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2016/17 Knowledge Sharing Program with Costa Rica:

Policy Consultation for Economic Development of Costa Rica: Focusing on Science and Technology Human Resources, National Transport System and Healthcare Industry

Ministry of Strategy and Finance

KDI Korea Development Institute

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Program Directors	Kwangeon Sul, Executive Director, Center for International Development (CID), KDI Siwook Lee, Professor of KDI School of Public Policy and Management, Former Executive Director, CID, KDI
Project Manager	Kwangeon Sul, Executive Director, CID, KDI
Project Officer	Jin Ha Yoo, Senior Research Associate, Division of Policy Consultation, CID, KDI
Senior Advisor	Sang-Seon Kim, Professor, Hanyang University
Principal Investigator	Kang Soo Kim, Vice President and Director of Department of Land Infrastructure Policy, KDI
Authors	Chapter 1. Kang Soo Kim, Vice President and Director of Department of Land and Infrastructure Policy, KDI Pedro Luis Castro Fernandez, President and General Manager, Consultoria e Ingenieria Civil de Centroamerica S.A Chapter 2. Jae Min Park, Professor Konkuk University Roberto Cruz Romero, Lead Project Researcher, University of Costa Rica Chapter 3. Joonmo Ahn, Professor, Sogang University Natalia Flores Sanchez, Independent Consultant Chapter 4. Jongyearn Lee, Professor, KDI School of Public Policy and Management Massimo Manzi, Executive Director, Council for the International Promotion of Costa Rica Medicine
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Preface

Knowledge is a pivotal driver of growth and the fruit of all endeavors dedicated to socio-economic development. Accordingly, knowledge sharing has become an essential tool in strengthening nations' capacity to design and execute policies and programs. On the global front, the UN is making efforts through its Sustainable Development Goals (SDGs) to underscore the role of both knowledge and knowledge sharing in tackling sustainable development issues and in establishing and enhancing global partnerships.

Indeed, knowledge laid the foundations for Korea's remarkable transformation from a poor agro-based economy into an industrialized nation with an open and democratic society. And the process, though arduous, has enabled Korea to accumulate invaluable and practical lessons not found in conventional textbooks. Now, as a global economic leader, Korea is working with the international development community and partner countries to identify key development challenges and solutions by sharing its tangible know-how and experience.

The Knowledge Sharing Program (KSP) was initiated in 2004 by the Ministry of Strategy and Finance (MOSF) and is implemented by Korea Development Institute (KDI). The program plays a vital role in further expanding knowledge sharing as well as in strengthening government partnerships with low to high income economies. As of this year, 940 research studies have been conducted with 59 partner countries. And in 2016, KSP policy consultations and capacity building workshops were organized with 28 partner countries including new partner countries such as Jordan and the Sub-Saharan Africa Partnership for Skills in Applied Sciences, Engineering and Technology (PASET).

The 2016/17 KSP with Costa Rica was undertaken by MOSF and the Ministry of Public Works and Transport (MOPT), Ministry of Science, Technology and Telecommunications (MICITT), Ministry of Foreign Trade (COMEX), Competitiveness Promotion Council (CPC) of the Republic of Costa Rica to support the "Economic Development of Costa Rica: focusing on the Science and Technology Human Resources, National Transport System and Healthcare Industry." To that end, KSP and Costa Rica engaged in a range of collaborative efforts including exchanging development experiences, conducting joint studies, and designing a policy action plan in line with the country's development targets.

It is with great optimism for the future Costa Rica that the results of the 2016/17 KSP are presented. I firmly believe that KSP will serve as a stepping stone to further elevate the mutual learning and economic cooperation between both our countries, and hope it will positively impact Costa Rica's attainment of its goals for sustainable development.

I wish to convey my sincere gratitude to Senior Advisor Dr. Sang Seon Kim, Principal Investigator Dr. Kang Soo Kim as well as project consultants Prof. Jae Min Park, Prof. Joonmo Ahn and Prof. Jongyearn Lee for their extensive contributions. I am also grateful to Executive Director and Project Manager Dr. Kwangeon Sul, Project Officer Ms. Jin Ha Yoo and all members of the Center for International Development (CID) for their hard work and dedication to this program. Lastly, I extend my warmest thanks to the Costa Rican collaborates, MOPT, MICITT, COMEX, CPC and related agencies, project coordinators, and participants for their steadfast effort and support.

