A ‘Mode 3’ Science Policy Framework for South Korea - Toward a Responsible Innovation System

Gouk Tae Kim*

Abstract

This article advocates for a Mode 3 science policy. Compared to the university research-based Mode 1 knowledge production system and the knowledge application-centric Mode 2 innovation system, Mode 3 can be defined as a system that integrates both Mode 1 and Mode 2-type knowledge production models. In this article, based on the major characteristics of the Mode 3 scientific knowledge production system, I agree with the advocates of Mode 3 that constructing a knowledge society requires an inclusive form of knowledge production and innovation system through the democratization of knowledge production as well as the promotion of social values. Moreover, the mechanisms for creating accountable innovation in the Mode 3 system should be given more attention from the science research and policy communities to make public policy for scientific and technological innovation more reflective of social changes. Similar to the ways that the Mode 1 and Mode 2 scientific knowledge production approaches have influenced the development of science policy models, the Mode 3 scientific knowledge production approach, or Mode 3 science, also has the potential to shape a new science policy model. I will refer to this as Mode 3 science policy. In an effort to conceptualize the democracy- and society-centric Mode 3 science policy model, I will articulate science policy strategies in four science policy domains in South Korea from the context of the Mode 3 science approach. These include (1) evaluation of publicly-funded research activities, (2) valorization of scientific knowledge (that is, enhancement of the value of scientific knowledge through governmental action), (3) development of a science policy decision-making support system, and (4) anticipatory foresight of science, technology and society. When adopting and implementing a Mode 3 science framework, one progressive change is to increase socially desirable innovation such as responsible innovation.

Keywords
science policy, Triple Helix, Quadruple Helix, knowledge production, innovation

* Research assistant professor, Strategic Planning Center, Korea Advanced Institute of Science & Technology (KAIST), Daejeon, South Korea, gouk_tae_kim@kaist.ac.kr

1. INTRODUCTION

Since the publication of 'The New Production of Knowledge' in 1994 (Gibbons, Limoges, Nowotny, Schwartzman, Scottm & Trow) and 'Re-Thinking Science' in 2001 (Nowotny, Scott & Gibbons), the concepts of two different modes of knowledge production, Mode 1 and Mode 2, have been influential for both the innovation research and policy-making communities (Nowotny, Scott & Gibbons, 2006). The Mode 1 approach has been useful for understanding traditional university-based knowledge production mechanisms, whereas the application-oriented Mode 2 framework reflects a network-based configuration for innovation such as the "Triple-Helix" network (Carayannis & Campbell, 2014; Nowotny et al., 2006).

Rather than separating Mode 1 from Mode 2, there is an impetus to inter-connect the Mode 1 and Mode 2 approaches to spur scientific and technological innovation. In this article, I focus on this emerging combination and examine one of the newly developed theoretical frameworks, the Mode 3 knowledge production system, which is known not only for responding to the need for improving the inter-connection between Mode 1 and Mode 2, but also for proposing new modes of knowledge systems such as the "Quadruple Helix" innovation network (Carayannis & Campbell, 2012a).

These different modes of scientific knowledge production coincide with different science policy priorities. For example, Gibbons (1999) points out the need to establish a 'new social contract of science' to encompass not only the 'unknowable implications,' but also 'planned or predictable applications' of scientific knowledge (pp. 83-84). From this perspective, the Mode 2 science includes a new social contract of science as well as a reflexive and demand-oriented science policy model valuing both unknowable and planned outcomes of public-funded research, whereas the previous science policy framework meshes with Mode 1 science approach in terms of valuing supply-aspects and unplanned outcomes of public-funded research.

In this context, a science policy framework stemming from the latter can be labeled as 'Mode 1 based-science policy,' and a science policy framework based on the former approach (a new social contract of science, or Mode 2 scientific knowledge production) can be labeled as 'Mode 2 based-science policy.' This is inspiring science policy makers to shape partnerships among scientific and technological innovators including government, universities and industries.

This article proposes the third option, a 'Mode 3 science-based science policy,' which differs from both Mode 1 based- and Mode 2 based-science policy approaches. Hereafter I call the science policy framework under the influence of Mode 3 science as 'Mode 3 science policy.' One of the major differences among these three modes of science policy is that Mode 3 science policy expands the scope of collaboration among innovators to better reflect non-economic as well as under-represented societal values when designing, formulating and implementing science policy.

By democratizing the knowledge of heterogeneous parties, including the public, as well as promoting social values when making decisions about future research investment, the Mode 3 approach is critical to designing a knowledge society in the era of uncertainty.

I thus suggest applying the Mode 3 science approach to formulating science policy strategies in the following four science policy fields in South Korea: (1) evaluation of publicly-funded research activities, (2) valorization of scientific knowledge (that is, enhancement of the value of scientific knowledge through governmental action), (3) development of a science policy decision-making support system, and (4) anticipatory foresight of science, technology and society.

2. EMERGING MODES OF KNOWLEDGE PRODUCTION

This section clarifies the concept of Mode 3 science and describes how it emerged out of concerns with Mode 1 and Mode 2.

2.1. Mode 1 and Mode 2 Scientific Knowledge Production

Mode 1 and Mode 2 knowledge production systems (Gibbons et al., 1994) have been useful concepts in science and technology policy research.

Mode 1 knowledge production is characterized as an "academic," "disciplinary," homogeneous, and "hierarchical" type of research (Gibbons et al., 1994, p. 3). Mode 2 knowledge production is oriented toward knowledge application and problem solving. Mode 2 is transdisciplinary, heterogeneous, accountable, and reflexive to the actors inside and out of the knowledge production network, and includes quality control in a broader context than that of Mode 1 research (Gibbons et al., 1994). Mode 2 puts more emphasis on the non-linear aspects of scientific and technological development, as well as on the mutual collaboration of actors in different domains for knowledge production (Gibbons et al., 1994; Logar, 2011). The Mode 1 framework describes academic research conducted mostly in universities, whereas the Mode 2 framework provided a theoretical basis for developing the Triple Helix innovation model (Carayannis & Campbell, 2012a). The Triple Helix model emphasizes the interactions among the three actors for innovation, which are university, industry and government (Lee, Lee, & Park, 2010).

Concepts similar to the Mode 2-type transdisciplinary knowledge system, such as 'co-production' of science and society (Jasanoff, 2004) have been discussed not only in the innovation research communities, but also in other disciplinary fields such as STS (Science & Technology Studies). Because of the blurring of the line demarcating basic and applied science as well as academic and non-academic disciplines in the contexts of primary research interest and practice of knowledge production (Carayannis, Cambell, & Rehman, 2016), there is an intellectual connection between the Mode 2 and co-production approaches.

