena in the 2006 document with an explicit formulation of "adding missions" – e.g., sustainability, social welfare, and cohesion – to the market rationale. These missions are a particular Danish focus. This includes the ambition to further expand the educational system. Subsequent documents elaborate the idea that stronger prioritization and direction of education and research towards societal challenges and "solutions" will also be business opportunities. Central missions also include cultural understanding and digital society. In contrast to the United States and China, there is no mention of defense and space.

5. Discussion

Our analysis has confirmed that the curiosity, market, and mission rationales are all salient in the selected documents and develop over time towards a more equal distribution. Each rationale

also undergoes internal changes with new foci, tropes and instruments added to or replacing previous ones. We anticipated national differences, but the similarities across countries are specifically striking and interesting. The documents all present science, technology, and innovation as key drivers of societal development and adopt narratives of an urgent need for mobilizing efforts and ambitions. They all call for reforms, both in selected areas and across the entire innovation system; the latter term illustrating that "innovation" has become a *sine qua non* in public policies (Pfotenhauer et al. 2019). The countries also agree on the importance of increasing R&D budgets, entrepreneurship, STEM disciplines, climate change, international collaboration, and ethical standards. In this regard we witness a strong element of isomorphism across these three different national settings.

The Chinese and Danish documents signal growing confidence and ambition during the period. The United States documents, in contrast, gradually acknowledge the heated international competition endangering the United States' global standing. Meanwhile, the countries' strategies for international positioning differ. As a small country, Denmark aims to foster international collaborative networks and international "filials," whereas the United States and China as global leaders adopt alternative approaches. The United States documents emphasize global standard setting and excellence and only later the need to import talent. The Chinese documents move from focusing on attracting foreign investments and knowledge, to increasingly preparing for global expansion of innovation networks and global standard-setting.

The identification of national specificities or differences within the market rationale supports findings in the existing literature, but also adds new dimensions. We confirm the observation made by Liu et al. that China's Medium- and Long-Term Plan (MLP) from 2006 marked the introduction of innovation systems as a central discourse in Chinese STI policy (Liu et al. 2011). However, the subsequent emphasis on frontier technology, regional S&T centers, and green transition technologies also supports the claim that Chinese STI policy increasingly stresses technological and industrial upgrading with strong state back-up and planning that bring policy toward "interventions into specific industrial sectors" (Chen et al. 2016)(p.2147). Lundvall and Rikap also argue that the MLP 2006 was a turning point, where China began managing its openness to foreign direct investments in order to contribute to building domestic technology capacity" (Lundvall and Rikap 2022). A similar migration from a "knowledge economy" towards a "technology economy" can be observed in the United States and Denmark. Whereas China aims for catching up and taking the lead in multiple technological areas, the United States

and Danish documents tend to single out selected core or frontier technologies: partly building on previous centers of excellence and core capabilities, partly coupling to and capitalizing upon selected societal missions. Alongside these national "hot technologies" is a widespread enthusiasm for the STEM disciplines in all three countries.

Different approaches, however, can be detected in the choice of language and terminology. Where Chinese and Danish documents address the role of universities and companies, the United States documents tend to speak more generically about public and private "R&D" and "S&T." Likewise, the Danish use of "knowledge institutions" as an umbrella term indicates an adoption of the knowledge economy concept. This contrasts with China's consistent use of "scientific research institutions" aiming perhaps to signal respect for scientific values and individual autonomy under state leadership; an interpretation that supports the hypothesis that China's next phase of innovation and development will be tied to its technological and scientific leadership (Hu 2020).

Interesting changes can also be noted within the market rationale. In Denmark, early documents view commercialization and internal competition for resources as crucial allocation mechanisms – perhaps reflecting a focus on the "European paradox" i.e., that EU allegedly underperforms in the commercialization of publicly funded science (Jacobsson et al. 2013). Later documents emphasize collaboration in and outside of Denmark in order to remain globally competitive. China has a parallel development from a focus on market mechanisms to including public procurement and state-owned enterprises as drivers of innovation. This combination of market and mission is also growing in the United States and Denmark. However, the Chinese missions appear more elaborate, targeted, and subsidized with state funding. In contrast, the Danish missions come with less designated funding and instruments and a preference for market dynamics; missions are singled out as "opportunities" for growth and as innovation niches (Kanger 2020). These observations regarding the mission rationale seem relevant for the debate about new and old forms of mission-orientation (Mazzucato 2018). We do not detect a shared "progression" towards expanded missions or societal transformation but have instead uncovered different mixes and depths of missions, some of which appear as rather general and non-binding commitments or as regular technology projects.

China employs the whole spectrum of missions and policy intervention points, including what Kanger terms "tilting the landscape" (Kanger 2020). However, we note a tendency for these to be translated into primarily STEM research and technological innovation. This finding may also

explain our methodological challenge to keep the market and the mission rationale apart and code national priorities regarding technological infrastructure and "technologies of the future" accordingly. These priorities may simultaneously be thought of as drivers of economic growth and solutions to societal problems. Rather than a development from old to new missions or to a "transformative paradigm" we have found in all of them an inclination towards a neo-Schumpeterian idea of economic growth and societal development through "novelty" (Hanusch and Pyka 2007). This may help explain the small but unmistakable growth of the curiosity rationale in all three countries and why it is increasingly coupled to the market rationale. While "science for its own sake" has been regarded a historical predecessor to contemporary innovation models (e.g., Nowotny et al. 2003; Lundvall and Borrás 2009), the increasing faith in novelty as the driver of innovation and economic growth may indicate a refurbishing of Polanyi's "Republic of Science." Prioritizing the curiosity rationale seems increasingly to be a competitive strategy that considers domestic scientific excellence and breakthrough knowledge as a winning formula. Having spent enormous effort on technological and scientific catch-up, Chinese STI policy for example, now seems ready to rely more on its own science and technology resources and take steps to abandon "excessive reliance" on international citation indices and focus on China-specific problems in Chinese journals (Liang et al. 2022).

Our analysis suggests that contemporary STI policies increasingly couple elements from the rationales in distinct blends with national "flavors." By decomposing rationales into elements and subsequently analyzing how they appear in policy documents we have been able to read across existing typologies and follow the combination of elements. For instance, mission-like elements sometimes assume a market-like character, and market ambitions become wedded to a curiosity rationale. In this, we contribute to the literature on policy mixes and layering. We further extend this approach by showing the value of fleshing out the ingredients in these blends and how they combine elements in distinct ways. A core finding in our analysis is the strong centering on technology and STEM across rationales and countries. Another is the increasing emphasis on scientific and novelty as a *sine qua non*. We interpret these as indicating new *isomorphic-difference* dynamics beyond separate layers of policy paradigms.

