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The conceptual evolution of responsible research and innovation in China: a systematic literature review

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ABSTRACT

Within the contemporary global economy, research and innovation are just as likely to come from non-western economic and political powers, such as China, as from western powers more traditionally associated with research and innovation production, such as in Europe and North America. Subsequently, how Responsible Research and Innovation (RRI) is conceptualised and applied in these alternative contexts is an important question. This review aims to contribute to a better understanding of the evolution and application of RRI in China by reviewing Chinese academic literature. Our analysis indicates that, on the one hand, there is wariness that a complete transplantation of a European conception of RRI to China might lead to cultural imperialism. On the other hand, it is hoped that RRI will improve the ethical governance of technological innovation in China. By analysing Chinese scholarship, the paper also attempts to define distinctive features of RRI in China.

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Introduction

Responsible Research and Innovation (RRI) has gained traction in both policy and practice in recent years since its conceptual development in Europe and North America. RRI is a policy framework that seeks to incorporate the societal and ethical values held by society into science, technology, and innovation (STI), and is often coined 'research and innovation for and with society' (Stilgoe, Owen, and Macnaughten 2012). Within the current global economy, innovations are just as likely to come from non-western economic and political powers, such as China, as from countries and regions more traditionally associated with research and innovation production, such as North America or Europe. Innovations from both western and non-western origins can have global reach and impact, yet, the concept of RRI emerges from regions with distinctly liberal democratic values, advocating openness, inclusivity, and a co-creative style (Wong 2016).

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Attempts at universalism are often criticised for creating unhelpful ‘thin’ normative frameworks, unable to account for the diversity found within emerging powers, including China. This raises the questions: how is RRI translated into non-western contexts, such as China, and how can it be applied, if at all? The nature of STI in China is somewhat of a black box. Both wider technological innovation processes – and specifically in relation to questions of research and innovation ethics – are relatively underexplored.

The discussion of RRI in China in relation to its western conceptualisation is first found in 2011 (Zhao 2011), and quickly gained prominence within Chinese academic and government circles. ‘Responsible innovation’ was included in China’s 13th Five-Year Plan (2016–2020) for science and technological innovation in 2016. Engagement with the theme of responsible innovation demonstrates an increasing concern with technology, innovation, and research management in Chinese thought and policy. For the 14th Five-Year Plan (2021–2025), the Ministry of Science and Technology of China formulated 15 major issues for China’s STI planning, including (1) ‘Research on the Comprehensive Impact of Science and Technological Innovation on Chinese Society and Response Measures in the 14th Five-Year Plan’ and (2) ‘A study on ideas and measures for scientific openness and technological open source in China in the 14th Five-Year Plan’. These themes do not directly reference RRI, but again represent ‘major issues’ potentially influenced by RRI thinking and practice in China. Issues associated with RRI, such as technology ethics and openness are clearly of concern for Chinese STI policy. However, it is unclear how a primarily western liberal and democratic concept, predicated on values of freedom, equality, and participation, is applicable within contexts where responsibility and inclusivity may be conceived of differently (Wong 2016); specifically, Wong (2016) problematises the application of an RRI seeded with liberal and democratic values into *decent*, but non-liberal and non-democratic contexts, without acknowledging the impossibility of applying RRI in such contexts, or supposing the acceptance of the liberal democratic values. Since the seeding of the concept in China, a body of research is emerging that explores RRI’s possible reconfiguration and application to the Chinese context (Mei, Rodríguez, and Chen 2020; Wong 2016; Yan and Ravesteijn 2019; Yandong and Liao 2019).

There is, however, no overview or synthesis of this work, leaving the question of how RRI in China has been reconfigured and applied to date unanswered in a systematic way. To tackle this challenge, we conduct the first systematic literature review on RRI in China in order to understand:

- (1) How the concept of RRI is currently interpreted by Chinese scholars?, and
- (2) What reconceptualization may be needed to further embed RRI principles into Chinese STI policy?

To tackle these questions, we undertake a review and analysis of Chinese academic articles on RRI. In doing so we explore how RRI as a theoretical concept is interpreted, disseminated, and accepted in the Chinese academic articles and academic community. This can help improve the international academic community’s understanding of developments within Chinese STI scholarship and policy.

The remainder of the paper is structured as follows. Next, we briefly outline the emergence of RRI, its core constituents and its western, liberal roots. Next, we explore why

RRI is relevant in a Chinese context, and what it means for China. Following this, we outline the approach we took to the systematic literature review, after which, we outline our results and subsequent observations and discussion points.

Literature review

RRI in the 'west' and beyond

RRI has established itself as a widely applicable umbrella concept focused on the integration of societal and ethical values and dimensions into STI (Grunwald 2011). The concept originated in the social, political, and economic contexts of Europe and the United States – hence our use of 'western' to describe its origins. It is increasingly supported at national and supra-national level, for instance, through the European Union (EU) Horizon research programme. RRI seeks to help policymakers, researchers, entrepreneurs, and society better understand and respond to societal and ethical challenges posed by innovations. According to the most widely used definition, '[RRI] is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products' (He and Li 2013).

RRI seeks to address the integration (or lack thereof) of socio-ethical issues into STI to better manage unforeseen and unexpected impacts, improve the societal embeddedness of innovations (Brusoni and Vaccaro 2017), and avoid societal resistance to the widespread deployment and use of innovations (Bronson 2019; Gremmen, Blok, and Bovenkerk 2019). RRI has been articulated in several ways since its conceptual emergence. Examples include, the EU principles, or 'keys' such as open science and gender (Ruggiu 2015; von Schomberg 2013), or governance frameworks, such as the AIRR (anticipation, inclusive deliberation, reflexivity, and responsiveness) framework, (Stilgoe, Owen, and Macnaughten 2013), or three P's structure, covering purpose, process, and product (Stahl et al. 2017). The approaches which achieved early prominence were notably European. The EU's six (sometimes five) keys are policy themes or research programmes, which are methodologically opens, covering 'engagement', 'gender', 'ethics', 'science education', 'open access', and 'governance'. The AIRR framework, conversely, focuses on the dimensions of anticipation, inclusivity, reflexivity, and responsiveness and is process orientated, with specific methodologies associated with each dimension (Pols, Macnaghten, and Ludwig 2019). Yet both approaches emerged within western, liberal democratic debates on how to better aligned research and innovation processes with societal needs, which resulted in the identification of higher-level principles, such as anticipation, ethics, reflexivity, engagement (with publics and stakeholders), and openness and mutual responsiveness regarding agendas and trajectories (Owen, von Schomberg, and Macnaghten 2021). Given these principles, the EUs keys are seen as somewhat disparate, reductive, and overly simplistic approach, and are seen as a compromise between adhering to the original principles and maintaining some continuity with the EUs previous 'Science in Society' programme (Pols, Macnaghten, and Ludwig 2019).

