



Science and Technology Policy Research in the EU: From Framework Programme to HORIZON 2020

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Abstract: Science and Technology policy is regarded as an essential factor for future growth in the EU, and Horizon 2020 is the world's most extensive research and innovation programme created by the European Union to support and encourage research in the European Research Area (ERA). The purpose of this study is to analyse and evaluate the changes to the EU's science and technology policies from Framework Programme to Horizon 2020 and to provide vital information to research organisations and academia to conceive and conduct future research on international cooperation with the EU. Through a policy analysis, this study summarised the four science and technology policy implications: (1) building ecosystems through mutual complementation among industries, (2) solving social problems through science and technology, (3) strengthening SMEs' participation, and (4) sharing knowledge and strengthening collaboration with non-EU countries.

Keywords: European Union; Horizon 2020; Framework Programme; R & D; STI Policy

1. Introduction

Over the past decade, the European Union (EU) has faced a situation in which economic growth and jobs have been lost because of the recent financial crisis, and sustainable economic growth does not appear easy in the future. Due to the economic and financial crisis, the EU's GDP declined to 4% in 2009, industrial production fell to levels characterising the 1990s' levels, and unemployment increased to include 9.6% of the economically active population. The EU has realised the need for science and technology policies to address the ongoing economic downturn and create economic opportunities for the future (World Bank 2017). Therefore, the EU has instituted an integrated technological innovation policy to complement economic growth models to address the problems faced by member countries and to create and develop different types of growth. Starting with the first Framework Programme (FP) in 1984 and eight continuous technological innovation policies up to Horizon 2020 in 2014, the EU secures Europe's global technological and industrial competitiveness to solve social problems, such as a low growth economy, climate change, and an ageing society (European Commission 2013).

Horizon 2020 is the world's most extensive research and innovation programme, and it is supported by the EU to ensure various research projects ranging from basic research to commercial development. It has a budget of €80 billion budget for the use of research institutions and firms from both EU and non-EU countries. By connecting outstanding studies directly to innovation, the objective of Horizon 2020 is to increase the EU's global research competitive ability and enhance collaboration between the public and private sectors. Therefore, the research objective of this study is to analyse and evaluate the changes to the EU's science and technology policies, from the Framework Programme to Horizon 2020, and to provide important information to research organisations and academia to conceive and conduct future research on international cooperation with the EU. According to the research purpose, this study investigates the background on science and technology policy in the EU and presents a systematic analysis of the EU's science and technology policy from 1984 to present.

Moreover, it describes the implications and prospects for Horizon 2020 and provides suggestions for international cooperation. In particular, it comprehensively analyses Horizon 2020 and compares the research and transfer policies of the latest science and technology policies in the EU. It aims to provide a policy direction for planning and researching international cooperation with the EU in government institutions, industrial research institutes and business and academia in non-EU countries.

2. Theoretical Background of the EU's Science and Technology Policy

The EU's science and technology policy dates back to the early 1950s. Cooperation between European countries was first initiated by socio-political need, rather than by science and technology. This began before the formation of the EU (Lundvall and Borrás 2005). To cope with American-centric nuclear physics research, the European Organisation for Nuclear Research (CERN) was first established in 1954, followed by the European Atomic Energy Community (EURATOM) in 1957. In 1962, the European Space Research Organisation (ESRO) and European Launcher Development Organisation (ELDO) were established. The Association of Space Explorers (ASE) was then established, absorbing both ESRO and ELDO. Therefore, socio-political cooperation was the key issue in the 1950s and 1960s (Peterson 1991). In the 1970s, the need to establish intergovernmental cooperation in the industrial sector was recognised and expanded, and the need to establish and coordinate a closer cooperation system emerged consequent to the disorder and inefficiency in the steel industry policy among European countries. As a result, the EU's industrial coordination policy was enacted. As this policy was implemented, European countries became aware of the importance of coordination and cooperation between nations. From the 1980s, it became clear that a conventional research and development policy was required because of the overlapping investments of various European countries (Camagni and Capello 2013), different product standards, and low telecommunication competitiveness. Based on the need for systematic cooperation between European countries, the first 'Framework Programme', a joint research and development programme in Europe (Scherngell and Barber 2009), emerged in 1984, followed recently by Horizon 2020, which has become the core of science and technology policy in the EU (Cram 1994; Kim 2014).