However, as Jasanoff (2004) emphasizes, there is a strong mutual transformation between science and society arising from the context of the co-production of science and society. Thus, the Mode 2 approach, when combining the concept of co-production, also needs to focus not only on scientific knowledge-based problem-solving, but also on the change of the scientific knowledge system in accordance with the broader social changes surrounding it. This focus on co-transforming science and society is what makes the Mode 3 science framework broader than that of the Mode 2 approach.

2.2. Mode 3 Science Framework

Mode 3 science is an emerging concept that calls for new approaches to scientific knowledge production compared to the Mode 1 and Mode 2 concepts. As a new category of knowledge system, Mode 3 is an extension of the academic research-based Mode 1 and the application-oriented Mode 2 knowledge production system. This is because the division between basic science at a university and applied research in the industrial sector is not apparent, and secondly, because basic science is not the sole origin of new knowledge production (Godoe, 2007).

Carayannis and Campbell (2007) define the concept of Mode 3 as the "interactive coexistence and coevolution of different knowledge modes (p. 99)." They identify five key elements of Mode 3. First, Mode 3 includes a 'knowledge-based and innovation-based democracy'; second, 'democracy-style governance' for integrating various modes of knowledge and innovation; third, 'balancing and integrating' plural knowledge modes; fourth, a 'democratic mode' of decision-making by emphasizing social accountability; fifth, learning from 'forward-looking, feedback-driven' as well as future-centric knowledge exchange through innovation networks (Carayannis & Cambell, 2007, pp. 98-105).

The development of the Mode 2 based Triple Helix has framed and deepened our understanding of the relations among university, industry and government (Etzkowitz & Leydesdorff, 2000). However, the Mode 3-based Quadruple Helix approach emphasizes the increasing role of the public and civil society for promoting innovation.

Frühmann, Omann, and Rauschmayer (2009) emphasize the need for expanding the Mode 2 approach when discussing the Mode 3 science framework for sustainable development. Godoe (2007) also proposes the re-calibration of Mode 1 and Mode 2 of scientific knowledge production in the Mode 3 context, as shown in Table 1.

TABLE 1. Change of Knowledge Production Modes in the Context of Mode 3

	Recalibration in the Context of Mode 3
Mode 1	Creating incentives for encouraging science researchers in Mode-1 institutions (universities) to engage in Mode 3 innovation settings
Mode 2	Recasting the goals of transdisciplinary activities to create innovative suggestions and solutions for the interests of society

Source: Godoe (2007, pp. 357-359)

The Mode 3 approach can be constructed by combining both Mode 1 and Mode 2 (Carayannis & Campbell, 2012b). In Mode 3, the public and civil society can play key roles for producing knowledge in collaboration with scientists in the Mode 3 system, and social values should be treated as key criteria for supporting and conducting scientific research (Carayannis & Campbell, 2012a).

There is also a specific research approach to Mode 3 science called 'transformative science,' which proposes a collaboration of science and society to frame and solve problems, the involvement of different actors of society including 'non-academic stakeholders' in the process of setting the research agenda, innovative methods to increase the options society can choose in dealing with 'unintended environmental and social side effects,' and rebalancing the power between science and society (Schneidewind, Singer-Vrodowski, Augenstein, & Stelzer, 2016, pp. 1-14).

2.2.1. Quadruple Helix Innovation

Since different stakeholders, including members of civil society, can be proactively involved in creating, disseminating, and evolving scientific knowledge in Mode 3 science-based innovation models, there tend to be more complex, democratic, and collaborative aspects compared to the Mode 1 and Mode 2-based innovation systems. This necessitates the construction of Mode 3 science configurations for democratizing knowledge and accelerating mutual interactions among actors of a Mode 3 type innovation network. One of the solutions proposed by scholars in Mode 3 research circles has been the Quadruple Helix system.

The Quadruple Helix has been acknowledged by the Triple-Helix research community as an emerging and competing approach to the Triple Helix model (Etzkowitz & Cai, 2014). Carayannis and Campbell (2007; 2012a; 2012b; 2014) conceptualize the Quadruple Helix model by adding the fourth helix civil society and the media- and culture-based public into the Triple Helix model (Park, 2014). Moreover, unlike the Triple Helix, they emphasize the need to integrate democracy into the Quadruple Helix innovation system, stating that "democracy frames and changes our conditions of innovation" as well as noting that "the Quadruple Helix is sensitive for the knowledge society and democracy (Park, 2014, p. 204)."

From this perspective, the Quadruple Helix innovation framework emphasizes the mutual transformation of science and society because of the increased role of society in innovation. In the Mode 3 Quadruple Helix setting, society promotes the change of knowledge production activities in science, which in turn results in the creation of innovative solutions society can use to adapt to change resulting from technological innovation.

2.2.2. Society-Centric Approach for Designing Future

In addition to bringing together the "explanatory-oriented" research of Mode 1 and the "solution-oriented" research of Mode 2, Mode 3 knowledge production is characterized by its "future-oriented knowledge production (Godoe, 2007, pp. 352-355)." Moreover, instead of designing and creating the future from market-driven rhetoric or the interests of economically dominant groups, the Mode 3 knowledge system focuses on creating an environment in which the public as well as democratic institutions have opportunities to project their concerns and anticipations to shape and conduct "future-oriented, sustainable research for the benefit of society (Godoe, 2007 pp. 355-356)." In other words, creating research that serves society is what differentiates the Mode 3 approach from Modes 1 and 2. Moreover, the Mode 3 approach is useful for promoting the collaborative efforts of science and society to define agendas for creating 'future solutions based on research' instead of letting industry (the primary user of scientific and technological innovation in the Triple Helix system) dominate research and innovation agendas (Godoe, 2007).

2.2.3. Democratic Values & Approaches for Knowledge Production & Use

The Mode 3 science approach emphasizes multiple dimensions of creating, diffusing, and sharing scientific knowledge by incorporating socio-cultural-political and economic systems (Carayannis & Campbell, 2009; Frühmann et al., 2009). In terms of integrating and mutually affecting different modes of knowledge and innovation, the way to produce scientific knowledge in the Mode 3 system is "similar to democracy (Carayannis & Campbell, 2012b, p. 40)." More specifically, Carayannis & Campbell (2012b) use the term "democracy of knowledge" to differentiate Mode 3 from Mode 1 and Mode 2 approaches (p. 40). One of the main ideas of democratizing knowledge in Mode-3 is to treat various modes of knowledge, such as knowledge of basic science and that of resolving socio-economic problems, as having the same relevant value (Carayannis & Campbell, 2012b).