How RRI is extended beyond its 'native' western context remains somewhat of an open question, and a question posed due to the global nature of STI and associated

international networks. The international nature of STI means that RRI policies and practices are likely to come into contact with different STI cultures and values, with different conceptions of responsibility and ethics (Macnaughten et al. 2014; Wong 2016). Given this, how could RRI be translated and practiced in other contexts that do not share similar founding values or norms? Early examples are evident, for example in Indonesia (Setiawan 2020), Brazil (Reyes-Galindo, Monteiro, and Macnaughten 2019), and more broadly, the global south (Wakunuma et al. 2021). But these early efforts are insufficient to gain an overall and comprehensive understanding.

China, due to its size and economic, scientific, and technological influence, represents somewhat of a special and interesting case when it comes to exploring the application of RRI beyond its western ‘heartlands’. Given the different values and governance traditions in China, it is natural to consider how RRI is translated and subsequently conceptualised (Gao, Liao, and Zhao 2019; Mei, Rodríguez, and Chen 2020; Yan and Ravesteijn 2019). For instance, it is highlighted that China is more economically orientated when it comes to STI policy, with implications for the relative focus on environmental protection or for instance the safe application of technologies (Gao, Liao, and Zhao 2019).

Given the context within which RRI has been developed, and its implicit – and to some extent, explicit – focus on liberal democratic principles (Wong 2016), an RRI agenda for China is likely to look somewhat different. A potential difference concerns levels and forms of participation, a key element in original conceptions of RRI through dimensions such as inclusivity (Stilgoe, Owen, and Macnaughten 2012; Yang and Han 2017), which considers: to what extent are societal members included? And in what ways? For example, in the case of the development of a green port in Dalian, from an initial application of a ‘euro’ centric RRI, quite a different RRI emerges, based on higher levels of government leadership and input, and drawing on corporate social responsibility framings around the balancing of people, planet, and profit (Yan and Ravesteijn 2019).

Given China’s rising prominence in STI policy, the questions of how to integrate socio-ethical issues in research and innovation processes – and the role of western traditions of RRI in this, takes on even more importance. And while we see early engagement with the question, these contributions are either conceptual in nature (Wong 2016), tentative and exploratory (Mei, Rodríguez, and Chen 2020) or more case based (Yan and Ravesteijn 2019), meaning a more systematic and comprehensive study is needed, and it is here that we aim to make our contribution.

RRIs relevance to China

The interest in exploring RRI within a Chinese context is based on several factors. First, the increasing strategic rivalry between China and other major economic blocs, such as the European Union and the United States, is driving demand for research and innovation governance systems for advanced STI. The need for scientific and technological advances raises important questions of responsibility as well as the wider need for the integration of socio-ethical factors into scientific and innovation processes.

Second, there is a growing need to ensure that STI incorporates ‘responsibility’ given the fact that China must often develop its own science and technology domestically as its access to existing solutions is often restricted, for example, by the 1996 Wassenaar

agreement.¹ Consequently, although China is emerging as a R&D power, it still lags behind in terms of technology development, and especially in terms of the quality of its technological innovation (Li, Ji, and Zhang 2020).

Third, and because of the international restrictions, China focuses on the development of an independent STI strategy. Given the need for advanced technology, while facing the limitations of technological imports, China has placed greater emphasis on the development of an independent STI capability. China's core technology in many areas – semiconductor chips, sensors, high-end materials and equipment, systems, and specialised software, for instance – highlights the 'stuck neck' problem (Xiao 2019). Solving this technology and innovation problem depends on whether China can successfully cross the 'middle-income trap', and whether it can achieve modernisation by 2035. Consequently, the governance of STI takes on renewed significance.

Fourth, given the prominence of STI policy and the need to consider wider questions of its governance, RRI approaches from the west could provide useful insights for the development of China's own STI policies. In the search for reference points and examples, there is interest in European STI policy in particular (Gao, Liao, and Zhao 2019).

We conduct a systematic literature review in response to these developments in China, and to address the lack of a systematic consideration of RRI's interpretation and conceptualisation among Chinese scholars. In doing so, we are also able to provide initial thoughts on the practical and conceptual development for and in the Chinese context. In the following section, we outline our methods and how we conducted the systematic literature review.

Methodology

We seek to explore how RRI is conceptualised and interpreted in the Chinese context and what reconceptualization may be needed in the future to further embed RRI principles in Chinese STI policy. To do this, we analyse the interpretation and conceptualisation of RRI in China. We do this via a systematic literature review, following the five steps of the Denyer and Tranfield literature review process (Denyer 2009), including (1) question formulation, (2) locating studies, (3) study selection and evaluation, (4) analysis and synthesis, and (5) reporting the results.

Study location, selection, and evaluation

We retrieved Chinese RRI academic articles to analyse from the CNKI full-text database, the most important and comprehensive database of academic articles in China (see <https://www.cnki.net/>). The search terms used covered all four key expressions, including Chinese parallel synonyms, for 'Responsible Research Innovation' and 'Responsible Innovation', including '责任创新, 负责任的创新, 负责任研发与创新, 责任式创新'.

We initially identified over 900,000 Chinese academic articles dealing with responsibility in general, while 78,000 Chinese articles deal with the issue of responsibility in innovation. Our research does not focus on responsibility in innovation in general but rather how Chinese scholars interpret and conceptualise RRI.

RRI is now largely expressed as ‘负责任创新 (Responsible Research Innovation)’, but in the early days of the introduction of RRI into the Chinese context, the term used included ‘负责的创新, 负责任研发与创新, 责任式创新’ (Chinese Parallel Synonyms for ‘Responsible Research Innovation’ and ‘Responsible Innovation’). The search took these changes and variance in terminology into account. The search yielded 96 articles; these were read individually to identify reference to, and/or overlap with the main paradigms of RRI based upon the conceptualizations of RRI by the European Commission, Von Schomberg, Stilgoe, Owen and Macnaghten and Van den Hoven (Timmermans and Blok 2018). Where no reference or overlap with the main paradigms of RRI was found, the articles were excluded. This results in a final sample of 77 articles.

The first Chinese academic article in our sample was published in 2011, in which Zhao Yinghuan (2011) introduced the theoretical concepts of value-sensitive design, emotional responsibility, sustainability, and responsible innovation in Dutch technology ethics, from an STS perspective. After nearly a decade, RRI has attracted widespread research interest in China in the fields of philosophy of technology, STI policy, technology ethics, and management.

Results and discussion

Theme development

We summarise the 77 articles included in the review in [Table 1](#) (below), and categorise the articles according to the ‘European’ keys of RRI: public engagement, gender equality, science education, ethics, open access/open science, and governance. Other themes include case studies, review of the theory of RRI, response to technology innovation risks, and innovation incentives.

Thirty-one articles discuss RRI issues in the context of Ethics, making it the most prominent theme in Chinese academic circles. In second place was Public Engagement, with 11 articles or around 14%. These articles often emphasised the inadequacy of the current role of the public in STI and the reasons for this situation. The third ranked was ‘Governance’ with five articles that focus on the role government should and could perform in STI in China. ‘Science education’ had three articles, focused on the process of responsible

Table 1. Thematic distribution of the content of Chinese academic articles engaging with RRI, including distribution of articles according to EU Keys and distribution of articles according to themes developed via the authors analysis. Please note some articles are allocated to more than one key or theme.