What does this mean for the paper's opening question regarding possible overlaps among models of changing STI policies? First, we have not found one model to be more applied than others. Instead, Mode 1 principles appear side by side with Mode 2 principles, combined with knowledge economy ideas and language, accompanied by fixing-the-market instruments. State-

led or state-backed missions are also added, some of which are old types of delimited mega-projects, whereas others are broader appeals towards solving grand challenges and transforming global systems. We also found classic science policy arguments co-existing with technological policy arguments combined with or dressed up in innovation policy language. With this observation, our contribution is not a better stage model or identification of a new paradigm, but a fresh perspective on ideational elements and their combination over time and space.

Ideational elements travel and intersect. Some ideas seem to stay intact despite entering quite diverse arrangements; other ideas undergo translation and domestication resulting in quite different versions of a rationale. Likewise, rationales may start out separate but later blend. While it is reasonable to say that the three rationales are sometimes competing, they also appear in our analysis as complements. New vocabularies emerge which make it difficult to track the actual similarities and differences: for example, concepts of "responsible innovation" and "transformational innovation" that suggest that something entirely new is taking shape, even if it may be a refurbishing of older ideas. By exploring the intersections and *isomorphic differences* of ideas, it is possible to trace developments over time without assuming a logic of progression or decline or incommensurability of elements. Hereby we contribute with a conceptualization of ideational change, and analytical frameworks and methodological approach that may enrich discussions about policy mixes within the innovation studies community (Kern et al. 2019).

Questions for future research arise from our finding of intersecting and co-existing rationales. Is this *isomorphic difference* a trend that can be identified more broadly and what are the varieties of blends that exist? We are also curious to learn whether the technological turn that we have identified continues and spreads, and whether it combines with or reduces an emphasis on scientific curiosity and autonomy. Finally, our analysis calls for further testing and exploration of the fate of international competition and collaboration. How will global leaders such as United States and China proceed vis-à-vis each other and vis-à-vis the rest of the world?

6. References

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7. Appendix. National STI documents

Listed documents were included in the analysis.

China

2006 MLP for Science and Technology 2006-2020

2012 Opinions on deepening the reform

2016 Innovation-driven development strategy

2019 Greater Autonomy on Scientific Research Institutions

2019 Joining forces and entering the ranks

Denmark

2003 New Ways of Interaction between Research and Industry

2006 Progress Innovation Cohesion

2012 Denmark A Nation of Solutions

2018 Denmark Ready to Seize Future Opportunities

United States of America

2004 A New Generation of American Innovation

2005 National Science Board (NSB) Vision 2020

2009 A strategy for American innovation: driving towards sustainable growth and quality jobs

2015 Strategy for American Innovation

2020 NSB Vision 2030

PART III. DISCUSSION & CONCLUSION

4. DISCUSSION

4.1 Comparing Global Ideas in Policy for STI across Contexts

This dissertation questioned how global ideas in policy for STI are understood within specific contexts to understand the way in which similar ideas come to be domesticated. The analytical insights gained from thinking *across* the empirical cases highlight the ways in which global ideas cannot be taken for granted in national policy for STI. A key argument in this dissertation has been that the use of global ideas in policy for STI has led to isomorphism across contexts. This work provides evidence of specific global ideas that have taken root in national policy for STI and their overarching modes of thought. All articles showed how these global ideas come to localized in particular ways. The findings highlight the baggage that global ideas bring with them, as well as the complexity that countries insert into the mix when adopting and adapting them. The analysis shows that when particular meanings get inserted in policy for STI, they also reveal the values that ground them and how these may displace competing claims (Berman 2022). By subjecting particular global ideas in policy for STI to analysis, each article showed how these ideas are riddled with 'far more paradoxes, puzzles, and uncertainties than the statesmen of pure science are generally willing to admit' (Greenberg 1967)(p.29).

Article 1 found that the global idea of 'diversity' emerges as a constitutive property of nanotechnology policy in the United States. First, the article identified three diversity frames found in policy for nanotechnology—*add-on, change agent,* and *transformation.* Diversity as *an add-on* signals diversity in research or technology portfolios in non-performative ways (Ahmed 2007b; Gushke 2023) that suggest closure (Bijker 1995) for example on matters of the expertise it needs to advice the national program. Diversity as *change agent* challenges existing institutional arrangements at a research level, but also in policy settings, in the development of nanotechnology. While diversity as *transformation* conceptualizes the opportunities in nanotechnology policy beyond the confines of the laboratory or the university. The *isomorphic difference* suggested by each frame underscores the interplay between the local context and global understandings of diversity in policy for STI. Second, the article also reveals that these frames are layered rather than replaced in policy for nanotechnology. These different notions of diversity co-exist in policy for nanotechnology suggesting that broader understandings of diversity, e.g., *transformation* as it relates to responsible development must be met with increased financial or institutional commitments to be realized. Finally, the article provided a blueprint for analysis that can trace global ideas within national contexts, revealing that global understandings of diversity can also be found in national policy for STI and the contextual ways in which diversity is framed by STI policymakers in the United States.

Article 2 found that the 'valley of death' trope in the NNI serves as a standard and much-reproduced representation of research-market relations. At the same time, the valley of death was interpreted, supplemented and modified in ways which reflect the specific policy context in which it was being employed. The metaphor might stay the same, but its specific meanings vary substantially and embody certain assumptions in the NNI. First, the analysis revealed at least

four accounts used to rationalize the 'valley of death' in the NNI: as a basis for intervention; as the point of no return; as a quilt of logics; and as practicing metrics. These elements demonstrated that the 'valley of death' works in different ways, even in one national setting, i.e., its meaning is open to (re)interpretation over time. Second, within the valley of death, it becomes difficult to escape notions of linearity, of a simple and constrained temporal progression, and of one common process applying to all sectors of nanotechnology development. The attachment to well-accepted, but rather static, understandings of commercialization in policy for nanotechnology, through the adoption of tropes like the 'valley of death' seem limiting in the face of the complex arrangement that the NNI represents and the kind of science-technology relationship that nanotechnology aims to foster. Finally, the trope served to coalesce around shared concerns about commercialization efforts in the NNI, but it also reinforced the differences that those actors and institutions involved try to bridge in practice. Article 2 provided a fresh look at what is otherwise seen as unproblematic, taken-for-granted, or beyond challenge, thus enabling new understandings of the translation and adoption of global ideas in policy for STI.

Article 3 found that 'innovation-based futures' in the United States and China come to be expressed in globally recognizable ways but also that their understandings reflected very national concerns. The evolution of meanings within policy instrument families as seen through the *isomorphic difference* lens, revealed the intricate complexity that they can harbor over time and across place. First, the article showed that while the general distribution policy instrument families in the United States and China appears very similar, within policy instrument families the analysis revealed that they are greatly informed by their distinct Varieties of Capitalism framework. The *isomorphic differences* identified revealed how well-known policy instrument mixes get locally adapted. Second, the article points to specific instances where the United States and China picked up on each other's ideational traditions in the increasingly competitive global technological race, primarily seen in the soft instruments. Third, findings suggest that the global market rationales do not change the key building blocks of dominant instrument mixes used to instrumentalize and institutionalize the innovation-based future in China and the United States. However, global frames of innovation nudge the evolution of meanings of dominant instrument mixes closer to the third frame. Article 3 contributes to the conceptual development of *isomorphic difference* (Irwin et al. 2021) by showing national variations of innovation-based futures and advancing a methodological approach to tracing global ideas within national contexts in a comparative way.