For example, 'basic research in the context of application' conducted by universities can be defined as the Mode 3 type of scientific knowledge production (Campbell & Carayannis, 2012a; Carayanis, et al., 2016). From this context, Mode 3 knowledge production is also similar to "use-inspired basic research" because both regard social needs and practical applications as important criteria for developing knowledge in basic science (Stokes, 1997). In Mode 3 science, both knowledge production and knowledge use have the same value instead of one being viewed as better than the other, which is the case under the Mode 1 and Mode 2 science.

With the development of interactive linkages between scientific research and social needs and values as an example of the Mode 3 science model, creating a knowledge system for stimulating the exchange of knowledge produced by the experts and by the public is the key for democratizing knowledge. Mode 1 and Mode 2 tend to regard trained experts as the main actors of innovation, whereas the public has been regarded as the target of scientific and technological innovation. Thus, democratizing knowledge in the Mode 3 framework can be regarded as reframing the role of the public as a key actor of scientific knowledge production and science policy making in systematic ways.

In a highly science and technology-centric society, increasing the dependence on knowledge of experts and their judgement does not always reflect the "interests and concerns of non-expert citizens (Kleinman, 2005)." Moreover, in many cases, such as utilizing farmers' knowledge to analyze the environmental impacts of radioactive contamination on farming, the public's non-expert knowledge can combine with and improve knowledge of scientists who are mainly working in the lab (Kleinman, 2005).

Based on this, Keinman (2005) argues that the involvement of the public in the process of producing scientific and technological knowledge as well as in the policy decision-making process is the key for the democratization of science, which encourages the flow of knowledge between society and science. Because of its 'human-centric' and 'strong bottom-up' approach, Carayannis and Campbell (2014) also emphasize that democracy matters in the Mode 3 science-based Quadruple Helix model. Thus, establishing the Quadruple Helix system is possible only within a democratic society, whereas both democratic and non-democratic societies can implement a Triple Helix innovation system (Carayannis & Campbell, 2014).

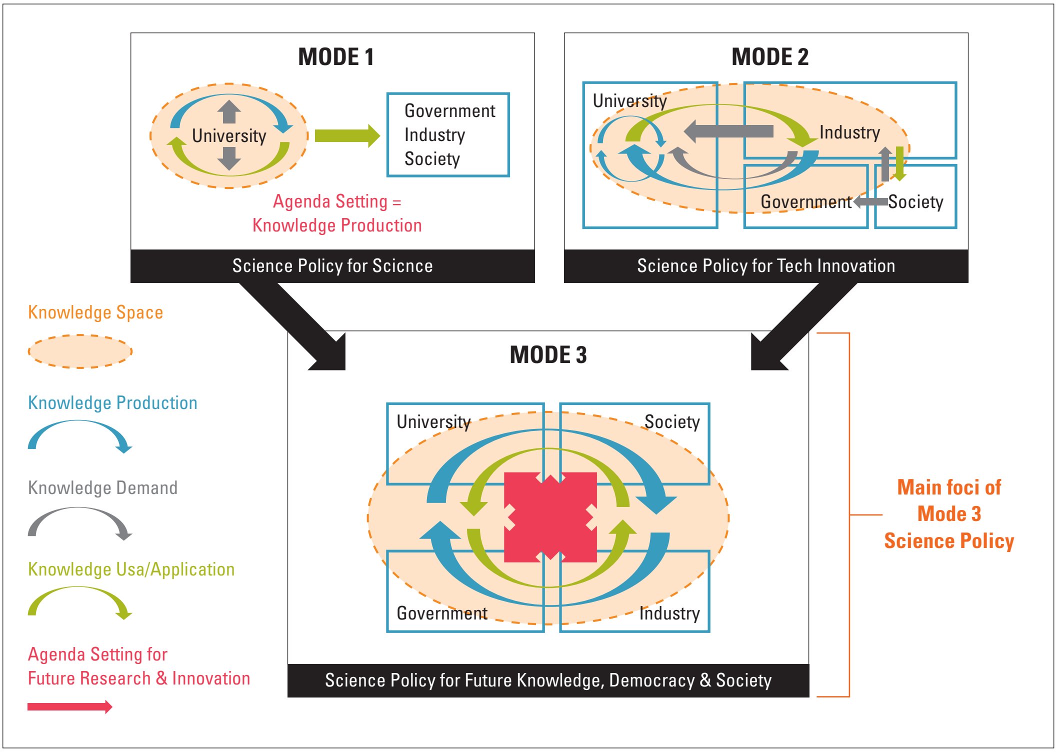
Kelinman (2005) proposes several tools as methods to promote democratized science, such as designing evaluation and promotion systems to give the same credit to scientists who have been working with civil groups as that given to researchers with records of collaborative activities with industry. In a similar way, for constructing a Mode 3 science system, science policy makers also need to develop a mechanism to institutionalize a democratized knowledge production system; policy tools to promote public engagement in scientific research and development (R&D) and the science policy process is a way to establish a democratic and future-oriented Mode-3 science system.

3. PROPOSED MODE 3 SCIENCE POLICY APPROACH IN SOUTH KOREA

The Mode 3 science approach, including the Quadruple Helix innovation system, deserves attention from science policy makers to promote a sustainable scientific and technological innovation system. I have developed a conceptual figure of the Mode 3 science policy model as shown in the Figure 1.

Mode 3 science policy aims at creating and sustaining a knowledge circle that encompasses university, industry, government, and civil society as well as promoting the interactive activities of producing, diffusing, circulating and utilizing knowledge among these actors.

FIGURE 1. The Concept of Mode 3 Science Policy



Source: Author's own conceptualization of science policy in Mode 3 setting based on the interpretation of Mode 3 concept (Carayannis, 2007, pp. 97-105; Carayannis & Campbell, 2012a, p. 52)

Table 2 shows more details of the differences among the three modes of science policy.

TABLE 2. Main Characteristics of Mode 1, Mode 2 & Mode 3 Science Policy

	Main Characteristics
Mode 1 Science Policy	• Science policy supports a supply-oriented scientific knowledge production system • Demarcation between experts and lay persons when making policy decisions • Little doubt about scientific research and little chance to project the value of society into the activities of scientists
Mode 2 Science Policy	• Represents social demands with well-defined public values when funding science research • Economic return and tangible outcomes of publicly funded scientific research matter when evaluating research projects/programs/organizations • Both producers and social users of scientific knowledge matter (Science is the producer of knowledge and society is the user of science, with industry as the major user) • Science policy decision-making and forecasting based on rigorously collected scientific data and evidence (for example, evidence-based science policy)

Mode 3 Science Policy	• Social demands with attention to under-represented public value and non-economic outcomes along with representing social and economic values • Both producers and social users of scientific knowledge matter (Science and society are both producers as well as users of scientific knowledge, with civil society and industry both being major users) • Scientific evidence still matters, but non-statistical/non-calculable data or intangible public value are also used as sources for science policy makers (for example, evidence-informed science policy) • Science policy decision making and forecasting based on extended discussion with civil society members instead of relying exclusively on experts, scientific data and evidence (thus finding and reflecting the concerns of society into science policy making for the future)

Mode 3 science policy can be constructed as a Quadruple Helix innovation system based on the 'Three-layer Triple Helix' (Etzkowitz & Cai, 2014) because of the common emphasis of both helixes on the role of society for innovation. In other words, Mode 3 science policy is not entirely new compared to both Mode 1 and Mode 2 science policy; instead, the latter two modes of science policy have constructed Mode 3 science policy.