Six keys of European RRI	Number
Ethics	31
Gender	0
Governance	5
Open Science	0
Public engagement	11
Science education	3
In total, there were 41 articles covering 6 keys of European RRI, with some discussing more than one key in a single paper.	
<i>Theme of articles</i>	<i>Number</i>
The theory of RRI	32
New technology innovation risk	15
RRI Case Studies	27

STI through scientific education and technological talent. We did not identify any articles, using the search terms, that discussed RRI in terms of Open science nor Gender.

In terms of article content following our thematic analysis, 32 articles elaborate on RRI theory, including its origins, structure, and change, suggesting that understanding and translating RRI concepts is an important task for Chinese academics. Twenty-seven articles discuss case studies of RRI in China, and 15 articles discuss how RRI can address new technological innovation risks.

Following a thematic analysis of the articles, we highlight three distinct themes of interest in articles focused on the question of RRI in China. The thematic analysis was performed on the basis of the keywords of the retrieved articles, which initially yielded the three distinct themes of interest in articles focused on the question of RRI in China. The themes that emerged through the analysis of the keywords and article topics were confirmed through more detailed reading and analysis of the papers.

First, these include theoretical articles, focused on summarising and describing the concept, associated frameworks, and current trends in RRI. These articles explore the concept of RRI and start to interpret questions of 'RRI' within Chinese contexts including finding potential connection points. Second, we identified practice-orientated articles, focused on how RRI is practiced in China, mainly described through case studies. The third theme focuses on the tension between the liberal democratic roots of RRI versus its Chinese application. This tension is between a more 'objective' or expert-based ethics, via engineers or scientists, versus, lay public engagement which is seen to conflict with Chinese traditions.

Chinese theoretical engagement with the RRI concept

Chinese scholars have undertaken somewhat of a systematic conceptual review of RRI. One explanation for why Chinese academic articles devote time and space to interpreting and translating the concept of RRI is that the concept does not translate directly to the Chinese context which is characterised by a deeply developmentalist, scientific, top-down system of STI (Zhao and Miao 2017). As will be explored, this is different to, and is maybe even contradictory with some of the fundamental ideas of the RRI that emerged in Europe and the United States, where there is greater emphasis on both 'public participation' and the re-balancing of economic and social interests (von Schomberg and Hankins 2019). Consequently, applying RRI to China potentially requires an interpretation that considers a Chinese theoretical identity and character. Consequently, one of the first tasks of Chinese academics has been to explore the concept of RRI through a Chinese lens.

We identify 32 articles, representing 42% of the total number of articles in the review, focused on introducing the concept of RRI to the Chinese context (Mei and Chen 2015). This includes summarising and discussing the content and framework of RRI (Yan, Zhang, and Wang 2014), the development status and trends of RRI (Liu 2015), and various other formulations, such as the paradigm (Mei, Jin, and Fu-jia 2017), essence (Liu 2018), doctrinal lineage (Liao 2019), as well as the context in which RRI emerged (Liao 2019). These articles were among the first to emerge in 2011.

Given that the concept of RRI is still under development, it is not surprising that we found little consensus on a definition nor how to extend RRI to China. Zhao Yandong

highlights that there is no unified nor precise definition of RRI (Zhao and Miao 2017). Liao Miao distinguishes between the concepts and terminology of ‘responsible innovation’ and ‘responsible research and innovation’ and argues that they are not equivalent concepts and should not be confused. Liao Miao analyses 11 scholars she considers to have made constructive contributions to the conceptualisation of RRI, including. Stahl, R. Owen, P. Macnaghten, J. Stilgoe, J. van den Hoven, A. Grunwald, M. Gorman, R. von Schomberg, D. H. Guston, E. Fisher, and S. van der Burg. By drawing on Timmermans’ (2017) work, Liao Miao categorises six dimensions: technological design, mid-stream regulation, anticipatory governance, technology assessment, public participation, and innovation transformation (Liao 2019).

Mei and Chen (2014) engage in the theoretical debate through several articles covering the theory and paradigm of RRI, its origin (Mei and Chen 2014) through to more specific questions, such as the integration of the connotation-theory-method (Chen Jin, Yin Ximing et al. 2017; Mei and Chen 2015; 2016; Mei, Chen, Huang et al. 2018; Mei, Chen, and Li 2018; Mei, Jin, and Xintong 2018; Mei, Jia et al. 2018; Mei, Jin, and Fujia 2017).

In the series of articles, Mei Liang and Chen Jin systematically introduced the AIRR framework and its dimensions of anticipation, inclusivity, reflexivity, and responsiveness (Stilgoe, Owen, and Macnaghten 2012). They summarise the core concept of RRI, including that: (1) technological innovation must be acceptable on a moral level; (2) technological innovation must meet social needs and expectations, consider economic, social, and environmental impacts and the realisation of the goals of social system norms; (3) RRI must reflect on the purpose of STI, as well as potential motivations and plans, so as to make science and technology development, systems and policies more socially responsive; (4) at its heart is the idea that innovation meets societal expectations and moral and ethical requirements, enabling multi-stakeholder participation, and that RRI represents a major challenge and innovation for society. Via their summary, Mei Liang and Chen Jin, offer a more direct translation and so very similar vision of RRI for the Chinese context.

Mei Liang and Chen Jin also provide a systematic summary of Van den Hoven’s account of RRI. They explore how innovation activities of curiosity-driven research and its outcomes can enable progress while also potentially producing harmful outcomes. However, their point is potentially a misapprehension, as they focus to a greater extent on the negative effects of commercial profit-driven technological innovation in RRI theory (von Schomberg and Hankins 2019). They suggested that developing a RRI for China involves: (1) introspection, reflection, and early warning of the innovation practices undertaken; (2) establishes public values for China’s national innovation-driven development, which may include ensuring that technologies are innovative and practical, meet public expectations, and are ethically and morally acceptable in terms of economic effectiveness and efficiency; and (3) the timely assessment of the process and outcomes of technological innovation and the establishment of a responsive management system for the entire STI process (Mei, Chen et al., 2018). Mei Liang and Chen Jin work through the disciplinary lens of scientific management and generally take a quantitative stance. As such, RRI as seen here, is translated for application, rather than being subjected to a deeper philosophical consideration of the concepts tenets and compatibility to Chinese systems, norms, and traditions.

RRI practice examples and case studies

We also identified articles where the concept of RRI has been used to explain, defend, or criticise STI activities. We find examples where RRI is used as an input into the development of analytical frameworks, or more generally to critique projects and current STI policy. Twenty-seven of the articles included in the sample focus on practical examples and practice, via cases. [Table 2](#) shows the thematic distribution of these articles.

