Brazilian Scientists Embrace Nanotechnologies

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Introduction

Beginning in 2000, programs and funds for research into nanosciences and nanotechnologies (N&N) – the study and manipulation of matter at the atomic or molecular level – gained importance in science and technology (S&T) policies worldwide.[2] Brazil quickly became part of this trend. From late-2000 through 2004, several events occurred that would galvanize an active policy for the sector and culminated in the N&N Development Program (PDN&N) as part of the Multi-Year Plan for 2004-2007 of the Ministry of Science & Technology.

Introduced as a revolutionary area of study, N&N entered the arena of S&T policy and were presented to the media and the general public wrapped in an euphoria of visions of a future nanotechnological society. These visions were revolutionary not only in a technological sense but also in social and cultural terms. Their content was not just cognitive, but also involved interests, values, ideologies and concepts concerning the relationship between S&T and society (Grundwald et al, 2004: 56). Let us consider for instance a report prepared for President Clinton entitled *Nanotechnologies: Shaping the World Atom by Atom* (NSTC, 1999). This title became a slogan for nanotechnology, putting forward a notion of a material world under an unprecedented degree of human control and precision (McNaghten et al., 2005). Equally suggestive was the title of another report on converging technologies: *Converging Technologies for Improving Human Performance* **(**Roco & Bainbridge, 2005). N&N foretold the enhancement of human physical and cognitive capacity[3], the convergence of man and machine. This transhumanism is considered the most advanced stage of human culture.

These visions, with their promises, seek to form and legitimize an emerging field of research, guarantee funding and, naturally, influence the course of the technological development itself. However, these visions of techno-scientific progress also led to criticism and public debate. In the case of N&N, the debate began early on in developed countries and in the wake of the previous conflicts on biotechnology, many countries included in their N&N policies mechanisms for public information and participation. In this environment we have seen both visions designed to gain public acceptance and political support for research programs and those attempting to create resistance to specific technologies or programs.

Nevertheless, it is difficult to determine the precise impact of a vision or the dynamic of contradictions between diverging visions on the concrete configuration of research programs and the resulting technological developments. Vision assessment, a tool integrated with technology assessment allows us to approach this matter. According to Fiedeler et al., (2005), the purpose of S&T vision assessment is to analyze the sense, role, bases, values and interests subjacent to the visions in order to understand their influence on the dynamic of the debate in a specific technological field.

In this article, we propose to map and analyze the visions of N&N disseminated by Brazilian scientists working in that field to the rest of the scientific community through the *Jornal da Ciência* (JC, Journal of Science). The *Jornal da Ciência,* published by the Brazilian Society for the Progress of Science since 1985, forwards to its 14,500 subscribers

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[2] In that year, President Clinton launched the National Nanotechnology Initiative, soon followed by N&N programs in other developed countries.

[3] "*Human enhancement*" is the increase of cognitive human capacities for work, heightening senses and prolonging of life through nanotechnology devices combined with other technologies, integrated with the organism.

news, articles and opinion papers on S&T issues.[4] These subscribers are mainly researchers, university professors and graduate students. It is worth noting that the Brazilian Society for the Progress of Science is an independent association of scientists with considerable influence on science and technology policy. The journal includes articles submitted by scientists, information gathered from or sent by S&T agencies and relevant reports from the national press. Most of these reports are either penned by the scientists themselves or their opinions are used by journalists as a quoted source. Reports on N&N were analyzed from the years 2002, 2003 and 2004, which was a key period in the structuring of N&N policy in Brazil.

Over these three years, N&N appeared frequently in the JC. In 2002, 24 reports were published, rising to 40 in 2003 and 61 in 2004. The subjects broached can be seen in Table 1. In 2002, reports about this new field and its applications based on domestic and international research information were predominant. In 2003, the focus was on the debate over N&N policy that was in the works, with general reports about the field of study continuing. In 2004 the reports included general information, discussions over policy, infrastructure and the organization of research. It was at this time that the matter of social and ethical implications arose, along with the risks of nanotechnologies. We also saw an increase in information about events, announcements, fairs and conferences on N&N at this time, signaling the gradual introduction of the field into everyday research in the country.