Etzkowitz and Cai (2014) developed the Mode 2 Triple Helix model further to the 'Three-Layer Triple Helix Model,' which treats civil society as a platform of interactions among the actors of the Triple Helix system instead of considering it as an additional helix to formulate the Quadruple Helix model (Etzkowitz, 2014; Etzkowitz & Cai, 2014).

One of the major differences between these two frameworks, Mode 3 science and the Three-layer Triple Helix is that the former regards society as an additional innovation actor (fourth helix) and the latter treats society as the 'supporting institutional environment' for the actions of Triple Helix innovation (Etzkowitz & Cai, 2014).

I contend that both frameworks can reinforce each other for the following reasons. First, Mode 3-type innovation activities that add society into the innovation process and consider society as an important actor can bring democratic values and practices into scientific and technological innovation activities, which in turn can help shape a democracy-based social environment which is also favorable to promoting Triple Helix innovation activities. Second, advocates of the three-layer Triple Helix model suggest that the roles of "end customers in the innovation system" along with the boundary-crossing institutions create "unexpected and ... unintended outcomes or different innovations (Etzkowitz & Cai, 2014, p. 4)." The experience of these consumers and boundary-crossing institutions would be useful for creating similar organizations under the Mode 3-type Quadruple Helix innovation system for encouraging interactions among the actors of Mode 1, Mode 2, and the public for social innovation.

However, I do not mean to argue that putting economic values first through Triple-Helix innovation system is not desirable. Through the examination of the Quadruple-Helix model, I intend to raise the concern that emphasizing economic value has the potential to undermine public values with less economic or well defined evidence that the civil society also expects to be promoted by publicly funded scientific and technological research.

In this article, I describe science policy strategies applicable to four policy spheres for constructing the ground of Mode 3 knowledge production and Quadruple Helix innovation system. These are the evaluation of publicly-funded research activities, the valorization of scientific knowledge, the development of science policy decision-making support system, and anticipatory foresight of science, technology and society.

These four categories of science policy were chosen based on changes in scientific research that motivated the scholars who originated Mode 1 and Mode 2 in 1994 to re-shape their arguments (Nowotny et al., 2006). More specifically, Nowotny et al. (2006) describe the three new trends of research that have resulted from recent changes in the research environment, including increased efforts to shape research priorities in a proactive manner, a growing emphasis on commercializing research, and securing the accountability of science through evaluating the effectiveness and quality of research.

Examining Mode 3 science policy strategies for science policy in South Korea is a worthy subject of research due to the need for scientific and technological innovation to resolve various social issues. Seong, Song, and Lim (2016) states that the science and technology policy approach for combining scientific and technological innovation with social innovations has gradually appeared in South Korea in accordance with social innovation movements in South Korea since the 2000s. This has occurred even though this "technology-based social innovation" approach has not yet fully been recognized by the science policy communities as being as important as the "industrial innovation-based" approach held previously (Seong, et al. 2016, p.13).

The preference of the South Korean government's investment in economic-value creation related research activities such as R&D for the objective of 'Industrial Production and Technology' is based on OECD research and development statistics (Ho, 2017). Ho (2017) points out that the portion of government expenditure for research to create economic value is too high compared to other developed countries, including the United States, Germany, and Japan. 'Industrial Production and Technology' was ranked first of thirteen different socio-economic objectives by the South Korean government in 2015, with approximately 61% of total government spending going to research and development (Ho, 2017; OECD, 2017).

In the News Feature 'South Korea's Nobel Dream' published in the journal Nature, Zastrow (2016) also points out that government's spending on research in South Korea has been weighted toward applied research and development of industrial technology as a way to boost the nation's economic growth during the past decades although there have been recent attempts by the government to recognize the value of curiosity-driven scientific research and increase funding for basic research. In other words, the South Korean government should recognize the shortcoming of its S&T policy emphasizing tangible, quantitative, and economic benefits when designing and implementing research spending as well as promote the long-term and intangible values of science including broader social impacts of it.

Since the emerging "social problem solving innovation policy approach (Seong, et al., 2016)" has a shared goal with the Mode 3 science policy approach for resolving social issues using scientific and technological knowledge, the Mode 3 strategies I examine in this section would contribute to the change of 'social problem solving innovation policy' from a niche to the core of future innovation policy in South Korea.

3.1. Evaluation of Publicly-Funded Research Activities

The Mode 3 science policy examined in this article has the potential to assist the recent efforts of the Korean government to emphasize and evaluate the social impacts of national R&D activities.

The concepts of Mode 1 and Mode 2 knowledge production have been influential in deepening our understanding of the modern scientific knowledge system (Hessels & Lente, 2010). For example, Etzkowitz and Leydesdorff (2000) proposed the 'Triple Helix' innovation model by expanding on the notion of the Mode 2 knowledge production approach.

However, Mode 2 approaches, including the Triple Helix innovation system, have also been criticized mainly because of the failure to produce 'socially robust knowledge (Hessels & Lente, 2010).' This stems from issues such as the lack of an effective incentive system for encouraging researchers to engage in Mode 2-type collaborative activities (Hessels & Lente, 2010). For example, the reality of modern research practices is that the evaluation criteria of individual scientists are mainly based on their scientific publications, and the proposed Mode 2 has not been successful in articulating the tools for influencing the change of scientists' behavior at universities and public research institutions (Hessels & Lente, 2010).

One of the reasons for the lack of an incentive system for producing socially robust knowledge is that the three helices of the Triple Helix innovation system (university, industry, and government) are interdependent for creating knowledge and innovation (Hessels & Lente, 2010), but each of them is an independent entity in the Triple Helix (Mode 2) system. Thus, each organization in the Mode 2-type network or Triple Helix innovation system would be inclined to maintain its own operational principles instead of being actively engaged in interactions to produce and share new knowledge. This would not change unless an incentive system such as Mode 3-type research evaluation tools to change the behavior of the actors was introduced.

In order to establish an effective research evaluation system under the Mode 3-based Quadruple Helix innovation model, which requires more complicated interactive activities among actors of the innovation network than those in the Mode 2-based Triple Helix, the following strategies would be considered.