The largest number of RRI case study articles (4) focus on artificial intelligence (AI). Mei Liang et al. (2018) use the concept of RRI to assess technological innovations in AI; they draw on RRI to propose the use of four dimensions: technical, economic, ethical, and social, to discuss the policy implications of the governance of emerging technological innovations. Similarly, Guo Linsheng and Liu Zhanxiong (2019), commenting from an STS perspective, discuss the regulation and design of ethical responsibility in AI using Van den Hoven's conception of RRI. Further examples of scholars using the RRI concept and related frameworks include Fu Ting's (2018) discussion of the governance of AI based on AIRR framework, and Duan Weiwen's (2017) critique of AI governance and the fairness of algorithmic approaches for the principles of transparency, understandability, and accountability, provided from a philosophy of technology disciplinary stance.

Yan Ping et al. (2015) analysed the application of RRI at Dalian Port. They conclude that 'responsibility' was operationalised through energy saving and emission reduction, integrity management, customer care, safety production, employee care, and social welfare. Comparing the differences between the RRI models of Dalian Port and those of European and American ports, the authors suggest that the RRI seen in European and American ports is 'bottom-up', versus at the Port of Dalian, where it is 'top-down', with government policy playing a major role (Yan Ping, Liu Wei et al. 2015). As such, rather than being process-orientated as with, for example, the AIRR framework, the Dalian cases present a more outcome-orientated approach, with implications for the inclusion of stakeholders, deliberation, and reflexivity.

Similarly, Li Yakun et al., use RRI as a lens to examine the Nansha Port project in Guangzhou. The central critique was that there was a lack of public participation, with local stakeholders having little influence over the project. The article notes the primacy of economic benefits, including business income and profits for the construction company, followed by environmental damage, with social issues coming third. The article proposed that the views of all parties be better balanced through a management structure modelled on the Quality Control Round Table of the Port of Rotterdam (Li Yakun, Li Zhiyuan et al. 2016).

Haoran, Zhanxiong, and Baohua (2017) explore the case of China Wireless Valley in Jiangning Development Zone, Nanjing, Jiangsu Province through the prism of RRI, again focussing on which stakeholders are included, i.e. universities, research institutions, park managers (a management department established by the government), and enterprises. Innovation in the Wireless Valley is top-down, with the government in a leadership position. This example is one of the first to highlight, empirically, how China's top-down management system is in potential conflict with the concept of RRI. The analysis emphasises the lack of ethical and moral awareness of innovation among researchers and the inability of the public to participate directly (Jia Haoran, Liu Zhanxiong et al. 2017).

Table 2. Thematic distribution of the case study articles on ‘responsible innovation’.

Theme	Numbers	Reference
Artificial Intelligence Governance	4	<p>段伟文. 人工智能时代的价值审度与伦理调适[J]. 中国人民大学学报, 2017, 31(06): 98-108.</p> <p>Duan Wei-Wen (2017). ‘Value Reflection and Ethical Adjustment in the Era of Artificial Intelligence.’ JOURNAL OF RENMIN UNIVERSITY OF CHINA 31(06): 98-108.</p> <p>浮婷. 推动负责任的人工智能研究与创新[J]. WTO经济导刊, 2018, (03): 51-2.</p> <p>Fu Ting (2018). ‘Promoting Responsible Artificial Intelligence Research and Innovation.’ China WTO Tribune (03): 51-52.</p> <p>梅亮, 陈劲, 吴欣桐. 负责任式创新范式下的新兴技术创新治理解析——以人工智能为例[J]. 技术经济, 2018, 37(01): 1-7 + 43.</p> <p>Mei Liang, Chen Jin and Wu Xintong (2018). ‘Innovation Governance of Emerging Technology from Responsible Innovation Perspective: Lessons from Artificial Intelligence.’ Technology Economics 37(01): 1-7 + 43.</p> <p>郭林生, 刘战雄. 人工智能的“负责任创新”[J]. 自然辩证法研究, 2019, 35(05): 57-62.</p> <p>Guo Linsheng and Liu, Zhanxiong (2019). ‘On the “Responsible Innovation” of Artificial Intelligence.’ Studies in Dialectics of Nature 35(05): 57-62.</p>
Researchers’ Responsibility for Innovation	3	<p>郝天瑶. 论科技工作者创新的道德风险[J]. 辽宁教育学院学报, 2016, 33(06): 46-9.</p> <p>Hao, T.Y. (2016). ‘On the Moral Risk of Innovation of Science and Technology Workers.’ Journal of Liaoning Institute of Education and Administration 33(06): 46-49.</p> <p>刘鲁. 孙鸿新: 负责任的创新[J]. 中国医院建筑与装备, 2017, 18(12): 41-4.</p> <p>Liu, Lu (2017). ‘Sun Hongxin: Responsible innovation.’ Chinese Hospital Architecture & Equipment</p> <p>郭丽芳, 崔煜雯, 马家齐. 创新驱动背景下新型研发机构员工负责任式创新行为研究[J]. 科技进步与对策, 2019, 36(16): 125-32.</p> <p>Guo, Lifang, Cui, Yuwen and Ma, Jiaqi (2019). ‘Research on Employee Responsible Innovation Behavior of New R&D Institutions under the Background of Innovation-driven.’ Science & Technology Progress and Policy 36(16): 125-132.</p>
Big Data Technology Innovation	2	<p>郭佳楠. 大数据技术创新的伦理审视——负责任创新方法论应用研究[J]. 科技和产业, 2014, 14(10): 143-5 + 53.</p> <p>Guo, JiaNan (2014). ‘The Ethical Review of Technology Innovation of Big Data—The applied research of responsible innovation methodology.’ Science Technology and Industry 14(10): 143-145 + 153.</p> <p>张艳菊. 大数据时代情报研究的责任担当风险与负责任式创新框架[J]. 情报理论与实践, 2017, 40(03): 9-13 + 9.</p> <p>Zhang Yanju (2017). ‘The risk of responsibility taking and the framework of responsible innovation in intelligence research in the era of big data.’ Information Studies: Theory & Application 40(03): 9-13 + 19.</p>
Port Construction	3	<p>晏萍, 刘伟, 张卫. 大连港负责任创新模式研究 [J]. 自然辩证法研究, 2015, 31(03): 122-6.</p> <p>Yan, Ping, Liu, Wei and Zhang, Wei (2015). ‘Research on Responsible Innovation Mode in Dalian Port.’ Studies in Dialectics of Nature 31(03): 122-126.</p> <p>晏萍, 张卫, 王前. “负责任创新”的理论与实践述评 [J]. 科技创新导报, 2014, 11(27): 4-7.</p> <p>Yan, Ping, Zhang, Wei and Wang, Qian (2014). ‘Review on Theory and Practice of “Responsible Innovation”.’ Science and Technology Innovation Herald 11(27): 4-7.</p> <p>李雅坤, 李致远, 刘子彦, et al. 基于负责任创新的广州南沙港发展模式分析 [J]. 山西建筑, 2016, 42(14): 224-6.</p> <p>Li Yakun, Li Zhiyuan, Liu Ziyuan and Chen Chaohe (2016). ‘Analysis</p>

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Table 2. Continued.