By the end of the decade, Europe faced a rapidly changing world order, lack of innovation, and various environmental and social challenges. The United States already has an absolute competitive advantage over the EU in the knowledge-based industry, and the number of high-tech workers in the country is higher than the combined number of high-tech workers in the EU. Asian countries have also become highly competitive in the high-tech market by industrialising traditional technologies. Korea and Japan have become highly competitive in the high-end products market, and China and India have increased their competitiveness in high value-added industries based on cheap and excellent human resources. Therefore, the EU became aware of the urgency of the situation and announced Horizon 2020 and the Innovation Union plan to respond with a new science and technology policy strategy. To overcome these problems, Europe 2020—a ten-year strategy proposed by the European Commission—and Innovation Union—an EU strategy to create innovation-friendly environment plans for long-term strategic policy—were announced (European Commission 2010). It clarifies the EU's willingness and attitude to respond to existing and emerging social problems. Europe 2020 focuses on achieving smart growth, and the Innovation Union suggests measures to contribute to this goal, such as increasing investment; reshaping research, development, and innovation policies into mundane tasks; and strengthening the commercialisation of innovative research. The primary goal of Horizon 2020, the core science and technology policy of the Innovation Union, is to invest approximately 3% of the EU's GDP into science and technology innovation, improve the competitiveness of science and technology research in Europe, and boost R & D to withstand the competitive pressures of the global market (Clarke 2010; Storey and Tether 1998).

3. Research Method: EU Science and Technology Policy Analysis

3.1. Existing Technology Innovation Policy: Framework Programme

3.1.1. 1st to 6th Framework Programme

The purpose of this study is to investigate the changes in and characteristics of policy and the implications thereof by examining the process of policy change from the first Framework Programme of the EU's science and technology policy program, which was launched in 1984, to the recent Horizon 2020 policy. First, the 1st to 7th Framework Programmes, the existing technology innovation policy programs, were analyzed. We then examined the policy, budget, and utilization of the 7th Framework Programme (FP7) and Horizon 2020, the new science and technology policy. In particular, by comparing the structural changes of Horizon 2020 with the Framework Programme, which has constituted the core of the science and technology policy for the past 30 years, we can confirm trends and implications of EU science and technology policy. As such, few studies have compared FP7 with Horizon 2020. Therefore, through the research analysis, this study seeks to answer the following questions: (1) What trends have the EU's science and technology policy changed? (2) What are the characteristics of the Horizon 2020 policy? (3) What are the implications of Horizon 2020 to non-EU countries?

The Framework Programme, first launched in 1984, progressed from the 1st to 6th versions in units of five years, and the period was extended to seven years with FP7 (See Table 1). In the 1st Framework Programme from 1984 to 1987, a strategy was applied to integrate the sporadically scattered individual programs. Investments in research to enhance industrial competitiveness increased (Luukkonen 2000). However, this Framework Programme demonstrated limitations in defining specific fields such as information and communication technology and material technology. The 2nd Framework Programme, which operated for five years from 1987, expanded the field of energy and environmental agriculture to information technology. This program aimed to realize a single market in Europe and emphasized industrial demand. In particular, 60% of the budget was invested in industrial technology research and in increased support for energy, environment, agricultural policy, and information technology (Bruce et al. 2004; European Commission 2005). In the 3rd Framework Programme (1990–1994), rapid budget expansion for the development and exchange of human resources began. To promote collaboration with non-EU countries, neighboring countries such as Norway, Sweden, and Switzerland began to participate in the 4th Framework Programme (1994–1998). The IT sector budget was dramatically increased to 38% of the total budget, and the humanities and social sciences sector was first established, indicating the expansion of the framework beyond R & D. In the 5th Framework Programme from 1998 to 2002, priority projects included adopting a horizontal program common to all sectors, building the European Research Area (ERA), and solving socioeconomic challenges (Scherngell and Barber 2009; Pandza et al. 2011). Specifically, strategic support was provided that focused on research on socio-economic issues, rather than research on performance itself. In the 6th Framework Programme, which ran five years from 2002, many large-scale projects progressed and new propulsion devices for activating cooperation, such as NoE and IP, were introduced. Furthermore, integrated research was required (Bruce et al. 2004).