Mode 3 type activities, including co-operation with the public, should be evaluated as important as publishing research in scientific journals or registering patents with a newly developed technology. Otherwise, the assessment of the quality of Mode 3 type activities would be limited to Mode 1 and Mode 2 knowledge production-based evaluation criteria such as SCI journal publications, impact factors, registered patents, and technology licenses.

These criteria are also the main standards used to screen applicants who are applying to positions at universities and research institutions. The issues with a Mode 3-type of evaluation approach in this context are that first, it would not be proper to promote and assess Mode 3-type knowledge production activities; second, scientists prefer to work with industrial sectors instead of with non-commercial areas when they choose research partners outside their institutions.

In order to establish Mode 3 science–centric evaluation criteria, science policy actors need to first recognize Mode 3-type activities, including the initiation and management of science outreach programs for improving public awareness of science, organization of public forums to unite lay citizens' knowledge to resolve technical issues, and initiation of field research in collaboration with the public. Second, in order to give evaluation of Mode 3-type activities the same credibility as given to academic researchers with journal publications and registered patents, there should be follow-up research to measure the quality of Mode 3-type activities. Third, the evaluation of Mode 3-type activities should assess the quality of the individual scientist, then expand to measure the outcomes of both project- and program-level research activities. Fourth, when designing evaluation methods of Mode 3-type activities, not only the results but also the transdisciplinary process itself should be considered as evidence to prove the merit of research. Fifth, engagement activities through media should be considered as the core of the research process instead of assessing it as an additional value attached to research. For example, media coverage of research activities and results should be evaluated as evidence to prove the merit of the research instead of being regarded just as researchers' informal or subsidiary work. Sixth, public engagement in the process of research evaluation should be promoted by developing deliberative evaluation methods.

These evaluation criteria should be treated as equally important as the current evaluation criteria, which stem mainly from the Mode 1 scientific knowledge production system. Mode 3-type evaluation criteria should not be applied to all research fields regardless of its location in Mode 1 or Mode 2; rather, evaluation methods appropriate to each mode of knowledge production should be designed and applied to the target research accordingly. Mode 1-type evaluation criteria, such as journal impact factors, are still valid for assessing the quality of Mode 1 academic research, whereas the same kind of evaluation criteria should not be directly applied to Mode-3 type research activities. Establishing a Mode 3-type evaluation system is also closely related to the valorization of scientific knowledge, which I examine in the following section.

3.2. Valorization of Scientific Knowledge

When adopting the Mode 3 science policy approach, promoting non-economic or intangible social outcomes of publicly-funded research should also be emphasized by public research and education agencies such as research universities. In order to support efforts to capture and promote socially valuable outcomes and impacts of research, I suggest that the selection and assessment of research projects be conducted in the context of knowledge valorization along with knowledge commercialization.

Since the rise of the 'science-as-engine' model to boost the economic impact of scientific and technological breakthroughs in the 1980s, the commercialization of research has been a widely used innovation tool that most academic research institutions such as universities have adopted for diffusing their knowledge into the industrial sectors (Berman, 2012). Baycan mentions that commercializing scientific knowledge is an exemplary method to connect academic research and the economy, especially in the United States (Baycan, 2013). Creating useful knowledge for market is the primary mission that the actors in the technology commercialization field are pursuing. Baycan also describes the emerging concept, 'knowledge valorization,' which is similar to knowledge commercialization, but puts relatively less emphasis on 'monetary values' of knowledge than the commercializing knowledge approach (Baycan, 2013).

Commercializing and valorizing knowledge activities are both critical components of a national innovation system because of their common emphasis on getting knowledge into use (Baycan, 2013). However, I suggest that knowledge commercialization is a typical Mode 2 type knowledge transfer method by targeting the market, whereas knowledge valorization has the potential to become a benchmark method of transferring knowledge in a Mode-3 type innovation system by targeting the broader users of knowledge, including the public. In other words, the concept of knowledge valorization aims at expanding the partners of knowledge use from the industrial sectors to society, which would result in promoting user-based knowledge production to benefit society as a whole. Carayannis and Campbell (2014) also argue that "innovation may not be narrowed down to economic concerns... innovation is more than only economics (p. 18)."

Tartaruga, Cazarotto, Martins and Fukui (2016) contend that the lack of interest in solving social problems is the issue the current economic development-centric innovation approach has, because the success of the market due to innovation does not always result in improving society. Thus, the social dimensions of innovation should be at least as equally important as the market dimensions of innovation, and the knowledge valorization approach can achieve this goal.

Efforts to encourage the public and civil institutions to propose the non-commercial issues they want science to solve, as well as to engage in the entire process of research, are the keys to expanding knowledge transfer from the market-oriented to the society-centric logic. From this perspective, I will articulate the strategy of knowledge valorization for the university. Universities are one of the major innovation actors of Mode 2 and Mode 3 innovation systems, mainly because knowledge transfer has become one of the major goals of the science and engineering universities in South Korea.

The paradigm shifts of university research from conducting academic knowledge production internally to promoting an entrepreneurial university movement through its 'networks with firms' and 'technology diffusion' activities began in the 2000s in South Korea (Park & Jeong 2014, pp.133-136). Compared to the history of the Mode 1-type academic knowledge production system, this paradigm shift is relatively new, whereas Mode 2-type research and education emphasizing industry-oriented collaboration with universities has been promoted in the past and is ongoing, especially since the Park administration (2012-2017) in South Korea.

Van Greenhuizen (2011) states that universities have begun adopting an 'open innovation' approach through which the actors of the open innovation network, including university researchers and business partners, try to adopt ideas from user groups as well as to introduce their knowledge and technology to market. The users' inputs and feedback are critical for co-creating and expediting open-innovation based technology commercialization. In order to speed up the user-based open innovation system, Van Greenhuizen (2011) introduces the concept of the "field lab," which is "a network of all relevant stakeholders in the value chain, often based upon a public-private partnership (p.10)" for coordinating research programs that consist of multiple research projects. Ensuring engagement of user groups from basic research to applied and commercialization stages in a systematic way is what differentiates field labs from other user-oriented innovation systems. However, constructing a new field-lab type of facility inside and out of universities requires additional efforts of actors in both universities and public policy fields.

The participation of individual members of society in project-level R&D activities has been increasing through societal-issue based R&D projects. For example, at KAIST, which is one of the leading institutions educating next-generation scientists and conducting world-class research, a research program was initiated in 2016 that has funded interdisciplinary research teams to resolve specific social issues gathered and selected by the project committee (Research Planning Center of KAIST, 2016). This case fits into Mode 2-type knowledge production, considering the support for solution-oriented research activities. In order to be labeled as a Mode 3 type activity, KAIST would also have needed to include the public in the entire research project selection process or collected the social issues directly from public inputs, instead of mainly from internal researchers' opinions.