Theme	Numbers	Reference
Innovative Development of Cultural Industries	2	on Guangzhou Nansha port development model based on responsible innovation." SHANXI ARCHITECTURE 42(14): 224-226. 高军, 吴欣桐. 西南民族大学学报(人文社科版), 2018, 39(07): 144-8. Gao, Jun and Wu, Xintong (2018). "Innovation-driven cultural industry development: A new development framework." Journal of Southwest University for Nationalities (Humanities and Social Sciences Edition) 39(07): 144-148.
Dalian Hi-tech Park	2	于晶, 刘盛博, 王前. 大连高新技术园区负责任创新模式研究 [J]. 科技进步与对策, 2015, 32(14): 36-40. Yu Jing, Liu Shengbo and Wang Qian (2015). "A Study on Responsible Innovation Model in Dalian High-Tech Park." Science & Technology Progress and Policy 32(14): 36-40. 于晶, 刘盛博, 王前. 大连高新区企业负责任创新评价指标体系研究 [J]. 科技管理研究, 2016, 36(20): 37-42 + 8. Yu Jing, Liu Shengbo, Wang Qian. Research on the Evaluation Indicator System on Responsible Innovation in the Enterprises of Dalian High - tech Zone [J]. Science and Technology Management Research, 2016, 36(20): 37-42 + 8.
Gene Edited Babies	1	曹顺仙, 周以杰. 一种复合生态伦理何以可能——基于基因编辑婴儿的伦理审问[J]. 南京林业大学学报(人文社会科学版), 2018, 18(04): 90-4. Cao, Shunxian and Zhou, Yijie (2018). "How a composite ecological ethics is possible – an ethical interrogation based on gene-edited babies." Journal of Nanjing Forestry University (Humanities and Social Sciences Edition) 18(04): 90-94.
Construction of Ecological Civilization Demonstration Zone	1	曹顺仙, 陈崇天. 以“负责任创新”推进生态文明示范区的创新发展[J]. 南京工业大学学报(社会科学版), 2018, 17(02): 51-6. Cao, Shunxian and Chen, Chongtian (2018). "Promoting the Innovation and Development of Ecological Civilization Demonstration Area with RRI ." Journal of Nanjing Tech University (Social Science Edition) 17(02): 51-56.
Hangzhou Water Treatment	1	丛杭青, 顾萍, 沈琪. 杭州“五水共治”负责任创新实践研究[J]. 东北大学学报(社会科学版), 2018, 20(02): 111-6 + 30. Cong, Hangqing, Gu, Ping and Shen, Qi (2018). "On the Responsible Innovation in the Practice of Governance of Five Waters" in Hangzhou." Journal of Northeastern University (Social Science) 20(02): 111-116 + 130.
China Aerospace Quality Assurance	1	范春萍. “双归零”与负责任创新: 中国航天质量保障案例研究 [J]. 工程研究-跨学科视野中的工程, 2017, 9(05): 465-73. Fan, Chungping (2017). "Double Closed Loops and Responsible Innovation: The Case Research in China Space Industry Quality Assurance." JOURNAL OF ENGINEERING STUDIES 9(05): 465-473.
Smallholder Farms	1	何治江, 李强. 舒心农场: 责任式创新下小农户“博弈胜出”新业态 [J]. 安徽农业科学, 2019, 47(09): 256-9 + 62. He, Zhijiang and Li, Qiang (2019). "A New Format of Small Farmers "Win the Game "Based on the Responsibility Innovation." Journal of Anhui Agricultural Sciences 47(09): 256-259 + 262.
Wireless Valley Construction	1	贾浩然, 刘战雄, 夏保华. 中国无线谷负责任创新研究 [J]. 自然辩证法研究, 2017, 33(09): 55-60. Jia Haoran, Liu Zhanxiong and Xia Baohua (2017). "The Study of China Wireless Valley's Responsible Innovation." Studies in Dialectics of Nature 33(09): 55-60.
Corporate Responsibility for Responsible Innovation	1	李荣华. 南方路机: 做负责任的创新企业 [J]. 中国公路, 2013, 01): 96-7. Li, R. H. (2013). "Southern Road Machinery: Being a responsible and innovative company." China Highway (01): 96-97.
Double-class Construction in Universities	1	蔺海洋, 赵敏, 廖沁. “双一流”背景下高校科研行动的负责任创新研究 [J]. 江苏高教, 2018, 04): 17-21 + 43. Lin Hefeng, Zhao Min, Liao Qin. Research on responsible innovation of university research actions in the context of

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Table 2. Continued.

Theme	Numbers	Reference
Financial Technology	1	“double first-class” [J]. <i>Jiangsu Higher Education</i> , 2018, (04): 17-21 + 43. 刘北骁, 黄小军. 由美国金融科技“负责任创新”监管理念带来的思考 [J]. <i>中国银行业</i> , 2019, (01): 40-3. Liu, Beizi and Huang, Xiaojun (2019). “Reflections on the regulatory philosophy of “responsible innovation” for fintech in the United States.” <i>China Banking</i> (01): 40-43.
Ethical Risks of Neurotechnology	1	刘成科. 神经技术的伦理风险及其治理: 负责任创新的视角 [J]. <i>自然辩证法研究</i> , 2019, 35(06): 28-32. Liu, Chengke (2019). “The Ethical Risk and Its Governance of Neurotechnology: A Responsible Research and Innovation Perspective.” <i>Studies in Dialectics of Nature</i> 35(06): 28-32.
Ethics of “Internet + Dual Innovation”	1	潘恩荣, 杨明芳, 乔丽莎. 公众与创新创业——工业革命视野中“互联网+双创”的伦理盲区及其应对 [J]. <i>Ibid.</i> 2016, 32(12): 53-7. Pan Enrong, Yang Mingfang and Qiao Lisha (2016). “Entrepreneurship, Innovation and the Public: Ethical Blind Spots and Their Solution of “Internet + Mass Entrepreneurship and Innovation” in the Perspective of Industrial Revolution.” <i>Studies in Dialectics of Nature</i> 32(12): 53-57.
Genetically Modified Technologies in Agriculture and Forestry	1	韦艳顺, 程刚. 农业转基因技术的负责任创新研究 [J]. <i>科技经济导刊</i> , 2019, 27(12): 13-4. Wei, Yanshun and Cheng, Gang (2019). “Research on responsible innovation in agricultural transgenic technologies.” <i>Technology and Economic Guide</i> 27(12): 13-14.
Forestry Transgenic Technology	1	薛桂波. 生态风险视域下林木转基因技术的“负责任创新” [J]. <i>自然辩证法研究</i> , 2015, 31(07): 32-7. Xue, Guibo (2015). “RRI on GM Tree Technology in the Perspective of Ecological Risk.” <i>Studies in Dialectics of Nature</i> 31(07): 32-37.
Nanomedicine Design	1	赵迎欢, DORBECK-JUNG B R. 纳米药物设计与负责任创新: 建构论视角的解释 [J]. <i>Ibid.</i> 01): 257-61. Zhao Yinghuan and B. r. Dorbeck-Jung (2016). “The Design of Nano -drug and Responsible Innovation: The Interpretation from Constructivism Perspective.” <i>Science and Technology Management Research</i> 36(01): 257-261.