Table 1
Main subjects broached in reports

	2002	2003	2004
General information on nano and its applications	7	5	6
International research reports	4	4	2
Brazilian research reports	2	1	3
S&T policies and financing for the sector in Brazil	3	12	7
Infrastructure, HR and organization of research in Brazil	3	0	6
Risks and economic, social, legal and ethical implications.	0	2	6
Sub total of reports	**21**	**24**	**30**
Information about events, courses, fairs, announcements, etc.	5	16	31
Total reports	**24**	**40**	**61**

Source: Prepared by the author based on information from the *Jornal da Ciência*

In section one we present a brief panorama of the most important events related to the development of the N&N policy in Brazil, with the purpose of putting the analysis of the different visions of N&N in context. In the following sections we explore the content of the articles. Those dealing with events, courses, fairs and announcements have been excluded from the qualitative analysis as they contain only specific information about these issues. We have organized the presentation of N&N visions into four sub-themes. First, we analyze visions on a future nanotechnological society, identifying the promises of nanosciences and nanotechnologies that are being made. Second, we examine whether these visions allude to social, economic and ethical implications and the potential risks of these new technologies. Third, we identify the main actors involved in spreading these visions. Finally, we analyze how they are used to legitimize a new field of research. We round off the article with a few brief considerations and reflections.

1. Development of the N&N Policy in Brazil

The creation of the national policy to develop N&N in Brazil began with a workshop held in Brasilia, in November 2000, called *"Tendencies of Nanosciences and Nanotechnologies"*.

[4] The *Jornal da Ciência* is also distributed in printed form every two weeks. See http://www.jornaldaciencia.org.br/index2.jsp

This workshop was organized by the Secretariat of Policies and Programs of the Ministry of Science and Technology and the National Council for Scientific and Technological Development (CNPq). In this reunion, 32 researchers from different fields such as physics, chemistry, biology, and engineering reached an agreement about the necessity of creating a national program of N&N. An *Articulation Group* composed by ten researchers was created, with the purpose of identify the expertise of Brazil in N&N and elaborate an agenda (CNPq Noticias, 2000).

In April 2001, the *Articulation Group* presented a document identifying 192 researchers working in six areas connected to N&N in the country: a) Nanoinstruments, nanosensors and nanoelectronics, b) Nanoestructured materials, c) Nanobiotechnology and nanochemistry, d) Nanoscale processes with impacts and applications on the environment and agriculture and e) Nanometrology (Knobel, 2002).

In the same year, the CNPq acted rapidly in response to these reunions and it called for inter- and multidisciplinary research projects to run the *Redes Cooperativas de Pesquisa Básica e Aplicada em Nanociências e Nanotecnologias* (Cooperative Networks of Basic Applied Research on Nanisciences and Nanotechnologies) with the purpose of creating and consolidating the national expertise in this field (CNPq, 2001). Three Million *reales* were allocated for the project (one-million dollars according to the exchange rate at the time). The outcome was the creation of four research networks: Nanostructured materials, Molecular nanotechnology and interphases, Nanobiotechnology and the Network of semiconductor nanoinstruments and nanostructured materials. Each network was composed of scientists, universities and research centers from different parts of the country.[5]

In addition, in 2002 the Ministério da Ciência e Tecnologia (MCT) (Ministry of Science and Technology), as part of the Millennium Initiative, created an institute for nanosciences, in the city of Belo Horizonte. This network has a multidisciplinary approach and connects scientists that develop new products and research innovative proceedings in several areas such as: sensors, nanocapsules, photo-voltaic cells, light emitting devices, nanotubes, infra-red light detectors and basic research on nanostructured materials (CNPq, 2007). In the same year, the efforts of the *Coordinação de Aperfeiçoamento do Pessoal de Nível Superior* (CAPES) (Coordination for the Improvement of the High Level Personnel) of the Ministry of Education were integrated, granting six scholarships in Nanotechnology in partnerships with the *Associação Brasileira de Luz Sincrotron* (Brazilian Association of Synchrotron Light) (CAPES n/d).

The N&N policy that was conceived at the beginning of the government of Fernando Enrique Cardoso (1999-2002) had the purpose of creating a Nanotechnology Reference Center linked to the MCT. This center had the dual mission of stimulating academic research and encouraging the use of new technologies by the private sector. These ideas were embedded in the first *Programa Nacional de Nanotecnologia* (National Program of Nanotechnology) coordinated by the Physicists Cylon Gonçalves da Silva, Emeritus-Professor of the *Universidade Estadual de Campinas* and former director of the National Synchrotron Light Laboratory (Silva, 2003). Shortly after the change of government, the project was abandoned and the opening of the laboratory was cancelled because it was argued that the project consumed too many resources that could be used by other laboratories.