Joon-Kyung Kim
President
Korea Development Institute (KDI)

Contents

Chapter 3

STEAM Education for S&T HRD and Policy Suggestions for Costa Rica

Contents

Contents | List of Tables

Contents | List of Tables

Contents | List of Figures

Chapter 1

Chapter 2

Contents | List of Figures

Contents | Box

2016/17 KSP with Costa Rica

Jin Ha Yoo (Project Officer, Korea Development Institute)

Since 2004, the Ministry of Strategy and Finance (MOSF) of the Republic of Korea in collaboration with the Korea Development Institute (KDI) has been implementing the Knowledge Sharing Program (KSP). The KSP is a knowledge-intensive economic cooperation program designed to share Korea's development experience with partner countries. The KSP with Costa Rica was first launched in 2013 and has covered over 12 consultation projects ranging from science and technology to national transportation system.

For the fourth year of cooperation, the project focused on four topics under the main theme of "Policy Consultation for the Economic Development of Costa Rica: Focusing on Science and Technology Human Resources, National Transportation System and the Healthcare Industry." These topics were selected through in-depth consideration of the written demand survey submitted by the Costa Rican governments to promote sustainable economic growth of the nation. The following topics and respected Korean researchers with specialty in the fields were chosen to address the challenges that Costa Rica face in the sectors. Also, Costa Rican experts were selected as local consultants to enrich the research analyzing the current status of Costa Rica. With joint efforts, researchers were able to suggest practical and meaningful recommendations to partner organizations.

2016/17 KSP with Costa Rica: Topics and Researchers				
No.	Consultation Topics	Partner Organizations	Korean Researchers	Costa Rican Consultants
1	Development of national DB center for transportation planning	Ministry of Public Works and Transport (MOPT)	Kang Soo Kim (KDI)	Pedro Luis Castro Fernandez(Consultoria e Ingenieria Civil de Centroamerica S.A)
2	Long-term employment projections and human resource planning for S&T R&D personnel of Costa Rica	Ministry of Science, Technology and Telecommunications (MICITT)	Jae Min Park (Konkuk University)	Roberto Cruz Romero (University of Costa Rica)
3	STEAM education for S&T human resource development and policy suggestions for Costa Rica		Joonmo Ahn (Sogang University)	Natalia Flores Sanchez (Independent consultant)
4	Enhancing capacity of Costa Rica's healthcare industry for strengthening globalization and fostering regional economy	Ministry of Foreign Trade (COMEX), Competitiveness Promotion Council (CPC)	Jongyearn Lee (KDI School of Public Policy and Management)	Massimo Manzi (Council for International Promotion of Costa Rica Medicine)
Senior Advisor: Sang-Seon Kim (Hanyang University) Principal Investigator: Kang Soo Kim (KDI) Project Manager: Kwangeon Sul (KDI) Project Officer: Jin Ha Yoo (KDI)				

For the first stage of the 2016/17 KSP with Costa Rica, the High-level Demand Survey and Pilot Study (August 20-27, 2016) was conducted to identify and survey policy priorities on the selected research topics and discuss the procedure of the project. The Korean delegation, headed by Senior Advisor Sang-Seon Kim, visited San Jose to participate on the Kick-off Seminar and High-level Meetings to discuss the Costa Rican government's main challenges and pressing issues related to the topic. Consequently, meetings were held with relevant ministries, institutions and personnel to examine current environment and collect the necessary information and data.

The Korean delegation visited Costa Rica for the second time from October 16 -24 2016 for the Local Reporting Workshop and Additional Pilot Study. Korean researchers aimed to share and review their findings with partner organizations. They also held dialogues with relevant organizations and experts to collect data and gain a comprehensive understanding of the demands and needs of the given topic. During the visit, all Korean researchers selected local consultants to take part in the research as experts in Costa Rica.

For the next cycle, the Costa Rican delegation, headed by Deputy Minister of Science, Technology and Telecommunications Carolina Vasquez, visited Korea to attend the Interim Reporting Workshop and Policy Practitioners' Workshop from January 15th to 21st 2017. During the Interim Reporting Workshop, the Korean delegation and Costa Rican consultants shared the interim results of their research, and all participants had a rigorous discussion to enhance the quality of policy recommendations. For the Policy Practitioners' Workshop, the delegation visited institutions related to four consultation topics including Ministry of Land, Infrastructure and Transport (MOLIT), Korea Employment Information Service (KEIS), Korea Advanced Institute of Science and Technology (KAIST), and Korea Tourism Organization (KTO) to gain first-hand experience of the nation's development experience.