Article 4 found that the three rationales (curiosity, mission and market) operate in the United States, China and Denmark, but that the rationales each get a particular 'tone' or emphasis in each of these rationales and over time. The analysis suggests that policies for STI can be understood as different ideational blends, currently united around technology and a quest for novelty. First, Article 4 developed and tested an analytical framework for capturing ideational familiarities and distinctions in STI policies over time. The analysis found instances of combining and showing how these rationales are translated and differentiated in each country. Second, the use of the conceptual lens of *isomorphic difference* was useful to capture both overarching patterns and local variations of the studied rationales. Interestingly, similarities

were just as surprising as the differences. For example, all three nations exhibited curiosity, market and mission rationales despite being very different economic and political systems. Results showed, for instance, the persistence of the curiosity-rationale in China, the presence of a strong mission orientation in the United States, and that the market rationale dominated the Danish policy documents. Additionally, the comparison revealed important similarities and differences regarding scientific freedom and excellence, forms of competition and collaboration, and technology as a type of mission. A 'market' rationale might appear isomorphic in the literature, yet this work reveals that it comes to be understood differently in China, the United States and Denmark. Local interpretations of the market rationale in China connect to catching up and taking the lead in multiple technological areas, while the United States and Danish documents tend to single out selected core or frontier technologies. These differences reinforce the need for comparative work in policy for STI studies. Lastly, the findings underline that ideational elements travel and intersect across countries. Some rationales seem to stay intact despite entering quite diverse arrangements; other rationales undergo translation and domestication resulting in quite different versions of it within particular contexts. Likewise, rationales may start out separate but later blend. While it is reasonable to say that the three rationales are sometimes competing, they also appear in our analysis as complements.

4.2 Contributions towards Development of Policy for STI

The empirical findings and analytical perspectives presented across the four articles inform our understanding of STI policy development. Together they show the importance of the local in global policy for STI, as sites that not only receive global or national pressures but that also generate new understandings and possibilities in policy for STI. The dissertation contributes to understanding trends and tensions in policy for STI by highlighting the complexity and diverse interpretations that global ideas have in national policy for STI. The contributions of the analyses can be discussed at macro, meso and micro levels in policy for STI.

First, at the macro level, global ideas provide material for isomorphism, standardization and closure that establish dominant conceptions. As Pfotenhauer et al. (2019) suggest, innovation has become a *sine qua non* in public policies globally. The cross-country comparisons in Articles 3 and 4 showed policy for STI as a key driver of societal development and the adoption of shared narratives about an urgent need for mobilizing its efforts and ambitions. The dissertation highlights strong elements of isomorphism across three different national settings, for example in the context of importance of increasing R&D budgets, entrepreneurship, STEM disciplines, climate change, international collaboration, and ethical standards. The work also shows that the co-construction of ideas can result in standardized ways of representing the complex policy reality, e.g., the 'valley of death' in Article 2. Similarly, Article 1 showed how science advisory groups described their 'diversity' in policy documents as an undisputed key element to nanotechnology policy while blackboxing the specifics of what diversity means in their context. Both of these articles provided a fresh look at two global ideas within a national context that would otherwise be seen beyond challenge. These findings also argue for a re-familiarization with the national in STI policy studies as a way to better account for the ways in

which national interests and global pressures mix in policy for STI (see e.g., Hofmänner and Macamo, 2021; Benner 2018b).

Second, at the meso level, global ideas can take on very distinct forms, through local adaptation in the form of frames, variations or blends. This highlights the intersecting and co-existing ways in which ideas get locally understood. In Article 3, the analysis revealed that the dominant instruments within countries were heavily informed by the taxonomic distinction of their distinct Varieties of Capitalism framework. The way in which countries like the United States take well-known policy instruments and localize them raises questions about the ways in which an institutional setting interacts with global ideas. Also, the local interpretations identified in Article 4 reinforce the need for comparative work in policy for STI studies. This kind of work can improve understandings of global ideas within policy for STI that show the contextual variation and blending that takes place within and between countries.

Third, at the micro level, global ideas must be understood within socio-material practice in policy for STI to recognize how they come to be locally performed. Article 1, for example, featured the material ways in which diversity comes to be framed in policy for nanotechnology showing the varied understandings of why diversity is needed, what diversity could address, and the institutional and organizational changes needed to achieve it. The analysis highlighted the role that mediating institutions (Cozzens and Woodhouse 1995), like the NNI, play to facilitate these understanding within national contexts. All articles also highlight the need to study global ideas as they are enacted and practiced in policy for STI to reveal how they come to be understood and performed within a country and between countries. The conceptual lens of *isomorphic difference* was key in operationalizing the relationship between the adoption of a global idea and how it gets appropriated in national contexts and across countries. Article 2, which took an inductive approach to understanding the use of the valley of death in the NNI, revealed the multiple ways American policymakers reimagine this trope. The varied players involved in the NNI contribute to the collective imagination of the valley of death in the national setting, also inserting their own contextual differences to bridge this hurdle in the process of commercialization of nanotechnology. These examples underscore the need to consider global ideas in the context in which they are imagined. Together these observations point to the powerful roles of both national institutions and specific contexts in policy for STI. These dimensions become more than mere conduits of global pressures and actively shape and co-produce global ideas in policy for STI.

The value of an *isomorphic difference* approach to understanding how global and national policy pressures interact with local understandings cannot be understated; not so they are put against each other, but to understand the way in which they intermingle. This work highlights the need for scholars and policy makers in STI to become critical consumers of global ideas challenging their assumptions and taken-for-grantedness. The dissertation suggests that the adoption of global ideas in policy for STI may not be providing the supply of 'fresh' perspectives it is commonly assumed by policymakers (e.g., Schot and Steinmueller 2018; Stilgoe et al. 2013). By reproducing models like the 'valley of death' or the rationales for research funding, policymakers deploy standardized packages that provide a recognizable idea without fully

realizing the ways in which these models also constrain what can be imagined possible in policy for STI.