When Luis Ignacio Lula da Silva became president, the MCT created a new program, under the supervision of Dr. Fernando Galembeck, another professor of the Universidade Estadual de Campinas. In 2003, a Working Group, coordinated by Gallembeck, was created by the MCT to develop a National Program of Nanoscience and Nanotechnology. The final

[5] These four networks worked until October 2005, but from a new call of the CNPq 10 new networks were created, all of them connected to the Brazil Nano Program.

proposal was submitted to public consultation and it was later incorporated to the *Plan Pluri Anual 2004-2007* (Multi-year Plan 2004-2007) of the MCT. The estimated budget for the four year project was 78-million *reales* (approximately USD 28-million).

The objective of the program was to develop new products and processes from nanotechnology with the idea of increasing the competitiveness of national industry. For that reason, it recommended actions to implement and support laboratories and networks, working with nanotechnology and the implementation of institutional projects focusing on R&D of the N&N (MCT, n/d)

Also in 2004 and parallel to this, the government took control of the Industrial Technological and Trade Policy, including nanotechnology policy which it depicted as "bearer of the future." This reinforced the strategic importance that the government granted to this field (Teixeira, 2005). At the end of the year, the *Brazil Nano Network* was created to bring together the National Program of Nanoscience and Nanotechnology and other actions on nanotechnologies included in the Industrial, Technological and Trade Policy. In this context, a year later, the CNPq launched a new call to create research networks and ten networks were opened which are still operating. The research profile of these networks reflects an orientation towards industrial application.

Still in 2004, the proposal of the MCT of constructing a National Laboratory of Micro and Nanotechnology worth 30-million *reales* in São Paulo appeared in the debate.[6] It generated a powerful reaction from the expert scientists of the area, who observed this as a centralizing measure in distributing the scarce resources and as an action contrary to the recommendations from the PPA 2004-2007. It also was viewed as a serious questioning of the cooperative networks policy, that was previously evaluated as successful (*Jornal da Ciência*, 2004a). The debate is still open.

Finally, in August 2005, President Lula da Silva and the Minister of Science and Technology, Sergio Rezende, launched the *Programa Nacional de Nanotecnología* (National Nanotechnology Program) with a budget of 71-million *reales* (USD $31-million dollars) for the 2005-2006 period. This program consolidated several of the previous initiatives, particularly the one from the PPA 2004-2007 and the orientation of the Industrial, Technological and Trade Policy. The additional funds doubled the estimate by the PPA 2004-2007 (*Jornal da Ciencia*, 2004 b; MCT, n/d).

2. The promises of nanosciences and nanotechnologies

The articles and reports introduce N&N as being revolutionary, using expressions such as "technological revolution", "change of paradigm", "rupture" and "industrial revolution". The main benefit of this revolution would be economic development (Table 2). In 2004, the benefits of nanomedicine for improving health and quality of life were also highlighted, as well as the potentials of nanotechnology for preserving the environment and reversing environmental degradation.

[6] This project is, again, a proposal from Cylon Goncalves da Silva, who is returning with a high position to the MCT.

Table 2

Potential benefits resulting from N&N research

	2002	2003	2004
Economic development	9	13	10
Health and quality of life	1	3	11
Preservation of the environment	2	2	5
Benefits for humanity	0	0	2
The article does not broach the subject	11 / 20	9 / 24	13 / 30

Note: More than one option is possible

Source: Prepared by the author based on information from the *Jornal da Ciência*

In the JC, the visions of the nanotechnological society tend to be more conservative than those that generally characterize the international debate. No one speaks of cyborgs. There is no mention of the controversial subject of molecular manufacturing, as discussed by Eric Drexler (1986).[7] Emphasis is placed on less futuristic subjects such as the efficiency of new products: better focused therapies, permanent monitoring of the body, extremely powerful computers, intelligent multi-functional clothing and more resistant and longer-lasting materials. Table 3 shows the main areas for the application of these N&N referred to in the articles: health and computers, followed by new products and materials. In Table 4 we provide some examples of the visions of efficiency in these areas.