Table 1. Analysis and Main Contents of 1st–6th FP.

Programme	Period	Main Contents
1st FP	1984–1987	Integration of individual programmes Increased investment in research for industry competitiveness
2nd FP	1987–1991	Emphasising the European single market and research programme
3rd FP	1990–1994	Expanding the IT sector and HR development
4th FP	1994–1998	Participation of Non-EU countries
5th FP	1998–2002	European Research Area
6th FP	2002–2006	Focusing and integrating European research

3.1.2. 7th Framework Programme

FP7, which ran for seven years from 2007 to 2013, was the world's largest single R & D program at that time. It comprised 6 segments, 4 core projects (cooperation, people, ideas, capabilities), plus the European Atomic Energy Community (EURATOM) and Joint Research Centre (JRC), and included 20 strategic areas such as health, information and communication technology, and energy (Peterson 1991; Peterson and Sharp 1998). "Cooperation," the first of the four major tasks, aimed to secure leadership in the core technology field through industry-academia cooperation including core cooperation between universities, companies, research institutes, and public institutions in EU member or third world countries. This project emphasised strengthening leadership in the technology sector. The second project, "people," aimed to foster human resources through exchange with researchers from Europe and third world countries.

The Marie Curie program aimed to strengthen research capacity and develop research capabilities together continuously. The third project, "ideas," established the European Research Centre (ERC) to strengthen basic research support to promote innovative creativity in the basic research field and create excellent research results, including in the humanities and social sciences. The final key task, "capabilities," aimed to utilise EU research capacity through large-scale, research-based, regional cooperation and innovative small and medium enterprises (SMEs) to strengthen the research capacity base and lead a knowledge-based economy. In the existing support programs EURATOM and JRC, EURATOM is legally independent of EC and its framework research program aims to secure safe energy by reducing reliance on nuclear energy. The JRC is the core research tool of the EC and aims to provide scientific and technical assistance in the conceptualisation, development, implementation, and monitoring of EU policies and scientific and technical research in member states (European Commission 2010, 2013).

To address the difficulty in ensuring the cost of research tasks, which has continuously increased as FP7 progressed from the first to sixth stage, a budget support device was provided in various fields ranging from R & D to personnel exchange and technology commercialisation. These fields were supported in different ways depending on the project or objectives and characteristics of participating organisations. In the case of R & D, 50% of the total budget was aimed at supporting 100% of projects for technology commercialisation, market activation, and cooperation promotion (Luukkonen 1998; Tulla et al. 2014).

3.2. New Technology Innovation Policy: Horizon 2020

3.2.1. Problem Recognition of the Framework Programme

Scientific and technological innovation is a critical element that will help Europe achieve smart and sustainable growth in the future and solve urgent social problems in the process. Solving social issues has proven more challenging. To improve social awareness, the EU argues four reasons: (1) lack of capacity for solving social challenges, (2) lack of technology leadership and innovation capacity, (3) need to strengthen the scientific base, and (4) lack of cooperation between countries. Because of these problems, the competitiveness of European science and technology has recently declined. Compared with major competitors in the United States and Asia, European patent outcomes are insignificant and lag behind the development of new products, processes, and services. To increase productivity and growth, it is crucial to create innovative technologies and convert them into new products, processes, and services (Luukkonen 1998; Tulla et al. 2014).