4.3 Limitations and Future Research

The dissertation by no means addresses all the intellectual and analytical possibilities of isomorphic difference. However, this work suggests refinements to the conceptual lens as well as the potential for its application beyond policy for STI. While the four empirical cases illustrated the value of the conceptual approach, they suggest that more systematic longitudinal and comparative work on global ideas in policy for STI could be useful. For example, the process through which global ideas 'count' (Slayton 2013) in policy for STI can be conceptualized as one of isomorphic difference. This work could more systematically connect particular global ideas to judgements, reasoning styles or policy cultures that enable them to gain traction in the political process. Pursuing this strand of work would open up space to understanding how particular communities in policy for STI perform isomorphic difference, inspired by Berman's work on economic style reasoning in the United States (2022), Slayton's work (2913) on how specific kinds of knowledge become persuasive across sectors, Godin's work on models of innovation (2017), and Knorr-Cetina's work on epistemic cultures (1999).

The use of contrast within policy for STI, i.e., how countries deploy ways of comparing themselves to others in their policy documents, provides another way to think about *isomorphic difference*. Many of the national strategies examined included material that framed national actions in the context of the global fields or their actions vis-a-vis other nations. This research idea moves the focus from specific global ideas toward the use of 'us-vs-them,' 'internal-external' comparisons that shape policy strategies. Pfotenhauer and Jasanoff (2017) revealed the multiple diagnoses that led to the same panacea of the 'MIT' model. This line of research would contribute to better understandings of the construction of diagnoses in policy for STI. The contrast invoked by countries in their policy documents can shed light on what they perceive as isomorphic and how they cast their uniqueness in the global stage of policy for STI.

The dissertation asked how global ideas are understood in local contexts and took inspiration from other scholars interested in understanding the trajectory of particular notions (Flink and Kaldewey 2018; Flink and Peter 2018; Schauz and Kaldewey 2018; Godin 2006, 2015, 2017). Its focus has not been to understand the 'translators' of STI ideas, but rather the multiplicity of translations of these global ideas. However, Articles 1 and 2 suggest that the advisory arrangement in the NNI may lead to particular kinds of policymaking in STI, e.g., cycles of periodic evaluation that may facilitate the layering of increasingly complex framing as shown in Article 1, or the deployment of multiple advisory bodies in one project over a long period of time. With an increasing use of advisory committees in US policy for STI and changes internationally through efforts around science diplomacy (Flink 2021), there is a renewed need to study the advisory landscapes that are developing and the global ideas they are reproducing in policy for STI. Influential scholars -like Bromley, Golden, Hilgartner, and Jasanoff- have written about aspects of the science advice apparatus within the US government (Bromley 1994; Golden 2003; Hilgartner 2000; Jasanoff 1990). This group have focused on the role of the US

President's science advisors or on the role of science advisers as policymakers. Their focus has been on particular types of organizations (i.e., President's Science Advisors or the interaction between expert committees and specific federal agencies) within the science advice apparatus in the United States. However, investigating the interaction of multiple advisory groups still remains underexplored (Hilgartner 2004). Conceptualizing science advice as an organizational field or an assemblage could open up space to reveal its dynamics and how these shape for example the activities of organizations in science advice that are chosen for their diverse knowledges. National models that bring together advisory groups to develop a technology area, like the NNI, are not unique in the federal government of the United States (Sargent and Shea 2020). Since the NNI model has also propagated beyond the confines of the United States (Shapira and Youtie 2011), it is worth considering the role of advisory groups in the adoption of particular global ideas and negotiating the relationship between isomorphic and difference-making pressures within policy for STI[1]. This line of inquiry can shed light on broader patterns in the world of science advice that influence national and international trajectories of policy for STI.

4.4 Contributions to Understanding Global Ideas within Specific Contexts

This section begins with how the dissertation contributes to understandings of global ideas in local contexts in relation to institutional theory and subsequently as it relates to STS.

This dissertation has argued for a research agenda that simultaneously regards global ideas as homogenizing pressures in policy for STI as well as to consider the local, its institutions and organizations as active shapers and interpreters of such ideas. The conceptual lens of *isomorphic difference* enabled the identification of large-scale rationales and overarching modes of thought across countries. A key result in this dissertation has been that the use of global ideas within policy for STI has led to isomorphism across contexts, but not in a uniform and similar way. All articles show the reliance on global ideas across the United States, Denmark and China, especially rationales about the purpose of research investment in countries, but also that there is a certain variation in how they take up these ideas.

The dissertation challenges assumptions of rational expectations dominating institutional and policy studies, in favor of a focus on the significance of global ideas and their adoption and domestication in policy for STI. Part I of this dissertation alluded to the influence of the United States in policy for STI that has shaped global ideas like grand challenges (Hicks 2016) or the deployment of nanotechnology programs worldwide (Shapira and Youtie 2011). Schauz and Kaldewey (2018)(p.2) posit that the country has also provided conceptual language to explain the nexus between science and politics. In studying global ideas in policy for STI within the United States and comparatively, this dissertation shows empirical cases where global ideas in policy for STI are shared with China and Denmark. The findings show surprising examples where Denmark's policy for STI emerged with more 'market' orientation than the United States.

[1] See e.g., Frandsen (2023) for a case of the mediating effects of advisory groups on pandemic preparedness and climate change.

The findings also revealed the increasing use of 'entrepreneurship' in Chinese policy for STI, even though the idea would be more closely associated with the United States[2]. These findings point to the isomorphic influence of ideation stemming from the United States, but also reveals the intersecting and co-existing ways in which global ideas get locally understood. This work advances scholarly understandings in institutional theory about how countries deal with global pressures and the use of policy tools that enable their execution and operationalization in particular contexts (e.g., Borrás and Schwagg Serger 2022).

The influence of global ideas stemming from the United States, must be considered in the broader context of an increasingly transnational policy for STI (see e.g., work on science diplomacy Flink and Schreiterer 2010 or Frahm et al. 2021 on the influence of international governance organizations). Djelic and Sahlin-Anderson (2006) posit that the transnational governance fields give an advantage to American actors, organizations and networks because these fields are 'shaped according to institutional principles with which they are in a sense "genetically" familiar' (p.397). This suggests that the influence of American global ideas in policy for STI can also be considered an advantage to the United States by promoting institutional arrangements close to what it is most familiar to the country. In line with *isomorphic difference*, and the growing situatedness of global ideas, it remains to be seen whether this change 'levels' the global playing field in policy for STI.

The research in this dissertation has also argued for a focus on the translation of global ideas in national policy settings as sources of difference in policy for STI. As such, it aligns with STS conceptualizations of global ideas in policy for STI as 'trading zones' (Godin 2015; Bensaude-Vincent 2014) of a common language that can be used by policymakers globally to address nationally perceived diagnoses (Pfotenhauer and Jasanoff 2017). The findings presented in Article 3 point to shared understandings between the United States and China about entrepreneurship along with shifting concerns in this area particular to the Chinese policy context. Similarly, intellectual property comes to be understood differently in both countries: with the United States taking an outward approach that focuses on the rights of American business in foreign countries, and China taking an inward look that aims to establish a viable institutional environment for intellectual property. The different assumptions in the construction of the same global idea (innovation-based future as enacted through policy instruments) points to different diagnoses in their use (Pfotenhauer and Jasanoff 2017). Collectively these findings contribute to STS by stressing how global ideas must be understood as spaces where distinct national deficits and needs are negotiated. The dissertation underscores the need to critically evaluate the adoption of global ideas within national contexts.