Table 3

Most frequently mentioned fields for the application of nanotechnologies

	2002	2003	2004
Pharmaceuticals, prosthetics, health	10	7	10
Computers, microelectronics, nanoelectronics	10	6	7
New materials	4	4	5
Cosmetics	1	2	4
Devices for products and productive processes	5	3	2
Production and storage of energy	0	1	3
Telecommunications	0	2	3
Chemical and petrochemical industry	3	1	1
Agriculture and agro-industry	3	7	0
Nanomachinery	3	0	0
Known consumer products with new features	3	6	2
Article does not specify a field of application	1 / 20	10 / 24	15 / 30

Note: More than one option is possible

Source: Prepared by the author based on information from the *Jornal da Ciência*

These visions are set in the immediate future, the next ten- to fifteen-years, a period that anticipates a huge surge in the nanoproducts market. This temporal horizon ties in with the emphasis on commercial viability and ready availability for the use of the products that are being researched today, as seen in over half of the articles analyzed. Moreover, the visions analyzed also differ from those in the international debate, in which the implications of nanosciences and nanotechnologies in the long term are also considered (Wood et al., 2003).

[7] The more radical visions of nanotechnology, such as that of Eric Drexler (1986), foresee possible production by way of molecular machines capable of replicating themselves and breaking away from human control, leading to a “gray goo” which would contaminate the planet.

Table 4

What does nanotechnology have in store for us? Examples

2002	2003	2004
Health		
Nanocomputers will navigate in the body to monitor drug delivery	Treatment with nanoparticles selectively absorbed by cancerous tissue	Brain cells will be reconstructed, leading to the cure of a number of diseases
Nanomachinery which will be able to operate even inside a living cell	From solar filters to cancer treatments…	Nanolaboratories capable of navigating in the human body to monitor the emergence of diseases and provide treatment for diseases through nanotherapies
Substitution of body parts reproduced from molecules		Use of nano robots to apply medication to specific cells
Computers, microelectronics		
Building of nanocircuits using biological materials (biochemical properties of DNA)	Faster, more compact computers with greater memory capacity	Much smaller computers with greater memory capacity
Molecular computers that are 1000 times more powerful than those of today		Extremely quick and powerful computers
New materials and products with new features		
Anti-collision sensors for cars	Carbon nanotubes in textiles capable of storing energy, picking up radio signals or working as sensors	Spectacles that will not get scratched Self-cleaning glass
New, lighter materials for planes	Odor remover for bathrooms using gold nanoparticles	Tires that last sixteen times longer than today's
Glass and lenses that reduce the intensity of sunrays	Self-cleaning glass	Intelligent, stainless clothing that does not wrinkle. Uniforms for soldiers to protect them from biological attacks

Source: Prepared by the author based on information from the *Jornal da Ciência*

3. Economic, social and ethical implications and potential risks

The echoes of the polarized international debate on the implications, risks and regulation of N&N are practically unheard among the Brazilian scientific community.[8] Subjects such as information and public participation, evaluation of risks, ELSI studies (ethical, legal and social issues of technology) are not only part of the international debate but also issues addressed by policies for the development of N&N, with a specific budget in most of the more advanced countries. From the selection of some topics that stand out in the international debate, listed in Table 5, we sought to map out the importance given to these matters in the JC reports.[9] Among the economic implications, most attention is paid to the change in production conditions and competitiveness. However, we can see that most of the articles do not touch on these questions.

In 2003 the ETC Group called for a moratorium on nanotechnology, pointing out possible risks to health and the environment at the World Summit on Sustainable Development held in Johannesburg. This call was highly controversial. However, in the JC, it was only raised in one report. In 2004, two events introduced the theme of risks: the foundation of the Nanotechnology, Society and Environment Network in Brazil and the

[8] See for example UNESCO (2006), Invernizzi & Foladori (2005); Wood et al (2003);

[9] The selection of topics was done based on previous research (Cf. Invernizzi & Foladori, 2005 and Foladori & Invernizzi, 2005).

publication of the report of the Royal Society and the Royal Academy of Engineering (RS&RAE, 2004).