To adopt a Mode 3-type evaluation approach, science policy makers and research university leaders should build policy tools and a systematic incentive structure that nudge scientists to pay attention to the research of not only public-proposed issue-solving, but also public-engaged research projects and programs. For example, one of the common elements of the national policies the South Korean government has recently initiated to reform higher-education in engineering is to expose science and engineering students to collaborative projects partnering with actors outside the university. As part of the 'Engineering Education Reform Plan' established in 2016, the Ministry of Science, ICT, and Future Planning (MSIP) of South Korea announced new policy programs in February 2017

(MSIP, 2017). One of these programs is to fund universities with $4.4 million in 2017 so they can organize science and engineering student-based interdisciplinary research teams, called 'X-Corps,' to improve their problem-solving capacities and resolve the issues of industrial sectors (MSIP, 2017).

The X-Corps program can be labeled as a Mode 2-type education program with research because of its focus on the interactions between the university and industry. However, the Mode 3-type approach to broaden the use of knowledge of society from commercial to non-economical areas can co-evolve along with Mode 2 because the basic goal of these two is the same, maximizing diffusion and use of knowledge for actors outside academic research. To achieve this, the research target of the collaborative research projects should be expanded to resolve social issues using non-commercial interests, as well as to let scientists and engineering students conduct the research with the public who proposed the issues for their research.

3.3. Development of Science Policy Decision-making Support Systems

The core elements of the Mode 3 science approach can also affect the efforts of the South Korean government to develop a science policy decision-making support system.

A democracy-centric approach of Mode 3 type knowledge production would improve science policy making. Godoe (2007) also emphasizes that knowledge produced in Mode 3 science has the potential to be "used for decisions pertaining to the future (p. 356)." If so, what should a Mode 3-type science policy look like? A public values-centric approach needs to be adopted for developing a science-based science policy decision making support system in South Korea.

Bozeman and Sarewitz (2005) adopt a 'public values failure framework' and criticize that the market- and economic-values centric science policy discourse (the market-failure model) in the United States has not sufficiently promoted public values when governing publicly-funded research activities of science and technology. They agree with the importance of science's contributing role for increasing economic values, their concern being the lack of interest and rhetoric in science and science policy communities to promote public values through creating, using, and distributing scientific knowledge. Their argument points out that a market failure-based science policy could be problematic when it emphasizes market efficiency rather than social values when justifying public R&D investment. They also recognize that their approach to a public value-centric science policy model is similar to the one by the scholarship of STS (Science & Technology Studies) because their research commonly emphasizes co-evolving science and society instead of science and economy.

In this model, science policy actors should make their major decisions based not only on correcting market failure and promoting market efficiency, but also on the public values scientific knowledge can promote. This is also a principle that government can adopt when designing and developing a science policy decision-making support system in the context of Mode 3 science. More specifically, public value-centric science policy meshes with the Mode 3-type knowledge system because a

Mode 3-type science policy should prioritize increasing the social outcomes and impacts scientific research activities and knowledge can bring to society, as well as equalizing the importance of the different knowledge produced by both scientists and the public. I suggest that this public values approach can be applied to a science policy decision-making support system.

The South Korean government initiated a project for developing a science policy decision making support system in 2012. The Korea Institute of Science and Technology Evaluation and Planning (KISTEP) is a government affiliated organization under the Ministry of Science and ICT (MSIT). KISTEP has been developing the K2Base (KISTEP Knowledge Base) system to build 'evidence-based S&T policy decision making support systems' using statistical data and information generated by its national R&D program evaluation and planning activities (Kim, Kim, Park, Lee, & Baek, 2013). The 'science of science policy' approach has provided the groundwork for KISTEP to establish the K2Base system; thus, an econometric-centric and scientifically collected evidence–based system is what the K2Base system is pursuing (Kim et al., 2013). However, in order to further develop an effective science policy decision-making support system, the K2Base research and management teams should put effort into identifying and articulating the values that the public in South Korea would most aspire to bring to society using scientific and technological development.

For example, the K2Base research and management teams could develop a quantitative index and criteria designed to systematically identify and assess public values that national R&D programs have brought and are expected to bring to society (Bozeman & Sarewitz, 2005). The use of media-based technologies such as on-line crowd-sourcing tools would also be useful not only for identifying the public values shared by society concerning specific science policy decisions, but also for improving the accountability of science policy (Kim, 2015).

In order to add the identification and articulation of public values regarding science policy into the K2Base system, the range of experts advising and contributing to the development of the K2-Base system should be expanded to include participation of the public with 'experience-based expertise (Collins & Evans, 2002).' In this way, the public can access the science policy decision-making process, and science policy makers can use the knowledge of the public for science policy purposes.

Popescu (2013) emphasizes the need to regard the citizen as 'co-participant to public policies' as well as to construct more interdependent and flexible policy networks through which different voices, ideas, and visions are expressed, shared, and negotiated for making policy choices. From this perspective, since the public should be regarded as the agent and contributor for shaping public policies, it is important for the actors, including the public and civil organizations, to participate in the process of deliberation for "making use of citizen's wisdom and knowledge (Popescu, 2013, p. 99)." From this perspective, the science policy field is not exempted.

If we assume that science policy makers need to initiate a responsible innovation policy for people in South Korea, it should follow that they need to identify the public values that the public prefer to promote through innovation. Owen, Stilgoe, Macnaghten, Gorman, Fisher, and Guston (2013).

emphasizes that, under a framework of "responsible innovation," it is critical for considering "purposes and motivations for the innovation" so as to make "technologically enabled futures" to be democratically negotiable as well as public value-centric (pp. 34-35).

Science policy makers in South Korea need to identify the public values to promote through innovation. They also must anticipate the potential changes of public values when the actual policy is implemented. In this situation, if the K2Base system is designed to identify and computer-simulate the public values that innovation might either promote or decrease when the actual policy is introduced, then the data and information the K2Base system can generate will be useful for informed decisions of policy makers. However, in the policy fields with specific target populations such as the one mentioned above (innovation for the people with disabilities), then the knowledge based on the experience of that population would be relevant as well. The K2Base development team needs then to transfer the knowledge of the public with 'experience-based expertise' into the K2Base systems' database, which will be useful as evidential information science policymakers can use for their decision-making.