In discussing RRI in relation to the case of forest tree transgenic technology in China, Xue Guibo (2015) similarly found a general lack of embedded ethical responsibilities and low public participation. The authors go on to propose a RRI framework for the project, including (1) embedding ethical responsibility assessment indicators in the early stages of basic research, (2) combining alternative and more risk-adaptive technological innovations, (3) taking a more gradual and trial-based approach, instead of adventurous large-scale commercial expansions, (4) promoting interdisciplinary cooperation and dialogue, (5) respecting local knowledge, (6) promoting the dissemination of knowledge about GM forests, and (7) promoting ‘public understanding of science’; this framework was argued to align with the EUs keys (Xue Guibo 2015). Yu Jing et al. (2015) develop a similar set of RRI principles during an analysis of the Dalian High-Tech Zone.

These articles and their analysis of specific innovation projects and cases, show firstly, that the top-down management system in China, often with administrators and scientists as the key RRI actors, is in tension with the RRI philosophy of ‘public participation’. Second, the cases also highlight a lack of embedded ethical values and a low regard for ethical responsibilities by some experts with decision-making power. And third, that STI governance in these cases may have to make a theoretical shift from *ex post facto*

responsibility to anticipatory responsibility – before consequences occur – to align more with RRI.

Tensions in the public engagement in China's STI as revealed by RRI

As illustrated in the previous section, the themes of public engagement and inclusivity emerge in RRI-based critiques of STI activities. Zhao Yandong and Liao Miao (2017) argue that public engagement and inclusion may be in conflict with Chinese traditions, and that current channels for public engagement in STI activities are insufficient. Key challenges include tensions with traditional perceptions, unclear roles, a lack of participatory mechanisms and procedures, insufficient public awareness of participation, and insufficient scientific literacy (Zhao Yandong and Liao Miao 2017). The result is that it is difficult to incorporate the needs and values of the public in STI decision-making.

In one example, RRI is proposed as an approach for water pollution control in Hangzhou, Zhejiang Province – ‘public participation-oriented conceptual innovation’ (Cong Hangqing, Gu Ping et al. 2018). However, in reality, quasi-collective players coordinate actual measures. The approach is one of social governance with Chinese characteristics, based on combining the leadership of the Communist Party with that of the government. The emphasis is on market-oriented efficiency, with enterprises as key actors for achieving shared governance. It is argued that this arrangement does not facilitate a role for the public (Cong Hangqing, Gu Ping et al. 2018).

In the articles we surveyed, it seemed generally accepted that researchers in official institutions – beyond the public – are the more important subjects for an application of RRI in China. Yet, there is not a complete lack of ‘public participation’ in STI in China, and in recent years there have been influential events, which have appeared to enable ‘after the fact’ RRI. These include the ‘gene editing baby affair’, the ‘tainted capsule affair’, the ‘Han Chunyu affair’, and the ‘inciting haze removal patent affair’. The most well-known of these internationally is ‘The Gene-Edited Babies Controversy’, where social media helped to facilitate a bottom-up public stakeholder engagement (Yan and Mitcham 2021).

Preference for RRI through top-down policy governance

China’s ‘top-down’ governance approach puts emphasis on policy to stimulate RRI, and we find articles that explore this angle. For instance, in their article, Xue Guibo et al. (2015) summarised the various Chinese policies and regulations that address technology ethics, including:

- the Law of the People’s Republic of China on Scientific and Technological Progress (revised in 2007),
- the Declaration of the Chinese Academy of Sciences on Scientific Philosophy (2007),
- the Measures for Ethical Review of Biomedical Research Involving Human Beings (for Trial Implementation) (2007),
- the Guidelines for Ethical Review of Drug Clinical Trials (2010),
- the Regulations on the Administration of Biosafety Testing of Genetically Modified Trees (2014), and

- the Self-disciplinary Code of Ethical Conduct for Science and Technology Workers issued by the Chinese Association for Science and Technology.

Specific initiatives at the level of national STI policy planning are suggested by Xue Guibo and Yan Kunru (2018), including: (1) expanding the study of RRI to policy, (2) further expanding the openness of government decision-making, (3) the proposed idea that education activities support public participation initiatives, and (4) strengthening the ‘philosophy of policy’ and ‘ethics of innovation’.

Scientists and engineers as key agents of responsibility for RRI

Several articles consider who should be included in STI activities, based on the RRI concept. For instance, in their discussion of RRI in new R&D institutions, Guo Lifang et al. (2019) focus on the role of the employees of research institutions as subjects, rather than the role of the public as subjects. This specific contribution reflects the fact that in the Chinese context, the public is not the main participant in research as a matter of course.

Similar results are observable with regards to AI, the Three Gorges hydroelectric dam project, and in relation to ICT development. For example, in Guo Linsheng and Liu Zhanxiong’s (2019) paper on RRI with regard to AI, they propose six measures to address the technological risks of AI, including (1) establishing ethical responsibilities for AI scientists and engineers, (2) designing AI ethics, (3) prudently conducting and slowing down the progress of research and applications, (4) formulating policies and regulations to regulate the development of AI, (5) developing cross-disciplinary collaboration and consultation, and (6) ensuring public engagement in AI innovation. Significantly, ‘public engagement’ is the last measure listed, while the role and responsibilities of scientists and engineers are listed first, indicating a lesser role for public participation.

With regards to the Three Gorges project, which involved the construction of the largest hydroelectric dam in the world, Hao Tianyao (2016) argues that scientists and engineers should take more responsibility for technological risks, while omitting any mention of ‘public participation’. This highlights interest in key tenets of RRI, but again falls short of aligning with participatory principles seen in the founding Euro-centric conception. A similar story is found in the Wireless Valley case (Haoran et al. 2017).

According to Liao Miao (2018), any realisation of RRI requires seeking truth from facts, avoiding fraud, gaining trust, fairness, and respect for social values, avoiding and controlling commercial conflicts of interest, and a degree of political pressure. Accordingly, researchers are signalled as the most competent subjects to consider RRI, and are the main actors in the shift from ‘truth-seeking’ science to ‘good’ and ‘stable’ science (Liao 2018). An example of this signalling can be seen in the March statement of the General Office of the State Council of China (2022), in which it is proposed that ‘scientific and technological personnel should take the lead initiative to participate in ethical governance of science and technology and promote self-discipline in the industry’. This included, a call to incorporate ethics of science and technology training into activities such as induction training for science and technology personnel, undertaking scientific research tasks, and academic exchanges and seminars to guide science and

technology personnel to consciously abide by ethical requirements of science and technology and carry out responsible research and innovation.