3.2.2. Policy Implementation

The EU decided to refer to Horizon 2020 rather than the current Framework Programme from the 8th Framework Programme in 2014, following the end of FP7 in 2013. The reason was that from the perspective of the public, the Framework Programme was difficult to understand and the participation rate was low. Thus, the program had to be simplified and the need for more intensive promotion emerged. Horizon 2020 is a "Competitiveness and Innovation Framework Programme (CIP)" that supports the innovation activities of SMEs in the EU and European Institute of Innovation

and Technology (EIT), as well as the existing R & D policies and programs promoted by the EU 19 (Granieri and Renda 2012). The EU's technology innovation policy is based on a policy initiative and system that was finally approved by the European Commission, followed by a review from the European Economic and Social Committee, EU Parliament, and Committee of the Regions (see Figure 1). The policy initiated by the EU Committee is reviewed by the Standing Representative Committee and implemented through the European Commission Service Organization. EU Horizon 2020 is undertaken and supervised by the EU Commission's "Research & Innovation" (European Commission 2011).

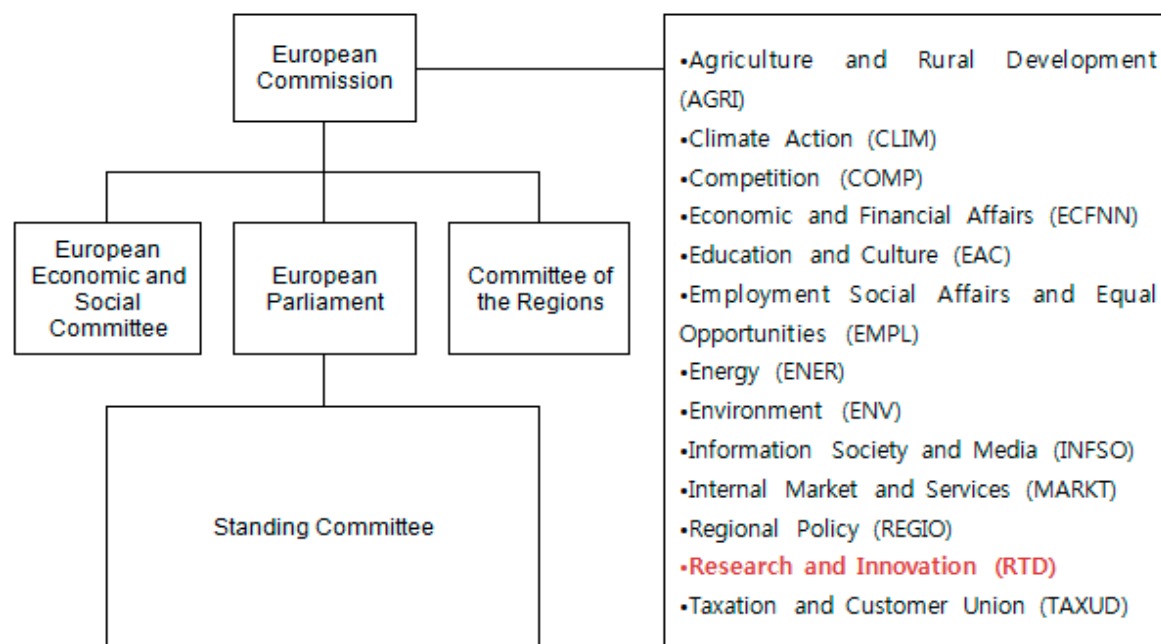


Figure 1. Research Model. Source: Authors' Elaboration.