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[2] For example, the entrepreneurial state narrative has grown from the United States (Mazzucato 2015; Larsson 2022). Scholars have written extensively about legislative changes in the United States, like the Bayh-Dole Act of 1980 (see e.g., Aldridge and Audretsch 2010; Berman 2008; Remington 2005; Mowery et al. 2001). The Act shifted the intellectual property rights of government-sponsored research to universities. In doing so, it supported the development of infrastructure towards entrepreneurial activity out of universities. Recent scholarship has questioned the decline of entrepreneurship in the United States against the increasing rates of entrepreneurship found in Nordic countries like Sweden (Heyman et al. 2019).

These contributions should be understood as a counterweight to the dominance of macro accounts about STI policy and as illustrations of how *isomorphic difference* provides an STS entry into the microprocesses that imbue what looks at a macro level like uniform global policy ideas. The dissertation shows how global ideas translate within national contexts but also perpetuate assumptions and understandings that may prevent change or alternative explanations from taking root. This work does not suggest that macro accounts should be disregarded, instead in line with STS scholarship it makes a compelling argument for the need to understand global trends in the context in which they are adopted and adapted. All in all, the empirical findings and perspectives presented across the four articles highlight the analytical advantages gained by thinking about isomorphic and difference-making pressures as relational. Together, they show how any discussion of global ideas in policy for STI must on some level account for the interplay between the local and global within them. The findings show how globalizing and localizing forces in policy for STI are brought together within specific practices and settings.

4.5 Strengths and Weaknesses of an *Isomorphic Difference* Approach

The conceptual lens proved useful in the methodological approach used in the dissertation showing the many ways in which isomorphic difference can be studied in policy for STI. Articles 1 and 3 adapted typologies from the literatures on diversity and policy instruments, while Article 4 developed an analytical typology framework that described three rationales for policy for STI. These coding typologies facilitated the analysis of national STI policies that enabled a look *within* and *across* policy contexts. Further research could test them in more countries and refine them.

Applying the conceptual lens of *isomorphic difference* (Irwin et al. 2021) means a research sensitivity to how global ideas in policy for STI come to be co-constructed with local and global influences, shifting emphasis depending on the circumstances. This approach facilitated a definition of the object of study (global ideas) along with or emerging from the analysis of the empirical data. The conceptual lens proved flexible enough to enable an understanding of the different empirical cases ('diversity', 'valley of death', 'innovation-based future', and 'mission/market/curiosity rationales') within and across countries. Seen together, these empirical cases emphasized different themes of the conceptual lens as originally introduced (see Section 3.1.2). This raised a series of key questions for me—why is it that some cases brought forth particular themes over others? What makes the empirical cases different?

A potential explanation for these questions is the approach with which the study of *isomorphic difference* was conducted. Articles 1, 3 and 4 took a deductive-explorative approach to analyzing data, whereas Article 2 took an inductive approach. The analysis in Articles 1, 3 and 4 sought to trace understandings of the phenomena under consideration (i.e., 'diversity,' 'innovation-based future,' or rationales) as conceived in the literature, whereas Article 2 took understandings of the 'valley of death' in the policy documents as the entry point. Even though Articles 1, 3 and 4 ultimately turned to inductive analysis of emerging themes after a first round of deductive coding, these analyses were partial to the existing positioning found in the literature. This means that in encountering the coding data these articles were trying to find

understandings about diversity, policy instruments and rationales as they were defined by scholars in STI. Considering that what scholars theorize is largely determined by their ontology, epistemology and positionalities, calls for rethinking dominant approaches used through interrogation and improvement of the theory and methods by which we investigate our phenomena (Jasanoff and Simmet 2021). Isomorphic difference offered a novel way to approach policy for STI by theorizing it as an emergent social phenomenon that is relationally constituted. The global and local are co-constructed. A relational ontology, like that suggested by isomorphic difference (Irwin et al. 2021), focuses on connections among agency, materiality, and structures that are embedded in social order, producing practices in organizations and society (Janssens and Steyaert 2019; Orlikowski 2008). Work in this direction would enable more grounded theories of the policy process (Richards and Farrokhnia 2016).

Another possible explanation to the questions raised across cases relates to the specific context of nanotechnology policy. The analyses showed that nanotechnology policy is not as uniform as theorized and suggest that material elements remain overlooked and tend to remain implicit in analyses. Articles 1 and 2, which focused specifically on the NNI, show that global ideas in nanotechnology policy evolve in particular ways. Unlike data for Articles 3 and 4, the analyzed policy documents for the NNI were produced through an institutional set up geared towards periodic evaluation of the initiative. This means that while individual documents were analyzed, they were produced in a particular sequence as established by law and by three very specific actors in the science advice landscape in the United States. Article 2 also touched on broader concerns about technology transfer and commercialization that have been the subject of great interest in nanotechnology policy over the years and that have become a national priority in the United States. This suggests that to better understand policy for STI, practices must be seen in relation to their material elements (Orlikowski and Scott 2008) and in doing so, the conceptual lens becomes more powerful.

Finally, the conceptual lens enables the unpacking of global ideas within the national institutional environments and reveals the ways in which countries express the national in globally recognizable language. However, the dissertation suggests that in the future adopting a more processual approach to the study of isomorphic difference could capture the ways in which these relations (Irwin et al. 2021)(p.6) are forged continuously. Rather than *isomorphic difference*, the conceptual lens can be thought of as isomorphic difference-making. Taking a more dynamic approach to observing these relationships could speak to the varied and ongoing ways in which global ideas in policy for STI are constructed. The suggested change, analogous to what other scholars define as sensemaking, would describe a process that is ongoing, subtle, social and easily taken for granted (Weick et al. 2005)(p.409). Taking a more dynamic or processual approach to analyzing these relationships can speak to the varied ways in which global ideas in STI are made into existence in policy that seeks to address them. Like sense-making (Brown et al. 2015), an expanded notion of isomorphic difference-making would better explain and describe the intertwined nature of micro-meso-macro processes nested within policy for STI, not just as a snapshot but more dynamically. It would direct the empirical exploration to follow actors or institutions more closely to trace how they enact isomorphic difference. This is

consistent with STS notions of symmetry and co-production that reframe away from taking global models as taken-for-granted ideas that get simply reproduced.

5. CONCLUSION

5.1 Starting Point and Overall Conclusion

This dissertation began by addressing the rise of global ideas in policy for STI across vastly different national contexts, including the ongoing debate in the social sciences about the relationship between a globalized world and local contexts. This is a particularly relevant topic within the world of policy for STI given its increasingly global aims yet very local histories (Hofmänner and Macamo 2021). To shed light on this important matter, this dissertation asked the following research question:

How are global ideas in policy for STI understood within specific contexts?