3.4. Anticipatory Foresight of Science, Technology and Society

One of the core elements of Mode 3 science is to embrace not only scientific experts but also civil society members for designing and shaping the future prospects for science and society. From this perspective, the Mode 3 science framework is similar to the 'anticipatory governance' approach which emphasizes a responsive, reflexive, integrative and engaging approach of government to shape future society and technology (Barben, Fisher, Selin & Guston, 2008). More specifically, 'anticipatory governance' consists of serious efforts to integrate and reflect knowledge and feedback of both lay persons and experts into science policy decision making to design and shape the discourse of future science, technology and society (Barben et al., 2008). Guston (2014) also emphasizes the validity of the "anticipatory governance" approach because it would allow "small voices of folks previously excluded from offering constructive visions of futures… (to) contribute to bending the long arc of technoscience more toward humane ends (pp. 218-242)." Low also refers to this kind of foresight activity as "anticipatory foresight. (Low, 2017, p. 69)."

When considering the similarity of both anticipatory governance and the Mode 3 science approach, the Mode 3 science policy framework needs to adopt the anticipatory governance methods described above such as promoting the engagement of non-government or civil society members in science policy decision making. Moreover, this kind of effort by government would result in transforming the science policy process that reflects the vision and concern (or even uneasiness) of the public for newly developed technologies into mapping the discourse of future science, technology, and society. One example could be expanding the civilian-led committee, similar to the newly launched public committee on nuclear reactors in South Korea.

It is widely accepted that science policy issues containing highly sophisticated scientific and technological aspects need to be resolved with the advice of experts in the relevant field. The energy policy field is no exception. The Korean government's investment strategies for supporting national energy infrastructure projects, such as nuclear power plants, have depended on experts' opinions to date. This is not unusual in the field of science policy in terms of policy for science framework.

This conventional approach should be changed when adopting the Mode 3 science approach in science policy, as has been done in the case of the newly formulated civilian-led committee on setting the future direction of nuclear power-dependency policy. South Korea President Moon Jae-In, who was elected in May 2017, has announced his new policy for changing South Korea's nuclear power-dependent energy policy as well as halting the construction of nuclear power plants (Shim, 2017). In order to provide advice to his administration for future energy policy, a civilian-led committee was launched in July 2017 (Ko, 2017). One of the striking features of this committee is that there are no nuclear reactor experts involved. Organizing civilian-led committees is not a new mechanism of science policy, but a Mode 3-based committee should play a role in shaping consensus on and influencing the future direction of science and society. This is quite unlike justifying government's science policy decisions or the direction of future development of science and technology made by the experts. This is what differentiates the mission of civilian-led committees under the Mode 3 science policy mode which is similar to the consensus conference model for dealing with "socially and politically sensitive scientific and technological questions (Klepsch, 1995, p. 7)." The consensus conference is usually designed to "stimulate broad and intelligent social debate on technological issues," through the participation of lay people in "a carefully planned program of reading and discussion" along with integrating perspectives of experts and citizens (Sclove, 2000, pp. 33-36).

President Moon Jae-In's administration has followed a different path to settling debates on a future nuclear-free direction of the country by excluding nuclear power experts from a civilian-led committee and instead asking these experts to communicate with the public and collect public opinions for the future direction of energy policy (Ko, 2017). This type of science policy approach meshes with Mode 3 science policy in terms of its reflective, collaborative, and responsible approach. Other examples of action the South Korean government could undertake might include the launch of similar public-led committees without experts to guide publicly-funded research projects or programs for future technology, such as artificial intelligence. The main roles of such committees are to identify any social or ethical concerns associated with funded research fields as well as to collect, communicate and examine public opinions on them.

4. CONCLUSION

Innovation studies including the Mode 2 knowledge production approaches have continuously made efforts to identity and promote innovation, with the belief that it would generate benefits to the society as a whole. However, these approaches have not commonly succeeded in capturing the engagement of the public and society in the innovation process. In the Mode 3 knowledge production system, as Carayannis and Campbell (2007) state, the engagement of the public and society is critical for scientific knowledge-based innovation. This kind of engagement among scientists, engineers, and the public means that diverse values and knowledge of the public would be freely disseminated through cultural or communication media, becoming a source of new scientific knowledge.

Moreover, democracy is what differentiates the Mode 3 science model from Mode 1 and Mode 2 approaches (Park, 2014). Regardless of its political system, any country can establish and manage a Mode 1 and/or Mode 2 innovation system. The Mode 3 science model, such as the Quadruple Helix innovation network, is plausible mostly in democratic societies (Carayannis & Campbell, 2014) because only democratic societies and cultures would allow diverse knowledge and values to exist together and interact with each other. Thus, in order for the countries with established Mode 1 and Mode 2 knowledge systems to boost their scientific and technological innovation further (i.e., preparing for the Fourth Industrial Revolution), democratic values and practices should pervade the existing knowledge production system and science policy.

A top-down approach is common to both Modes 1 and 2, whereas the Mode 3 framework is based on a bottom-up approach to produce, share, and use new knowledge. Knowledge circulation among the heterogeneous actors of an innovation network, including the public and civil society instead of trained experts such as scientists, is another factor that a non-democratic society cannot accommodate.

In order to promote and institutionalize the democracy-based innovation system, however, Mode 3 science policy tools need to be designed and implemented to democratize knowledge and prioritize public values in the knowledge system. Thus I have presented science policy strategies such as the development of a system to evaluate R&D impacts to encourage scientists to engage in interactions with the heterogeneous actors including the public, the revision of the knowledge diffusion system focusing on non-commercial as well as commercial benefits, and reshaping the science policy decision-making support system for identifying and predicting the change of public values surrounding the choices of science policy and future. In this article, I also referred to concepts such as responsible innovation, which would be useful for deepening the understanding of and designing tools for the development of the Mode 3 science policy model.

The advocates of the Mode 3 framework agree that the proposed Mode 3 science approach is not the sole answer to resolve various issues regarding knowledge production and innovation for the future. However, government would be able to more effectively represent the diverse values and interests of the public in the innovation system if science policy communities would adopt into policy-making practice a new mode of scientific knowledge production approach with the Quadruple Helix model. I also emphasize that the research community of innovation would benefit from the scholarship of STS for designing and promoting a Mode 3-type knowledge system because of its specialized knowledge of the interactions between science and society.

Three major factors have discouraged the South Korean government from representing the diverse interests of the public in policy circles, although these factors can also serve as an argument for Mode 3 science policy for South Korea.

The first barrier to including the public in policy circles is the dominant role of government committees in the circle of public policy making in South Korea over the past 10 years. In South Korea between 2007 and 2015, the number of government committees increased from 416 to 549 (Park, 2015). However, the government committee system has not worked well for representing the values and interests of the public in South Korea, mainly because experts rather than the lay public or members of civil organizations become participants of the government committees. Since these experts are more inclined to reflect the interest of their groups and research domains than to survey and deliver the interests of the public into the policy making process, the results have not represented the latter.