3.2.3. Horizon 2020 Policy Review

Horizon 2020 aims to strengthen the competitiveness of "excellent science," "industrial leadership," and "social challenges." It provides specific strategic objectives for each field and aims to invest in R & D for the sustainable development of science and technology in the EU. "Excellent science" is a strategy for cultivating human resources and increasing science and technology talent to improve future competitiveness and welfare in Europe. It is primarily divided into the European Research Council (ERC), future and emerging issues, Marie Skłodowska-Curie actions (MSCA), and research infrastructure. The estimated funding costs are €24 billion (2014–2020) at current prices. All funding figures are in accordance with the European Parliament and ERC's multi-year financial framework and active and open research activities, thus establishing European research infrastructure policy and strengthening international cooperation. Another crucial issue is to support basic science R & D such as engineering, social science, and humanities to develop infrastructure after Horizon 2020 (Pacheco-Torgal 2014; Salmelin 2013).

"Industrial leadership" is the priority to secure industrial competitiveness in promising core technology fields by supporting research innovation activities in companies. Leadership in Enabling and Industrial Technologies (LEITs) invests in telecommunications, nanotechnology, advanced materials, biotechnology, space, advanced manufacturing, and processes to enhance productivity and innovative capabilities. Access to risk finance is improved by utilising bond issuance and stock issuance financing, thereby financing SMEs and innovative research activities. Furthermore, this fund has established a special task force for innovation in SMEs, providing them with innovation support to internationalise innovative companies (Soldani and Manzalini 2015).

The bulk of funding from the approximately €30 billion (2014–2020) for “social challenges” is invested in the R & D strategy to solve social issues in Europe. In response to the persistent aging society in Europe, this theme continues to improve services for the prevention of diseases and improved health. It also responds to consumer needs for the development of sustainable agriculture, forestry, and safe food, and the creation of a bio-industry infrastructure. Furthermore, it strengthens rural capacity, promotes policy and agricultural innovation, and promotes the development of a sustainable and competitive food industry. In addition, this theme promotes marine innovation through biotechnology, supports market development, and transforms the fossil fuel-based European industry into a renewable biofuel industry structure. It is pursuing sustainable energy consumption and the reduction of carbon emissions, supplying low-cost and low-carbon electricity, developing alternative fuels, and promoting the smart grid through safe and efficient energy development, carbon emission reduction, and alternative fuel development. To promote the development of advanced technologies and new solutions such as advisory, financial, and demand management services to promote the competitiveness of buildings with zero carbon emissions and energy-efficient industries, this theme pursues the development of new and renewable energy sources and fuel. By 2020, the global leadership of the transport industry will be strengthened by constructing resource-efficient transport systems for environmental protection and expanding an intelligent transportation network. At that time, 30% of road freight transportation will be converted to train and water transportation, and an efficient and stable road traffic network constructed. The aim is to decrease the use of fossil fuels in EU cities by half by 2050 and to complete a logistics transportation system that realises zero carbon emissions in major urban centers by 2030. It also promotes the customised production of vehicles and associated infrastructure, shortens life-cycle costs and development time, leads the standardisation of production processes for transport vehicles, and promotes the sustainable management of natural resources and ecosystems. Thus, the transition to a green economy for innovation is another important role of “social challenges” (European Commission 2007, 2014).

4. Findings: Policy Comparison and Utilisation

4.1. Policy Comparison of Horizon 2020 and 7th FP

The Denuclearisation Joint Research Centre, one of the five core projects in the existing 7th Framework Programme, is not included in the core strategy of Horizon 2020, but it is managed as a separate item. Conversely, support for the ICT enterprise development strategy and the European Innovation Research Institute, which was not operated in the existing 7th Framework Programme (See Figure 2), was included in Horizon 2020 (KIST-Europe 2014).