The conceptual lens of *isomorphic difference* has been employed to describe, analyze, and compare policies in the United States, China and Denmark to facilitate a new approach to global ideas in policy for STI. Through four empirical analyses, this approach produced findings that revealed how the global and local in policy for STI are entangled and sustain each other over time. This dissertation helped show how as global ideas become national strategic priorities or coveted international goals in policy for STI, they take on particular frames and variations. It has also discussed how these findings contribute to the STI and STS literatures.

The central argument of this dissertation has been that local discussions, processes and practices shape understandings of what global ideas in policy for STI are and what they can do within countries. These understandings evolve, vary across contexts, and are layered within national policies for STI. The ways in which global ideas become embedded and localized shows how the mundane social, organizational and political contexts within national, sectoral and organizational boundaries gain a new significance in the understanding of global ideas in policy for STI.

5.2 Core Contributions

The dissertation makes three overarching contributions. First, it builds upon and develops a new conceptual approach, *isomorphic difference*, which regards global and local ideas as relational. Second, it provides ways to operationalize this approach to pursue similarities and distinctiveness within and across countries. Third, it produces empirical insights that advance our understanding of the fate of global ideas in policy for STI. I elaborate on each below.

The first contribution is theoretical. One of the central aims of this dissertation has been to highlight how global ideas in policy for STI are shaped by the interplay between global and local pressures. This approach builds on a novel conceptual lens, *isomorphic difference* (Irwin et al. 2021), that regards homogenizing and difference-making pressures in policy for STI as relational and which enables a better understanding of how struggles over global ideas in policy

for STI relate to broader patterns of social organization. The dissertation's employment of this approach pushes understandings in STS that tend to be focused on the local by incorporating insights from institutional theory that facilitate a connection to the global pressures that are ever present in policy for STI. By promoting knowledge flows between the scholarly traditions (see e.g., Bhupatiraju et al. 2012; Berman 2008), the findings produced advance understandings in STS about policymaking by conceptualizing isomorphic and local pressures within global ideas as dynamic and co-producing. It also contributes to scholarship on policy for STI (Simon et al. 2019) by providing better understanding of how global ideas are embedded within national policy and their interplay with global innovation processes. Moreover, this work results in a deeper understanding of the global travel of ideas in policy for STI, including dynamics of local interpretation and re-appropriation within and across countries. Additionally, the dissertation shows how the conceptual lens connects with concepts of local-global relations in institutional theory like glocalization, but extends them by arguing in favor of a relational approach between the global and local that unfolds beyond notions of 'two sides of the same coin' (Meyer 2013)(p.79). Finally, this work extends the conceptual lens of isomorphic difference by pointing to the need for further theorizing and conceptual refinement. The empirical cases in this dissertation suggest the need to better account for the ongoing ways in which processes of isomorphic difference emerge and unfold in policy for STI, i.e., proposing a more processual approach to future iterations of this conceptual lens.

The second contribution is methodological. This dissertation tested the novel conceptual lens of isomorphic difference empirically in three national contexts and across four different global ideas. The methodological approach combined two elements, i.e., detailed empirical analysis of specific policy settings and comparative frameworks to investigate global ideas within and across settings. The empirical analysis of particular policy settings included two cases analyzing the NNI in the United States (Articles 1 and 2) that showed how to operationalize isomorphic difference deductively and inductively. The development and application of a documentary analysis system in this dissertation allowed the analysis and comparison of national policy statements within and across countries (Articles 3 and 4). The four articles examined specific global ideas to showcase different elements of the evolution of policy for STI, from recent developments that point to the incorporation of diversity in STI (Article 1) to science's core founding principles as an area of public investment (Article 4). This methodological approach proved useful and productive, but also as demanding in terms of selection of cases and analytical granularity.

Third, an important descriptive ambition of the dissertation was to depict the use of global ideas in policy for STI, showing not just how but in what specific contexts they are called upon and for what purposes. The dissertation thus produces substantive empirical insights that shed light on the presence and fate of global ideas in STI policy across national contexts and domains. The empirical examples responded to the need for applying the conceptual lens of *isomorphic difference* and needed comparison across countries that can enhance it (Irwin et al. 2021). The findings advance our understanding of specific global ideas in policy for STI (i.e., diversity, valley of death, innovation-based future, and rationales for research). It revealed how diversity is framed in policy for nanotechnology in the United States and how each frame inserts

increasingly complex expectations of diversity. But also, it revealed how the valley of death initially appeared as a unitary mode of persuasion in the NNI that came to be understood, interpreted and supplemented in ways that make it the product of a very specific national policy assemblage. Similarly, at a high level, an innovation-based future appeared to be operationalized similarly in China and the United States; yet, the analysis showed that even when similar policy instruments were called upon, they took meanings that reflected the national context in which they are used. Across the United States, China and Denmark, it was clear that foundational rationales for research funding have taken root in national policy for STI appearing strongly in all three countries. Yet the analysis also revealed the subtle ways in which countries make these global ideas their own, i.e., the national interpretation of each rationale pointed to how the local-global are co-constructed in local policy settings. Together, these findings point to the ways in which countries not only adopt global ideas but localize them to meet national goals or needs. These cases highlight important dimensions of contemporary research and innovation policy such as the pressures that countries face in light of global goals in policy for STI or the varied national understandings that emerge from seemingly consistent global ideas. This work underscores the value of a conceptual lens like isomorphic difference that can keep pace with emerging trends in the global enterprise of global policy for STI (Hofmänner and Macamo 2021; Flink and Kaldewey 2018). By making these connections visible, the dissertation may stand as a point of departure for discussing how particular global ideas and institutions work together to promote change or reinforce the status quo in policy for STI. The findings show the need to consider global ideas in policy for STI as situated, pointing to multiple, sometimes conflicting understandings that get flattened-out in the national and global contexts.

In sum, the dissertation interrogates global ideas as taken-for-granted elements in policy for STI and conceptualizes them as ‘sites of the performance and enactment of isomorphic difference’ (Irwin et al. 2021)(p.8). In this way, I foreground the need to study global ideas in policy for STI and how they come to be understood and performed within a country and between countries. The in-depth analyses of the case of national nanotechnology policy and the study of national STI strategies combines attention to the structural or macro-level phenomena and micro-sociological processes, symmetrically. The dissertation also contributes to scholarship in STS and STI policy on the ideational content of policy for STI and to scholarship in institutional theory interested in the interplay between local and global pressures. In this sense, the application of the conceptual lens of *isomorphic difference* opens important empirical, theoretical, and practical contributions providing new insights into global governance of policy for STI as a technoscientific practice.