He and Liu (2018) also discuss addressing the risks of new technologies, using real social experiments to predict and prevent the potential risks of unpredictable technological practices, without mentioning public engagement as a means (He and Liu 2018).

Overall, we see that within the academic debate in China, that the public is not considered a legitimate actor to be included in STI activities where RRI discourses are used. Rather, experts, typically those coming from academia or other professions are considered the main legitimate agents, with government guidance and policy briefs specifically calling on science and technology personnel to take a lead role in the consideration and management of innovation and technology ethical risks, and to communicate with the public regarding such issues (General Office of the State Council of China 2022).

The primacy of ethics over public engagement

To further highlight how engagement and inclusion of the public appears to be downplayed within the Chinese debate, much of the Chinese literature engaging with RRI focuses on the development of research ethics codes and policies, accounting for 32 articles, or 42% of the total. For example, the first RRI paper in China in 2011, by Zhao (2011), discussed the ethical issues involved in the application and management of technology and proposed the establishment of policy-oriented ethical constraints.

Within our sample, when translated into the Chinese context, RRI ethics are central. For example, Mei, Jin, and Fu-jia (2017) argue that the moral and ethical acceptability of innovation activities and the satisfaction of social expectations are the central criteria for distinguishing a RRI approach from a traditional innovation paradigm. Indeed, Mei and Chen (2019) argue that RRI concerns the value of morality and ethics as a measure of technological rationality. Liu and Zhu (2018) argue that the core of the ethics of RRI concerns the ethics of the pursuit of virtue, and that responsibility can be divided into prospective positive responsibility and retroactive negative responsibility. ‘Responsibility’ is seen to include the judgment of moral value conflicts, the prevention of moral value conflict escalation as well as the adjustment of moral value conflicts.

Within these contributions, the most significant feature of the western RRI – the introduction of the public, a new innovation subject, into the traditional innovation system – is missing. The incorporation of ethical responsibility, via codes, is characterised as involving soft constraints and ‘weak systems’ (Xue and Wang 2015). In technical activities involving complex interests and multiple subjects, the effectiveness of codes is limited (von Schomberg 2010), and it is necessary for engineers to adopt an individual ethical responsibility. Within the Chinese RRI literature, it is pointed out that the lack of ethical and moral responsibility in the process of technological innovation is an important reason for the structural problems of China’s STI system, and that developing a ‘Chinese RRI’ is of core concern for Chinese STI policy (Liu and Zhu 2018).

The absence of open science in Chinese RRI

Open Science is an important component in the von Schomberg paradigm of RRI. It is included in the EUs keys and is the core element of the newer three ‘Os’ innovation agenda (open innovation, open science, openness to the world). Yet, Open Science is

rarely discussed in Chinese articles that engage with the concept of RRI. One reason is that Chinese scholars, such as Huang et al. (2018), believe that RRI and Open Science (as a type of innovation incentive) are two different ideas. Innovation incentives and RRI are innovative concepts that limit each other's influence. In this conceptualisation, innovation incentives are seen as concepts that enable innovative entities to actively innovate and maintain the dynamism and momentum of innovation through policy instruments and measures. RRI, on the other hand in this conceptualisation, refers to the ethical responsibility of innovation agents to take responsibility for the ethical and social consequences of their actions and outcomes.

Some suggest that the omission of open science is due to China's strict publication regulations and information control policies, which include an Internet firewall (Jia 2017). However, the absence of open science in discussions of RRI does not mean that open science is excluded from Chinese STI policy. While the exploration and answering of this question may be beyond the document analysis presented here another potential explanation may add to our understanding of the interpretation of RRI. Specifically, that open science is absent because much of the RRI debate in China draws on the AIRR framework and earlier conceptual work on RRI, rather than on the EUs thematic and programmatic application, as represented by the keys. While the keys have the benefit of being implementable, measurable, less abstract, and more recognisable, they are also criticised, as noted by Owen, von Schomberg, and Macnaghten (2021), as failing to incorporate the more ambitious aspects of the RRI agenda. The keys seek to improve business-as-usual, rather than encourage transformational change (Pols, Macnaghten, and Ludwig 2019; Owen, von Schomberg, and Macnaghten 2021); as such, the seeding of the Chinese RRI debate by the AIRR framework, which is more associated with reframing and reconfiguring innovation and innovation systems and to drive and direct innovation in mutually responsive, inclusive and ethical ways, may bode better for the future of STI policy in China.

Summary

Our thematic analysis of the literature highlights that the concept of RRI has been the subject of scholarly attention in China. A range of contributions are observable, including those which explore the basic concept of RRI (as introduced by the Chinese scholars), those that interpret what RRI includes and how, as a lens, it changes the interpretations of Chinese STI activities, and finally, those that present Chinese scholars' original points of view, or a Chinese RRI.

The analysis reveals that, based on the discussion and interpretation of RRI, (1) top-down policies are preferred within the Chinese context, even while the incorporation of ethically responsible policies and ethical principles for technology at a strategic national level are lacking, the implication being that there is a lack of policy and activity in this regard in general; (2) scientists and engineers are signalled as the actor's central responsibility for the consideration of innovation and technology ethics and risks; and that (3) there is a need for further development of interdisciplinary cooperation and public participation in relation to ethical issues in technology.

Many of these characteristics show that the conceptualisation and translation of western RRI in Chinese academic literature and thinking has primarily been seeded

from earlier RRI thinking, showing more aligning with the AIRR framework, rather than the EUs Keys. For example, public engagement in China aligns with the inclusive deliberation dimension of the AIRR framework. Yet, while inclusive deliberation is evident, it is primarily based on the inclusion of experts and of other proxies for communities, rather than a wider public. For instance, Guo, Cui, and Ma (2019) noted the inclusion of employees of research institutions as subjects, rather than the public. Genuine public engagement and inclusivity are only evident in cases of public controversy.

In our sample, the primary Chinese dimension of RRI is that of ethics, which can be linked to reflexivity within the AIRR framework. Yet, ethics are often formally incorporated via codes of conduct, or other soft constraints (Xue 2015). As previously noted, this could result in limited effectiveness and relies heavily on individual-level responsibility, often of scientific and technology staff, who may not have sufficient training. Finally, there is governance, corresponding to responsiveness in the AIRR framework. However, in the Chinese context, the approach is one of top-down social governance combining the leadership of the Communist Party with that of different levels of government. This aligns with the approach to public engagement, limiting any role for the public (Cong, Gu, and Shen 2018).

In response to the status-quo, recommendations emerge in the literature, with scholars calling for at (1) the establishment of a forward-looking governance mechanism for ethical evaluation; (2) the construction of a responsibility-sharing mechanism involving multiple subjects; (3) the establishment of an ethical self-reflection mechanism for interdisciplinary cooperation; and (4) the establishment of a follow-up feedback mechanism in line with ethical norms (Xue and Kunru 2018).