For the final stage of the 2016/17 KSP with Costa Rica, the Korean delegation headed by Senior Advisor Kim, visited San Jose for the Final Reporting Workshop and Senior Policy Dialogue. The workshop was held on February 22nd to share the research results with relevant ministries, agencies and other stakeholders. Ministers of each partner organizations attended the event. The Senior Policy Dialogue was held separately by each partner organization, and the Korean researchers presented their policy recommendations and discussed further applications and implications of their findings.

Executive Summary

Kang Soo Kim (Korea Development Institute)

Economic growth and public investment are closely interrelated. Public investment that is both properly managed and selected can raise national competitiveness by enhancing productivity and innovation capacity. Costa Rica's infrastructure has suffered from insufficient and ineffective public investment, and its government is aware of this shortfall, especially in transportation infrastructure, R&D and the service sector.

The Costa Rican government is striving to build an innovation-oriented country via investment in S&T human resource development as well as a transportation database of higher consistency and reliability to enhance the efficiency of transportation investment. Furthermore, government officials seek to spur economic growth by linking the country's well-developed medical device industry to the growing medical services sector. This is expected to enhance successful outward-oriented development, which has been attracting FDI.

The four topics of 2016/17 KSP with Costa Rica were selected based on the identification of Costa Rica's needs and are closely related to the aforementioned policies. The four are (i) Development of National DB Center for Transport Planning, (ii) Long-term Employment Projections and Manpower Planning for Research Personnel in Science and Technology and Costa Rica, (iii) STEAM Education for S&T HRD and Policy Suggestions for Costa Rica, (iv) Enhancing Capacities of Healthcare Industry in Costa Rica for Strengthening Globalization and Fostering Regional Economy. The main content of and recommendations for each topic are as follows:

1. Development of National DB Center for Transport Planning

This chapter will suggest policy recommendations to make Costa Rica's transportation database (DB) more efficient, consistent and reliable. Consequently, it will provide suggestions for developing a DB center for transportation planning based on lessons from the Korean development model. Based on the diagnostic study on Costa Rica's transportation DB and lessons from the Korean experience, the following policy recommendations were devised:

• Need for National Transportation DB Commission

The planning and decision-making processes for transportation infrastructure in Costa Rica are highly fragmented among government institutions. Numerous bodies take part in transportation infrastructure planning and this leads to excessive policy fragmentation and uncertainty of implementation of transportation projects. To overcome these problems and enhance coherency in transportation DB policy, a national transportation DB commission is needed under an executive order or jurisdiction of the Costa Rican Ministry of Public Works and Transportation (MOPT).

• Establishment of National Transport DB Center

To overcome institutional fragmentation and improve expertise for the development of a transportation DB, an agency or unit for this specific purpose is needed. The envisioned center will ensure a more effective and reliable transportation DB and better articulate transportation planning mandates. The prime location for the center is within the Secretary of Sectorial Planning of the Costa Rican Ministry of Public Transportation. The secretary has been active in data collection and works as a liaison with the Costa Rican Ministry of Planning for the execution of the National Transportation Plan. The secretary also has many pre-investment feasibility reports, agreements and prioritization of projects.

The center should be a politically objective supplier of accurate and statistically sound data used to support decision making for transportation planning. It should act as a gateway to all transportation data and provide assistance to relevant institutions in planning. Furthermore, it must provide technical assistance for the collection and analysis of the transportation DB.

In addition, the DB center should come up with useful indicators that meet international standards and provide a reliable and statistically sound DB used to support decision making in transportation planning.

• Formation of Solid Legal and Regulatory Framework

To effectively introduce and develop a transportation DB system, corresponding regulatory and institutional DBs need to be prepared. The first priority in the transportation DB's development is enactment of a relevant law for implementation. The law should stipulate well-defined institutional arrangements detailing the roles and responsibilities of main participants since many ministries and institutions in transportation and infrastructure are involved in the development of the transportation DB.

• Improvement of Decision-making Process in Transportation Planning

A reliable and consistent transportation DB will raise the speed and transparency of project prioritization and selection, as well as enhance the efficiency and credibility of transportation planning. The DB will also strengthen accountability in transportation planning with the public. An effective and efficient decision-making process boosts transportation investment productivity, and the developed transportation DB will serve as a good instrument to set the process through consistency and improving accuracy across evaluated projects. The Secretary of Sectorial Planning with the National Transportation DB Center should have the sole authority to supervise the appraisal and selection of investment projects and create a system for managing transportation investment with the development of the transportation DB.

2. Long-term Employment Projections and Manpower Planning for Research Personnel in Science and Technology of Costa Rica

This chapter seeks to assess Costa Rica's science and engineering human resources to improve the country's capacity to nurture them and forecast the supply and demand of S&T R&D personnel to make policy recommendations to Costa Rica.