5.3 Lessons Learned

It is often easy to argue that things should have been done differently once a project is completed. However, reflecting on the process underscored the value of the approach taken. A review of the original research proposal submitted to the PhD School was a sobering reminder of an ambitious researcher who could not predict conducting the project during a global pandemic. COVID-19 upended plans to travel and do field work in the United States; meant that

much coursework and conferences were either cancelled or moved online, missing thus crucial socialization during a formative time as an early-career scholar; and it inserted a high dose of uncertainty that delayed even the most carefully planned journey. But the pandemic also steered the research into something 'doable' that pushed the investigation toward research basics in a world increasingly dazzled by 'big data' and automation to analyze it. And while it would be foolish to say that these are the only lessons, there are at least three worth sharing for those who have made it this far in the dissertation: (1) kill your darlings; (2) follow the money; and (3) it could have been otherwise. Each lesson is described separately, but these lessons are intertwined, and they reinforced each other throughout the research journey.

First, to 'kill your darlings' is probably the most valuable lesson learned from carrying out the research project. Not just because the research had to be done under circumstances that were often unpredictable, but also because it made the workload more bearable and coherent over time. This lesson applied to everything that seemed necessary at the start but over time, was evidently not. For example, on the question of how to identify global ideas in policy for STI, field work seemed like the perfect approach to immerse this research into the 'working' policy world. The pandemic made this aspiration impossible, which led to identifying steps that were manageable within the global context in which the project was unfolding. Document analysis became a primary method that provided a simple and comparable entryway into three distinct national settings and within a country. This lesson also applied to all parts of the research process, e.g., data collection, writing, analysis, dissemination. As a researcher, it is hard to kill your darlings, especially early in the process, but time and time again it revealed the value of simplicity in approaching the research inquiry.

Second, in setting out to answer the research question, it was hard at first to see the forest from the trees, meaning that you enter a world of so much information that it can be hard to focus on anything. It all seems important. A wise mentor told me that this is common for all doctoral students, but that people with professional experience especially find themselves in this dilemma because after seeing the messiness of the 'real' world, it is hard to simplify it for the research process. Dealing with this mess led me to follow the money, an unintended tribute to the business setting for my doctoral journey. And while this dissertation was not about political corruption in policy for STI like the phrase may imply, by focusing on where a particular technology or policy area was investing in, good empirical cases were revealed. These investments inspired a focus on commercialization in nanotechnology, which enabled the analysis of a familiar trope, 'the valley of death.' But it also made the foundational rationales used by policymakers to justify investments in research within and across countries an obvious place to take the research. Following the money made the project interesting and workable.

Third, Susan Leigh Star once wrote that we must '…as Everett Hughes once said, remember that 'it could have been otherwise'…Do not accept the current constructed environment as the only possibility…' (Star 1995)(p.6). I hope the dissertation make us question whether the global ideas analyzed here are the ones needed to achieve the futures that current policy for STI imagines. This means that we must ponder whether they are the best for improving the quality of STI, addressing climate change, improving pandemic preparedness or being responsive to other

important societal challenges like poverty or disability. It was surprising to find how accepted 'diversity,' the 'valley of death,' innovation-based futures, and foundational rationales appeared across contexts, but also how distinct they were when seen up close. The national adaptation of these global ideas offers hope about the potential re-imaginations taking place. As researchers, we must remember that it could have been otherwise, and it remains critical to question the global ideas that make it into policy if we aim to affect change in the world we live in. I would like to highlight the work of two scholars and friends whose work I believe can inspire this re-imagination: Megan Neely and Bontu Lucie Guschke. First, Megan Neely's work offers a cautionary tale about the stories used to rationalize inequality in the United States (Neely 2022). Her work on the hedge fund industry stresses how by highlighting 'the unique skill sets and talents of hot shot traders' (Neely 2022)(p.10) participants are able to justify and maintain a workplace where women and minority men are displaced and undervalued. Setting out to explore the mechanisms through which global ideas get rationalized in policy for STI supports this call for imagining that things 'could have been otherwise.' Bontu Guschke (2023) reminds us that as researchers we must take into account our embodied experience when conducting research. I did not take this methodological approach here, but in my interview notes I could identify a similar uneasiness to that described by Guschke (2023). I understand now that this is something that I should center more in my future work. In returning to the scholarly study of policy for STI and the global ideas that get taken for granted, this approach offers an alternative that can probe and theorize problems that may otherwise remain unseen.

This dissertation, albeit limited, aspired to stimulate others to consider the relationships between global ideas in policy for STI and their enactment within countries. The lessons learned through this journey may help others embarking in large research projects or those that are curious about the role of global ideas in policy for STI because this work showed they are integral to current policymaking.

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Appendix 1. Memorandums of Understanding for Co-Authorship

Updated: 16.12.2020

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HANDELSHØJSKOLEN

MEMORANDUM OF UNDERSTANDING FOR CO-AUTHORSHIP

The following parties:

The PhD student

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The co-author

Name: Alan Irwin

Address: Department of Organization, Kilevej 14 A, Room 4.96, 2000 Frederiksberg

(the above parties also individually referred to as a "Party" and collectively as the "Parties")

1. Co-authorship

1.1 This Memorandum of Understanding (hereinafter referred to as "the MoU") contains the Parties' understanding regarding the Parties' collaboration on a joint research article or manuscript ("the work").

1.2 The contribution of the co-author may be, but not limited to:

a) Formulation/identification of the scientific problem to be investigated and its operationalization into an appropriate set of research questions to be answered through empirical research and/or conceptual development.

b) Planning of the research, including selection of methods and method development.

c) Involvement in data collection and data analysis.

d) Presentation, interpretation and discussion of the analysis in the form of an article or manuscript.

1.3 By signing this MoU, the Parties agree to sign CBS' co-author statement upon completion of the work. The MoU is non-terminable and will expire upon submission of the PhD thesis.

1.4 The co-author statement contains a specific description of the co-author's contribution to the work alongside the acknowledgement and consent of the co-writer, that the work will be a part of the PhD student's thesis and that the work will be published electronically and in a limited edition in print as a part of the PhD thesis by the CBS Library in connection with the PhD defence.

2. Signatures

For the PhD student

Place: Copenhagen Date: July 4, 2022

Name: Aixa Y Alemán-Díaz

Signature:

For the co-author

Place: Copenhagen Date: July 4, 2022.

Title: Professor

Name: Alan Irwin

Signature: G. A. Irwin

Updated: 16.12.2020

MEMORANDUM OF UNDERSTANDING FOR CO-AUTHORSHIP

CBS COPENHAGEN BUSINESS SCHOOL HANDELSHØJSKOLEN

The following parties:

The PhD student

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1. Co-authorship

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2. Signatures

For the PhD student

Place: Copenhagen Date: 4 July 2022

Name: Aixa Y. Alemán-Díaz

Signature:

For the co-author

Place: Copenhagen Date: July 4, 2022

Title: Dr.