Table 5
Main social, economic and ethical implications of nanotechnology

	2002	2003	2004
Changes in conditions for production and competitiveness	3	5	3
Obsolescence of technologies, products and materials	3	1	2
Fall in traditional exports	0	1	0
Changes in way of life	0	1	3
Greater social inequality	0	1	2
Ethical dilemmas	0	1	1
Risks to health and the environment	0	2	7
Risks to workers in laboratories and industry	0	0	1
The article does not broach the subject	13 / 20	16 / 24	20 / 30

Note: More than one option is possible.
Source: Prepared by the author based on information from the *Jornal da Ciência*

Indeed, the scientific community "doesn't talk" to outsiders such as NGOs or social movements that have spoken of the possible risks and social and ethical implications of N&N. References to potential conflicts between science and the public over N&N is scarce, although the sensitivity of the scientists to the possibility of new conflicts would have been heightened by what had been happening in the country because of the controversy surrounding genetically modified organisms (Pelaez & Schmidt, 2000). Among the few references to society, we found some that attempt to dismiss the capacity or legitimacy of NGOs to voice their opinions on nanotechnology. One researcher, for instance, recognizes the existence of the risks of nanoparticles to human health and the environment. He says these risks are low and avoidable and speaks of the need to inform the public in order to "face activists who fight, armed only with popular fantasies, [and who] are organized against this type of science, demanding a moratorium" (Garcia, E, 2004). Another scientists informs us during an interview that there are already cosmetics with nanoparticles on the market but that the companies who make them do not make this public "so that they won't suffer with NGOs" (Geraque, E, 2004). It is necessary to note that both emphasize the importance of scientific information for the public, but they do not recognize the right of social movements to voice their opinions on technologies, their implications and their potential risks. A good question in this context is: would environmental regulation be on international agendas today if social movements had not started protesting against pollution and environmental degradation forty years ago?

4. Legitimizing the Field

Brazilian scientists introduce N&N as a revolutionary field that is about to take off, with a huge potential for benefits, and a fabulous market being developed over the next few years.[10] They endorse linear visions of progress. Possible social implications and risks are so marginally considered that they do not cast a shadow on this optimist vision of the nanotechnological future. To legitimize the field of research, scientists stress these visions of progress by means of three arguments: opportunity, necessity and viability.

The scientists have repeatedly characterized N&N as a change in the scientific and technological paradigm that will open up a historic *opportunity* for Brazil. The PDN&N clearly supports this point of view when it states in its justifications that: "in an imminent breaking of paradigms due to nanotechnology and nanosciences (N&N) we are now faced

[10] Lux Research (2006) estimates that the nanoproduct market will be worth US$2,900,000,000,000 (2.9 x 10^{12}) in 2015.

with a unique opportunity to join this new era along with developed countries…" (STM 2003:8). From opportunity comes the *necessity* of developing aggressive policies and investing resources because, if this is not done, Brazil will remain outside of this new paradigm in which so many countries are investing so quickly. Metaphors such as "we can't miss the bus" or "we've got to catch this wave" are used a great deal.

In 2003, during the preparation of the Development Plan for Nanosciences and Nanotechnologies (PDN&N), the argument of national *capacity* was often used. It was argued that the networks cooperating in N&N research, created following an announcement by the CNPq (Brazilian Research Council) in 2001, gathered highly qualified and productive human resources capable of advancing world-class research and pushing innovation towards the promising nanoproduct market. The greatest obstacle, according to the scientists, is the lack of resources for improving infrastructure and increasing the size of the research team.

It is worth mentioning that in the midst of all the discussions surrounding the approval of the Law of Innovation, the relationship between capacity for research and capacity for innovation by the productive sector was discussed very little by scientists. This is significant because the goals of the PDN&N and the discourse of the scientists strongly agree in the basis of a need to support N&N research in Brazil: the development of national competitiveness (see Table 6). Other arguments such as technological autonomy, sustainable development and meeting social needs at a national level are only marginally utilized to legitimize the field of research.