Moreover, there has been a lack of commitment of government committees to capture and reflect public interests, especially in STI policy, because of the general belief that new scientific knowledge and technological breakthroughs are only possible by experts such as scientists and engineers with credentials in their subject fields. Thus, the diverse input of the public is not regarded as critical as are the opinions expressed by the expert groups involving scientific and technological issues.

As the government committee system has not worked to accommodate and project diverse public interests into public policy making, the Mode 3 science policy approaches would be an alternative to the existing system or improvement to the way government committees currently work. TheMode 3 science policy has the potential to promote the role of the public in scientific and technological innovation in South Korea, which would motivate government committees and the government agencies managing them to channel the interests of the public into the scientific and technological innovation process.

Second, the STI policy tradition in South Korea is that scientists and engineers have been serving as the key contributors to the economic development of the nation since the 1960s. This tradition has reinforced the two notions that, first, they need to focus on the activities related only to their research and engineering activities, putting less value on other activities such as politics and social change. Secondly, this reinforces the approach that an industrial development-centric focus should be the first priority of both the communities of STI policy and of researchers (Lee, 2017; Park, 2017)

In the South Korean context, the dominant STI policy model since the late 1960s has been to utilize scientific and technological innovation to maximize economic outcomes and impacts. More specifically, the main motivation of the South Korean government's support of scientific research and technological innovation activities has been economic, intended to catch up to developed countries since the late 1960s. This economic value-centric STI policy approach has been so influential that improving economic value (such as creating new jobs through research) is still the main STI policy mission in South Korea. Mode 2 science policy aligns well with this kind of STI policy approach.

The government-led economic development from the late 1960s to the early 1980s, and the revitalization of the economy after the Asian currency crisis from late 1990s to early 2000s are the two distinctive periods when science, technology, and innovation have fulfilled the mission of supporting economic development successfully in South Korea (Park, 2017).

Mode 2 science science policy tools include developing the Triple Helix innovation system through the creation of the International Science and Business Belt and designing a national plan for promoting entrepreneurial universities in engineering education. Both of these examples show the force of the economic rationale in shaping STI policy in South Korea. However, the major issue stemming from this STI policy model is that diverse non-economic value, such as environmental protection or research ethics surrounding scientific research and technological innovation, become of less concern than the economic rationale when designing and implementing science policy strategies as well as conducting scientific research. In other words, economic value-centric approaches have limitations on exploring and projecting diverse values and knowledge expressed by the public when designing and executing STI policies, as well as conducting scientific research activities, even though economic well-being is only a part of the broader social value system.

What I would like to emphasize here is not a value judgement of the South Korean government's efforts to pursue economic value creation through scientific and technological innovation. Rather, I wish to suggest how the economic value-centric Mode 2 science policy might result in blinding the communities of STI policy on various non-economic social values and interests that would be a useful resource for creating new scientific knowledge. Thus, there is a need for the South Korean government to expand the scope of science policy from a Mode 2-type economic-value centric approach to embrace broader social norms and interests. From this perspective, the Mode 3 science policy approach can motivate not only science policymakers, but also scientists and engineers to consider the diverse values and interests expressed by the public outside the research laboratory.

Third, the government's agency-wide emphasis on tangible outputs and outcomes of scientific research, such as journal publication through the evaluation of research activities and institutions, has been another reason that science policy communities do not capture and reflect the interests of the public. Tangible and statistically measurable outputs are useful for analyzing the performance of research projects and programs, but public values and interests, such as improving safety or the change of social systems and science education for people with disabilities, tend to be expressed as intangible outcomes. With little reward for doing so, scientists are less motivated toward activities producing outcomes other than journal publication. Therefore, public values and interests are not well represented and transferred to new knowledge production under the current science policy model unless they can be measured and assessed by statistical data.

In contrast, the Mode 3 science-based approach regards the public as key to improving the quality of research activities and creating new scientific knowledge. Thus, scientists and engineers would be more motivated to interact with the "media-based, culture-based and values-based public (Carayannis & Campbell, 2012b, pp. 39-40)." They would also tend to regard these interactions as useful resources for producing new knowledge, which would result in producing socially valuable outcomes and impacts of research. A change in research evaluation criteria would follow as well. Otherwise, the government's efforts to shift its emphasis from tangible output to intangible outcomes of research would not be sufficient to encourage scientists to value diverse knowledge and innovation produced and shared by the public through culture and media.

These three reasons I examined above regarding the inability of science policy in South Korea to value diverse interests of the public in science policy circles can also be used as the justification of the need for the South Korean government to change its current mode of science policy for democratizing knowledge, as well as creating an innovation system built on it.

I also suggest that two additional issues be considered when designing and implementing the Mode 3 science policy model. First, in terms of balancing market-oriented innovation with industry and democracy-centric innovation with society, market value and social value should not be treated as mutually exclusive. Market-oriented value is a part of the social value system, but not all social value can be captured in terms of market or economic value. Thus, under the Mode 3 science policy framework, science policy makers should balance improving not only market-oriented value, but also under-represented non-economical social value. In terms of capturing and projecting under-represented non-economical social value into the science policy system, science policy can be a more democracy- and society-centric framework than both Mode 1 and Mode 2 science frameworks under the Mode 3 science policy model I propose. The Mode 3 model would also influence the South Korean government to re-shape its research portfolio and expand support for societal and environmental research activities.

If economic value is the top priority of South Korean society, then it would make sense for government to invest more in research targeting the development of marketable technology or the one expect to create new jobs. However, the Mode 3 science policy model should motivate science policy makers to identify the core socio-economic values that the public expects scientific research to achieve most, and then adjust the priorities of government support for science. The process that identifies the core social value to be achieved by publicly funded research should also be inclusive and reflective.

The Mode 3 approach is already beginning to spread in the current national innovation system in South Korea, where both the Mode 1 and Mode 2 science approaches are still dominant modes of knowledge production. A few successful cases, including the initiation of user-oriented and social problem-based research projects, co-exist with Mode 1 and Mode 2 innovation systems. However, in order to expedite the sustainable development of Mode 3 exercises inside and out of scientific R&D activities, a democracy- and society-centric approach should be applied to expand not only current Mode 3 type activities, but also Mode 1 and Mode 2 activities. Otherwise, these Mode 3 type activities would be one-time, sporadic attempts, which tend to have less impact on improving a national innovation system.

Future research should examine the current social consensus of science agreed on by the public in South Korea as well as determine whether or not emerging Mode 3 science is compatible with the change of this consensus shared and agreed on by the public on governing science. Possibilities for future research include examining the 'Quintuple Helix' innovation of Mode 3 science (Carayannis, Barth, & Campbell, 2012). This mode of knowledge production framework adds the 'natural environmental of society' as the fifth helix to the Quadruple Helix for the sustainable development of the society (Carayannis, et al., 2012).

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