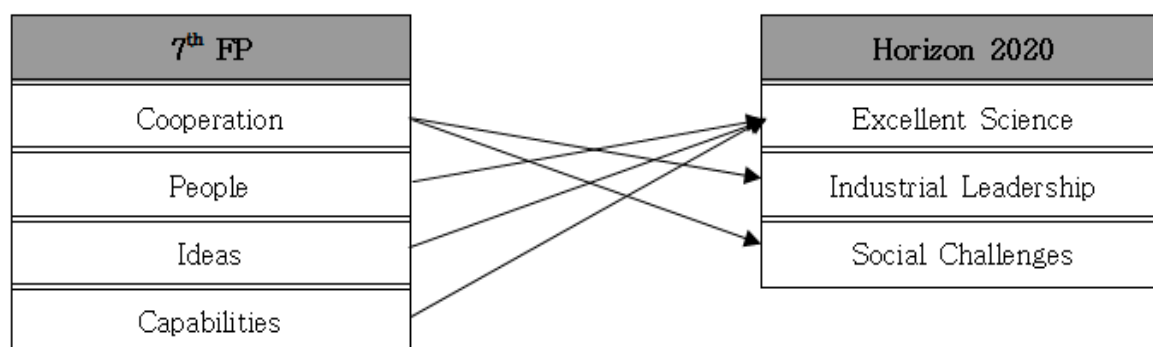


Figure 2. Horizon 2020 and 7th FP. Source: Authors' Elaboration.

4.2. Budget Comparison of Horizon 2020 and 7th FP

Horizon 2020 plans to invest around € 80 billion (at current prices), which is about 60% more expensive than the 7th FP with a budget of 50 billion euros (Figure 3). The former 7th FP supports the

largest budget (67%), about € 33.8 billion for the ‘cooperation’ project, while Horizon 2020 supports ‘social issues’ such as green energy and health, with the largest budget of about € 31.7 billion (40%) (European Commission 2014; Granieri and Renda 2012; Pacheco-Torgal 2014).

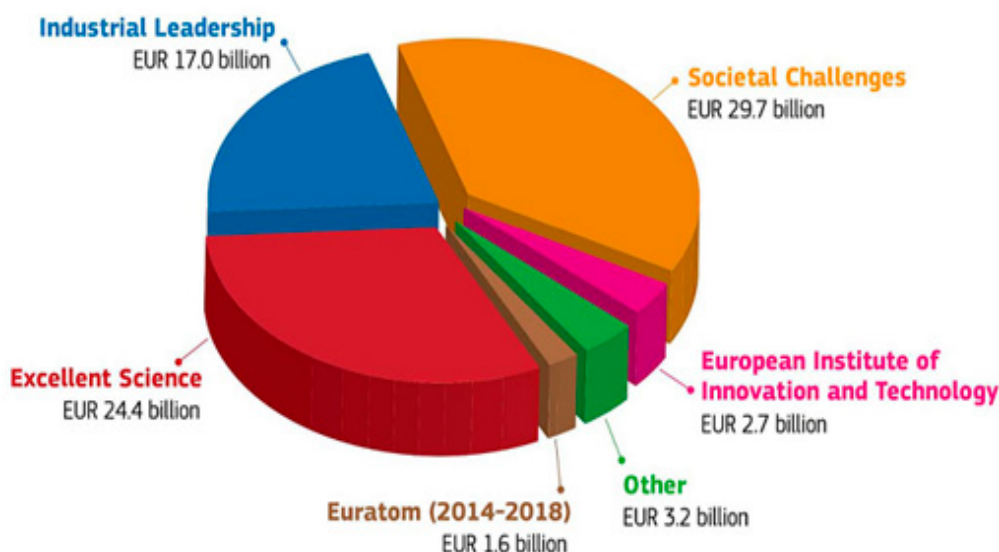


Figure 3. Horizon 2020 Budget. Source: European Commission (European Commission 2014).

The difference between the current and unchanged price is that the current price includes the inflation effect, as it is the actual amount to be applied to the budget authority every year. However, regular prices do not include inflationary effects in calculations; rather, all prices are “fixed” at the year’s price. The multi-year financial framework is displayed as an invariable price, because the constant price is used to make it easier to compare the annual budget with the “bargain price” in the political negotiation process. However, when distributed to real beneficiaries, these prices are always shown at current prices.