Table 6
Main reasons to justify support for nanotechnology research in Brazil

	2002	2003	2004
To develop competitiveness to enter the international market	6	7	6
N&N is a strategic field. Brazil cannot fall behind	3	2	3
To train qualified human resources	0	2	2
To meet local social needs	0	1	0
To gain technological autonomy	0	0	1
Sustainable development	0	0	1
The article does not broach the subject	12 / 20	12 / 24	21 / 31

Note: More than one option is possible.
Source: Prepared by the author based on information from the *Jornal da Ciência*

5. Main Actors

Within the scientific community that carries out N&N research, there are actors who have an outstanding role in the promotion of certain visions concerning nanotechnology. The scientists most mentioned in the JC are physicists. In Table 7, we can see that they have a profile considered to be of excellence in national research and they are the product of the investment that has been made in the country since the 1970s in order to achieve this development: they have obtained their doctorate degrees at the most renowned universities in Brazil and overseas and have carried out their post-doctoral research at universities and research centers abroad. Most of them work at universities and research centers in São Paulo State, where the S&T infrastructure is concentrated. It is worth noting, however, that in N&N, the Northeastern region also stands out, due to the excellence group at the Federal University of the State of Pernambuco. In other words, the most active scientists in spreading visions on N&N are the elite of the national scientific community.

Table 7
Academic profile of researchers quoted in articles

	2002	2003	2004	Total
Predominantly qualified in physics	9	12	9	30
Predominantly qualified in chemistry	0	4	5	9
Predominantly qualified in engineering	1	3	4	8
Predominantly qualified in pharmaceuticals, biochemistry and medicine	3	1	2	6
Predominantly qualified in social, human and applied sciences	1	1	2	4
Post doctorate and other qualifications overseas	10	16	12	38
Doctorate degree overseas	7	10	10	27
Master's degree overseas	1	1	0	2
Doctorate degree in Brazil	6	11	11	28
Master's degree in Brazil	11	12	14	37
Work at universities or research centers in São Paulo State	8	11	13	32
Work at universities or research centers in Rio de Janeiro, Minas Gerais and the Southern Region of Brazil	0	4	4	8
Work at universities or research centers in the Northeast of Brazil	3	5	5	13
Work at universities or research centers in other Brazilian states	1	1	0	2
Researchers with connections to companies	1	0	0	1
Total number of researchers quoted	12	20	25	57
No information available about the researchers	0	2	3	5

Source: Prepared by the author based on information from the *Jornal da Ciência* and the Currículos Lattes data base of the CNPq.

Only four social scientists are cited in the articles analyzed, demonstrating both the scarce attention paid to the economic, social and ethical implications of N&N, and the still-limited familiarization of Brazilian social scientists with the coming nanotechnology revolution.

Comments and reflections

The definition of a national policy for N&N was legitimized by the elite of the scientific community before the rest of the community and the public through visions of progress, efficiency and competitiveness. Brazil is facing a technological revolution that it cannot afford to ignore.

These visions are linked to a linear perspective of progress, according to which investment in S&T, transformed into innovation, will result in greater competitiveness. More efficient technologies and a more competitive country will, in turn, lead to social well-being. This mechanicist perspective is questionable for a very unequal country like Brazil. In fact, the poverty gap has widened globally while technology has developed fast over the past few decades (PNUD, 2005; Invernizzi & Foladori, 2005). On the other hand, a technological revolution at the level being announced will have highly destabilizing implications and its effects will hit the most vulnerable sectors of society hardest.

The international debate on N&N has emphasized the need to democratize decision-making to influence the development of this technology in order to democratize its benefits, limit its risks, and face its social, economic and ethical implications. However, the scientists who are developing nanosciences and nanotechnologies in Brazil are reluctant about having new actors in the S&T debates. This could lead to conflicts between science and society and the loss of public confidence in S&T.

The reconfiguration of the relationship between science and society is still quite new and restricted to more advanced countries (Invernizzi, 2005). Most scientists in Brazil were certainly not trained in this paradigm of a closer relationship between science and society. To make advances in this way requires greater interaction among scientists from the natural and physical fields and social scientists to reflect on the research policies of the country. It also

means incorporating new social actors into the dialogue, actors who doubtless endorse specific interests, as is common in the democratic game.

The N&N policies of developed countries include a number of mechanisms for public participation. Brazil needs to join this trend to be in a position to guide the development of nanotechnologies democratically so that they are in line with the social needs of the country, with the Precautionary Principle as a guide for potential risks and the evaluation of economic, social and ethical implications as a reference for concomitantly preparing policies that face the potential problems that may arise in these fields.

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