Liu (2018) who was a visiting scholar with Van den Hoven in the Netherlands, gave a systematic introduction to the latter's concept of responsible innovation, including its key constituents, the realisation of responsibility, and the boundaries of responsibility. He argues that the responsibility for RRI could be realised by going beyond economic benefits to also include social values (Liu 2015). According to Liu Zhanxiang, the realisation of RRI involves shared and cooperative responsibility, based on sincere cooperation between different stakeholders in the field of modern information and transport technology, supported by their own credit and mutual trust. Achieving such a purpose requires modern information technology as a basic condition for open storage and access to information and openness and transparency of processes and results (Guo and Liu 2019).

Conclusions: developing a RRI for China

Explanations

After a little over a decade, RRI has attracted widespread research interest in China in the fields of the philosophy of technology, STI policy, technology ethics, and management.

Since the reform and opening of China in the 1970s, China, as a technological latecomer, has been committed to technological adoption and diffusion. Many technologies have been adopted and diffused more extensively compared to where they were originally developed, such as the United States and Europe. And much of this has taken place within a context of high need. This need and urgency likely acted as a barrier to the

effective consideration and management of technological risks, and may have stymied early thinking and conceptualisation of socio-ethical dimensions of STI policy. This history also illustrates another way in which the context in China differs to that of the west, with potential repercussions for how the concepts encapsulated within RRI are interpreted.

Second, we can observe a clash between the traditional Chinese approach and the prominence given to public engagement and inclusion in the western RRI. The overall theoretical system of RRI in China is interpreted to include ethical content as its common denominator. In contrast, the EU seeks to establish fundamental rights and ethical standards based on the common values of European society (European Commission 2017). The Chinese approach to RRI proposes that through ethics, the social relevance and acceptability of research and innovation results will be enhanced, and ethics will be a guarantee of high-quality output, rather than being seen as a constraint on research and innovation. However, the ethics of RRI is not practically applied in European policy due to differences in the understanding of the ethical dimension among European countries (Pellé and Reber 2015). In contrast, China, as a unified and integrated country, has developed a relatively uniform ideology and set of moral values over a long period of time, making it easier to develop a consensus-based ethical code.

What does the future hold?

Liu and Xia (2016) discuss the risk that transplanting RRI unchanged to other countries and regions will lead to cultural imperialism; the authors argue that China's development of RRI must prevent Eurocentrism, break the obsession with innovation, and promote more modest, less risky innovation. Wang and Yao (2017), as philosophy and technology scholars, suggest that RRI's view of responsibility is based on EU human rights values and that China risks being subjected to value colonisation if it introduces and applies RRI without reflection. Consequently, for RRI to be applied to Chinese contexts, these authors argue that it must be reconceptualised and adapted. Views such as these illustrate why RRI is not able to be applied 'untranslated', raising the question of which aspects can be applied and which cannot – and we observe in our results that the debate in Chinese academia engages to some extent with these topics.

While there is broad support for tenets of RRI in Chinese academia, there are also opposing views, as illustrated throughout the review. For example, Wang and Gao (2019) argue that RRI theory is a 'Western' solution to the ethical and moral dilemma of technological innovation and that at present much of Chinese academic research is devoted to the promotion of foreign theories, with too little discussion regarding the boundaries of RRI's rationality and limitations. Many RRI measures are unrealistic and too idealistic to be implemented; a similar criticism can be found being applied to the EU's development and application of the keys, incidentally. As such, more formal assessments are needed, from disciplines such as the philosophy of science and technology, to help adjust frameworks and approaches and enable China to develop an autonomous innovation strategy, consistent with Chinese characteristics. For example, key institutions, such as the National People's Congress, the Chinese People's Political Consultative Conference, Trade unions, women's

federations, and academic institutions, could be formally integrated into STI activities, as a type of Chinese RRI.

Recent events have demonstrated firstly that there is interest from the Chinese public in science and innovation, and second, that Chinese public opinion can be influential. Social media has provided the Chinese public with a channel to express their opinions. However, this has mainly operated ‘after the fact’, with RRI-type initiatives pursued primarily through top-down measures. For instance, a patent application in 2017 to use large, human-powered fans for the removal of haze from Beijing received widespread public attention and discussion, with 190 million related links on Baidu, China’s Internet search engine. This was despite such an idea being impractical at best. Eventually, this patent application was withdrawn on 6 November 2020, after public pressure – effectively, societal rejection – about the issue.

So, while there is public interest and even action in some cases (although after the fact) RRIs’ role in Chinese STI activities is still uncertain due to the concept’s western origin and European bias. Yet this does not address the urgent need to integrate research and experiences from non-western contexts to enhance the generalizability of RRI research and practice. The development of cross-cultural discourses and norms in relation to RRI can avoid old paths of academic colonialism, and ensure Chinese or more widely, non-western scientists can study the institutional, philosophical, and cultural aspects as well as the development drivers and social needs of RRI in the context of China as a guide for the top-level design of innovation systems. A pertinent example is highlighted by Hong and Wang (2016), who point out the need to maintain a cautious attitude towards research – for example, human embryo genome editing technology – while also preventing a Western monopoly of discourse and the use of ethical issues to suppress scientific research.

With regards to the future, influence may also be shifting away from the state, with companies playing an increasingly leading role in the development of technological innovations. For instance, the development of 4G, 5G, and even 6G wireless communications (Lee, et al., 2022). Or Chinese pharmaceutical companies’ investment in autonomous innovation of original compound drugs and biologics. China is beginning to play an increasingly important role as an engine of scientific research, and the pressure to take risks with new technologies is likely to grow in the future, and with it, the need for effective governance systems. This may result in an increased need for a shift from ethical governance to public engagement, as proposed in the earlier RRI debates within the West.

Future research directions and limitations

There were limitations within this study, which point to areas for future research. First, this was a single literature review of Chinese academic articles. However, our findings are likely to be relevant to other national contexts, especially other East Asian countries such as Japan and Korea that are also influenced by Confucian culture. As RRI ideas spread into different Chinese sectors, RRI strategies will increasingly require the consideration of a multitude of social contexts in different sectors. Our literature review study provides insights as it focuses on the understanding, judgment, and practice of RRI in the context of China, which requires increased attention. Future research is necessary to address

more of a diversity of sources beyond the academic articles, such as government documents and online news including the popular WeChat platform. These documents may more comprehensively show the appearance and characteristics of RRI in the Chinese context. Secondly, RRI is a new conception in China, and is still subject to a process of digestion and interpretation. Future research is also needed to explore the integration of RRI elements within national strategies in China, as our study mainly focused on academic community perspectives and needs.

Note

1. For example, the Wassenaar Agreement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies was signed in 1996 by 33 major industrial equipment and weapons manufacturing countries, led by the United States, to impose export restrictions on non-member countries, including China. The restrictions cover nine categories, including advanced materials, materials processing, electronic equipment, computers, telecommunications and information security, sensors and lasers, navigation and avionics, ships, and propulsion systems and spacecraft.

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