Horizon 2020 allocated approximately €80 billion to the EU’s science and technology research and innovation R & D investment fund from 2014 to 2020 and €24.5 billion for “excellent science,” “industrial leadership,” and “social challenges.” Approximately €17.9 billion from €31.7 billion were allocated for the budget. In addition, the European Institute of Innovation and Technology, Non-nuclear Direct for the Joint Research Centre (JRC), and Atomic Energy Research were respectively budgeted €1.39 billion, €1.96 billion, and €1.66 billion (European Commission 2007; Salmelin 2013).

4.3. Utilisation of EU Science and Technology Innovation Policy

The largest institutional reform of Horizon 2020 is integrated support. From the research stage of technology development to the commercial application stage, a single regulation was applied: (1) FP7, (2) innovation aspects of the CIP, and (3) the EU contribution to the EIT. This was rolled into one program from research to innovation. The program structure was simplified, and a single rule applied. Furthermore, time and cost were reduced through the simplification of documents and administration. The purpose throughout has been to promote industrial participation and expand international cooperation. To promote industry, Horizon 2020 has set three goals: (1) To strengthen leadership in promising industrial technology, (2) to secure access to risk financing, and (3) to strengthen the innovation and support of SMEs. It also aims to promote science and technology through strengthening international cooperation by encouraging participation not only in EU member countries, but also in neighboring countries. By adhering to the principles of openness and encouraging cooperation with third country programs, Horizon 2020 is committed to cooperating with advanced, emerging, and developing countries, while simultaneously advancing technology development and comprehensive growth.

The budget analysis indicates that in the best science, the largest budget for the ERC is about € 13.2 billion. This role is judged as being important. It is predicted that high-end and value-added industries such as ICT and nano-technology will serve as a growth engine for the European economy, given that the industrial leadership has allocated the highest budget for LEITs (€13.3 billion). With a budget of approximately €77.7 billion, the “social challenge” aspect demonstrates the EU’s policy commitment to supporting the aging society through the development of health and healthcare services to prepare for the “health & wellbeing” segment. The total budget of social challenges for the “secure, clean & efficient energy,” “green & integrated transport,” and “climate, environment, and resource” segments is about €15.2 billion. These budgets are used in various programs and demonstrate the value of investment. For instance, EDCTP2, which refers to the European and Developing Countries Clinical Trials Partnership, aims to reduce the social and economic problems of developing countries such as poverty and disease through partnerships for the development of safety and medical technology. The European Metrology Program for Innovation and Research (EMPIR) is a joint research and innovation framework program among EU member countries. The Eurostars program aims to develop the research capacity and innovation of SMEs and improve their competitiveness through various promotion programs. Horizon 2020 includes the “active and assisted living” program to address the challenges of the aging society.

5. Conclusions

5.1. *Synthesis of the Findings*

The most significant features and implications of the Horizon 2020 policy are that it reconstructed existing science and technology policy research and led integration and implementation. The policy is delineated as “R & D of national competitiveness strengthened through national industrial technology re-vitalisation (industrial leadership)” and “social problem-solving R & D (social challenges)” to solve social problems. In addition, the cooperation sector other than R & D has been integrated into “excellent science” and clarifies further R & D cooperation. Based on the Lisbon strategy, a policy based on science and technology that integrates the research base, R & D, and commercialisation support has been expanded to demonstrate further policy features. This policy aims to induce SMEs to participate in solving social problems and technology development, which will strengthen linkages between industry and academia as well as strengthen support for innovation through the participation of international cooperation partners.