Demand is analyzed by examining the status of researchers employed in a number of sectors, with previous trends and productivity considered. The number of researchers required in each R&D sector is computed using sectoral output, R&D investment and research productivity. The overall number of researchers is computed by projecting future R&D spending, sometimes by extrapolating the previous level of sectoral R&D, and multiplying the employment coefficient, which is the reciprocal of labor productivity. The next step is to estimate the demand based on the R&D personnel projection derived from the employment coefficients in Costa Rica (2010-20). Demand can be divided into that of expansion and replacement. The former is the difference between the two points in the R&D personnel projection shown above. The latter refers to demand incurred by an incumbent to replace his or her position due to retirement because of old age or transfer to a business or other occupation. The assumption is that the annual average of 4 percent will be eliminated. The two demand types were summed up to yield recruitment (total) demand.

Supply forecasting begins with consideration of trends in sociodemographics and labor market participation. The gross birth rate has declined and the annual death rate is expected to increase. Given both trends, educational enrollment at the tertiary level is assumed to be stable. Graduates from 2015–20 for each sub-field are estimated using STEM graduates in Costa Rica by sub-field from 2000-14. The next step is to convert supply forecasts by municipality into those by degree. Ideally, this step should look at the degree structure by major. Based on these ratios and the overall number of STEM graduates, the graduates from 2015–20 for each degree were yielded. The final step was to compare recruitment demand and number of graduates given above as supply.

As a tentative analysis, supply and demand of STEM fields graduates are projected for the 2015–20 period. Overall, the number of STEM doctorate holders in Costa Rica is expected to significantly constrain the effective implementation of research needs by 2020. If researchers simply mean PhD holders, a considerable shortage in the near future can be expected. The number of researchers is expected to see no significant change, going from 290 in 2015 to 281 in 2020, with demand for 1,748 seen over this period. Yet the number of doctorate holders is expected to reach just 450 over the same timeframe. On the other hand, if the required qualification for a researcher can meet with a master's degree, the supply could be considered sufficient at least in quantity.

The supply of doctoral candidates is also insufficient to perform stable R&D in Costa Rica. Demand for them is estimated at 422 in 2015–20 and rising. Assuming a dissertation preparation period of three years after a doctoral student has completed the final qualification exam and proposal process, and assuming that two-thirds of them graduate, 900 doctoral candidates can be estimated. When comparing these two figures, supply is about double the demand.

In conclusion, the supply of STEM doctorates in Costa Rica is expected to greatly hamper effective research needs by 2020. The supply of doctoral candidates is also expected to be insufficient to perform stable R&D in Costa Rica. Bigger concern is that the supply-and-demand gap will worsen if analysis is conducted at sub-major levels, even if aggregate supply and demand seem fairly balanced.

3. STEAM Education for S&T HRD and Policy Suggestions for Costa Rica

This chapter aims to suggest short-, mid- and long-term policy recommendations based on the Korean experience in STEM and STEAM education. As indicated in the OECD's PISA results, Costa Rica has one of the world's smallest gaps between the top and bottom 10 percent. This implies a good system of universal education and successful implementation of the Costa Rican Constitution's values. Yet the country's science and math score was lower than the OECD average and even those of other Latin American countries. This suggests that Costa Rica must enhance the quality of its STEAM education.

The results of semi-structured interviews and document analyses suggest obstacles and challenges for STEAM education in Costa Rica. First, many interviewees mentioned problems in "teacher quality" caused by a vicious cycle of quality gap between public and private universities and ineffective teacher recruiting and training. Second, science, technology, engineering and math are not correlated into one group in the Costa Rican educational system, making it difficult to introduce STEAM education there. Third, no special track exists for gifted and talented students. Costa Rica has science high schools that effectively select elite students and provides a high quality education, but the problem is keeping such students in science and technology. Fourth, improvement of STEAM capability in female students is a priority. The gender imbalance in STEM performance is serious and can cause gender disparity and issues in STEM jobs. Fifth, because of Costa Rica's industrial structure and teaching-oriented universities, demand for high-level S&T human resources from academia and industry is insubstantial.

Korea's STEAM policy comprises five key agenda items: (1) incubation of leading groups, (2) empowerment of teachers, (3) dissemination of content, (4) hands-on inquiries by students and (5) systematization of infrastructure. In addition, as an excellence track, the Korean government established the Korea Advanced Institute of Science and Technology (KAIST), a university specializing in science and technology, under a special law as well as science high schools. To build a talented human resource pipeline, students at such high schools are encouraged to apply to KAIST through incentives such as early graduation and free tuition.