Name: Jane Bjørn Vedel

Signature:

Updated: 16.12.2020

MEMORANDUM OF UNDERSTANDING FOR CO-AUTHORSHIP

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2. Signatures

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Place: Copenhagen Date: 4 July 2022

Name: Aixa Y. Alemán-Díaz

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Place: Copenhagen Date: 4/7-22

Title: Dr.

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Updated: 16.12.2020

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2. Signatures

For the PhD student

Place: Copenhagen Date: 4 July 2022

Name: Aixa Y. Aleman-Diaz

Signature:

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Place: Frederiksberg Date: 13/7/22

Title: Professor

Name: Signe Vikkelsø

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Updated: 16.12.2020

MEMORANDUM OF UNDERSTANDING FOR CO-AUTHORSHIP

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2. Signatures

For the PhD student

Place: Copenhagen Date: July 4, 2022

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Signature:

For the co-author

Place: Copenhagen Date: 27/06/2022

Title: Dr.

Name: Xiaobai Shen

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Updated: 16.12.2020

MEMORANDUM OF UNDERSTANDING FOR CO-AUTHORSHIP

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2. Signatures

For the PhD student

Place: Copenhagen Date: 4 July 2022

Name: Aixa Y. Aleman-Diaz

Signature:

For the co-author

Place: Copenhagen Date: 14 July 2022

Title: Dr.

Name: Xuan Li

Signature: Xuan Li

Appendix 2. Co-Author Statements

Updated: 27.11.2020

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CO-AUTHOR STATEMENT

Title of paper	Into the 'Valley of Death': Isomorphic Difference in Policy for Nanotechnology in the United States
Journal and date (if published)	

1. Formulation/identification of the scientific problem to be investigated and its operationalization into an appropriate set of research questions to be answered through empirical research and/or conceptual development
Description of contribution: Identification of research area and its oprationalization was done collectively.
2. Planning of the research, including selection of methods and method development
Description of contribution: Identification of the empirical material and operationalization of the study was done by first author.
3. Involvement in data collection and data analysis
Description of contribution: Literature review, thematic analysis and interviews were conducted by first author. Data interpretation was a shared undertaking.
4. Presentation, interpretation and discussion of the analysis in the form of an article or manuscript
Description of contribution: Presentation, interpretation and discussion of analysis were done mainly by first author with critical contributions by the second author.

P2

Publication
Please note that the article will be published electronically and in a limited edition in print as a part of the PhD thesis by the CBS library in connection with the PhD defence.

1. Co-author (PhD student)	Aixa Y. Alemán-Díaz Name
I hereby declare that the above information is correct	
July 4, 2022 Date	 Signature

2. Co-author	Alan Irwin Name
I hereby declare that the above information is correct	
July 4th, 2022. Date	 Signature

3. Co-author	 Name
I hereby declare that the above information is correct	
 Date	 Signature

4. Co-author	 Name
I hereby declare that the above information is correct	
 Date	 Signature

Updated: 27.11.2020

CO-AUTHOR STATEMENT

Title of paper	National Varieties of the Knowledge Economy: Isomorphic Difference in Science, Technology, and Innovation Policy Instrument Mixes across the United States and China
Journal and date (if published)	

1. Formulation/identification of the scientific problem to be investigated and its operationalization into an appropriate set of research questions to be answered through empirical research and/or conceptual development
Description of contribution: Formulation of the scientific problem and its operationalization was done collectively.
2. Planning of the research, including selection of methods and method development
Description of contribution: Identification of empirical material was done by each author. Methods were planned collectively, but first author entered all manually coded data into Nvivo and produced the graphcs. Method development was a shared undertaking.
3. Involvement in data collection and data analysis
Description of contribution: Data collection and analysis was a shared undertaking.
4. Presentation, interpretation and discussion of the analysis in the form of an article or manuscript
Description of contribution: Presentation, interpretation and discussion of the analysis was done collectively. First author organized reference list for the manuscript.

P3

Publication
Please note that the article will be published electronically and in a limited edition in print as a part of the PhD thesis by the CBS library in connection with the PhD defence.

1. Co-author (PhD student)	Aixa Y. Alemán-Díaz Name
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14/July 2022 Date	Xuan Li Signature

3. Co-author	 Name
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 Date	 Signature

4. Co-author	 Name
I hereby declare that the above information is correct	
 Date	 Signature

Updated: 27.11.2020

CO-AUTHOR STATEMENT

Title of paper	Blending Curiosity, Market, and Mission Rationales: Analyzing Isomorphic Differences in National STI Policies
Journal and date (if published)	

1. Formulation/identification of the scientific problem to be investigated and its operationalization into an appropriate set of research questions to be answered through empirical research and/or conceptual development

Description of contribution:

Formulation of the scientific problem, conceptual framework, and its operationalization was initially done by SV with support from AYAD, but involved all authors in its evolution.

2. Planning of the research, including selection of methods and method development

Description of contribution:

Identification of empirical material was done by country teams (USA:AYAD; CH; JKK, XL, and XS; DK: AI, JBV, and SV). Methods were planned collectively, and coding was done was all authors. Re-coding and entering manually coded data into Nvivo and producing the graphs in the paper were done by AYAD. SV and AYAD led a final check of coded material ahead of submission. Method development was a shared undertaking.

3. Involvement in data collection and data analysis

Description of contribution:

Data collection and analysis was a shared undertaking.

4. Presentation, interpretation and discussion of the analysis in the form of an article or manuscript

Description of contribution:

Presentation of findings was done by individual country teams. Interpretation and discussion of the analysis was primarily by SV and AYAD, but all authors contributed to the final product.

Publication
Please note that the article will be published electronically and in a limited edition in print as a part of the PhD thesis by the CBS library in connection with the PhD defence.

1. Co-author (PhD student)	Aixa Y. Alemán-Díaz Name
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2. Co-author	Alan Irwin Name
I hereby declare that the above information is correct	
July 4th, 2022 Date	G A. Irwin Signature

3. Co-author	Julia Kirch Kirkegaard Name
I hereby declare that the above information is correct	
4/7-22 Date	Julia Kirch Kirkegaard Signature

4. Co-author	Xuan Li Name
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14/7-22 Date	Xuan Li Signature

P4 continued

Publication
Please note that the article will be published electronically and in a limited edition in print as a part of the PhD thesis by the CBS library in connection with the PhD defence.

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July 4, 2022 Date	Signature

2. Co-author	Name XINTONG SHEN
I hereby declare that the above information is correct	
Date 27/06/2022	Signature

3. Co-author	Jane Bjørn Vedel Name
I hereby declare that the above information is correct	
July 4, 2022 Date	Signature

4. Co-author	Signe Vikkelsø Name
I hereby declare that the above information is correct	
July 13, 2022 Date	Signature

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