Horizon 2020 is a policy that fosters the innovation of science and technology in the EU, including the development of infrastructure and promising industrial technology, cultivation of human resources, and construction of infrastructure. This research summarised the four core policy implications. First, Horizon 2020 will not only create economic benefits for a single industry, but also synergies by generating ecosystems through mutual complementation among industries. Specifically, Horizon 2020 ensures competitiveness by pioneering and leading new industrial markets such as smart grids; artificial intelligence transportation systems through integrated communication; information technology; and competent automobile, energy, and chemical industries, which are representative technologies of Europe. In addition, it will facilitate research through industry-academia collaboration by securing unity in the technological innovation strategy; strengthening the linkage between policies; and presenting a concise fundraising model to promote R & D participation from universities, research institutions, industries, and SMEs. Second, Horizon 2020 could have a positive impact on solving social problems through science and technology by allocating the largest budget with a significant emphasis to solving social problems such as aging, climate change, and food problems facing the EU. The third is strengthening the participation of SMEs. Unlike the existing Framework Programme policy, Horizon 2020 focuses on strengthening the competitiveness of SMEs by including support items to promote their participation in all essential strategic items and by establishing a dedicated organisation to support them. Fourth, Horizon 2020 promotes knowledge sharing and diffusion through ERA expansion and strengthening collaboration with non-member countries. In addition to helping to

create a single market for knowledge-based research innovation, the ERA has been optimised for access to scientific knowledge through a concise R & D funding model that emphasises cooperation with non-EU countries. Moreover, international organisations are presented. Horizon 2020 is expected to support the EU technical innovation sector by supporting collaboration between public and private partnerships and public-private partnerships.

5.2. Expected Effects and Using the Plan in Non-EU Countries

The EU has been steadily developing its policies to reduce the gap in science and technology competitiveness with the United States and provide the best technology innovation. The Horizon 2020 convergent technology innovation policy, which integrates industry and academia, provides non-EU countries with many opportunities. This study introduced and analysed the EU's technology innovation policy, which is necessary for international technical cooperation between the EU and non-EU countries, science and technology research institutes, and enterprises. The EU recognises that it can strengthen its competitiveness through cooperation with both member and non-member countries. Recently, Horizon 2020 also actively supports international technical cooperation with non-EU member countries. The aim is to develop Horizon 2020 into a global program in which researchers worldwide can participate. In particular, the need to participate in Horizon 2020, which is about 60% larger than the previous policy, may be important for non-EU governments. However, the research and analysis of the EU's technology innovation policies have been weak. In addition, there is no cooperation network with EU laboratories.

Therefore, this study also aimed to provide general information highlighting that science and technology researchers in non-EU countries need to cooperate with the EU in international technology innovation. The characteristics of Horizon 2020, which quantitatively and qualitatively differs from FP7, are aligned with the requirements of policymakers and government agencies in non-EU countries, industry and academic research institutes and academia, and researchers interested in participating in the project. In the future, it will be necessary to investigate the difficulties and problems faced by non-EU companies and researchers in the implementation process through case studies. Furthermore, more advanced research should be conducted by analysing cases from neighbouring competitors such as Japan and Taiwan, which have recently been cooperating with the EU in many technological innovations.

Horizon 2020 is a strategy to promote mutual complementarity among industries and generate synergies by creating new industries and economic benefits. Efforts to create synergies through the integration of existing R & D policies are an important factor in this policy. Now, the science and technology policy in Europe is developing into a global program in which researchers worldwide from both EU and non-EU countries can participate. For Horizon 2020 to succeed, long-term efforts will be needed to establish cooperation and coordination between EU and non-EU countries, foster international cooperation experts, and build trust. Therefore, if non-EU research institutes and companies wish to implement international technical cooperation through Horizon 2020, designated programs and research topics should be addressed and partners prepared. Non-EU governments can lay out a policy consensus centered on Horizon 2020 based on its strategy for developing technological innovation policies with Europe. Non-EU members can select specific technical fields and propose research themes with each member country. Therefore, non-EU institutes are needed to utilise technology innovation systems and for R & D collaboration projects with the EU in the future for the development of enterprises and the country by establishing an international technology innovation system, infrastructure for international cooperation support, bipartite cooperation and coordination, and a cooperation roadmap.

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