This report proposes STEAM education as a priority goal for Costa Rica, and considering its situation, the nation must enhance its STEAM capability and set the foundation for achieving multidisciplinary integration. The policy recommendations presented here are comprised of six items: excellency track, leader groups, teachers, content, hands-on experience, infrastructure and timeline. All six are considered to distinguish short, mid- and long-term policies. The following are suggested as policy recommendations.

- Hands-on experience: Costa Rica's university community work (UCW) program should be reformed into "STEAM with university student," and STEAM outreach should be initiated with help from CONARE national lab and public universities. Content: In addition to the regular curriculum, STEAM supplementary content should be developed and distributed.
- Teacher training: Online training content of KOFAC can be implemented by IDP or UNED and advanced offline training is needed to enhance the quality of training.
- Fostering leader groups: Support for a STEAM teacher research society is needed to promote teacher development from the bottom up, not to mention designation of STEAM leader schools that can play a regional hub role in STEAM education.
- Excellence track: Strong incentives are needed such as a special university admission system (e.g., exemption of entrance exams for top students) or scholarships. Over the mid to long term, technical education centers (TECs) and/or national technological universities (UTNs) need to be transformed into science-oriented universities governed by a special law (i.e., the KAIST model). Once TECs (and/or UTNs) are converted per the KAIST model, an excellence track from STEAM leader or science high schools to TECs, will be completed.
- Infrastructure: STEAM-support institutions like the Costa Rican Foundation for Advancement for Science and Creativity (COFAC) and the National Science Museum are highly recommended. The alleviation of the gender imbalance in STEM students is also a priority.

4. Enhancing Capacities of Healthcare Industry in Costa Rica for Strengthening Globalization and Fostering Regional Economy

This chapter assesses Costa Rica's healthcare industry to identify and resolve challenges. In medical technology, the issues are relatively weak small and medium enterprises (SMEs) compared to multinationals, mismatch between supply of skilled labor and production structure needs, and the gap between the capital and provincial areas. The medical and wellness tourism (MWT) sector lacks collaborative public policy and international marketing plan. Overall, this chapter attempts to answer the following questions in two categories: (1) how to link segmented domains and (2) how to narrow the gaps to achieve balanced development.

In medical technology, Korea's masterplan for linking specialized clusters that are regionally allocated is introduced to provide a long-term outlook. As the main content, a case study of a cluster specialized in medical devices is analyzed in depth, namely the Wonju Medical Industry Techno Valley (WMIT). This exemplary model shows that government support can effectively help spontaneous efforts in the private sector. WMIT's success is due to seven factors: (1) collaboration between a think tank (area university) and local government; (2) consistent support independent of change in leadership (local government); (3) full support from the central government; (4) timely supply of facilities to new and potential tenant companies; (5) overcoming of resident opposition; (6) steady expansion of production base; and (7) easy access to skilled labor. Additionally, a privately led incubating model for startups is supervised by the Korean Small and Medium Business Administration (SMBA) namely the Tech Incubator Program for Startup (TIPS). The program seeks to foster high-tech startups and create jobs. Finally, the masterplan suggests building a cluster specialized in medical devices for domestic SMEs based on lessons from the Korean experience. In so doing, the Costa Rican government needs to focus on four key recommendations. The first is the need for a strategic location. In the interest of balanced regional development, the Costa Rican government should carefully consider labor supply (high schools and universities), proximity to highways, ports and airports, and access to multinational corporations (e.g., those manufacturing in the COYOL Free Trade Zone), to name a few. The second recommendation is clear definition of the division of labor among industry, academia, research bodies and government. For example, provincial S&T universities such as Costa Rica Institute of Technology (TEC) and think tanks like the National Center for Biotechnology Innovations (CENIBiot) can play a significant role from the inception stage. The third recommendation is for the private sector to maximize its creativity and efficiency. So the government must make stakeholders actively engaged rather than adhering to a top-down approach solely driven by itself. And the fourth recommendation is that policy sometimes must be bold and the government must be patient. Since a technology-oriented system evolves amid uncertain circumstances, performance can see volatility over time.

In MWT, Korea has a short policy history. Since the medical service sector is non-profit per se under law, advertising and promotions to attract patients are generally not allowed. To promote medical tourism, however, the Korean government and legislature amended the Medical Service Act in January 2009 to allow medical institutions to woo foreign patients. In May 2009, the Ministry of Justice of the Republic of Korea started to issue medical tourism visas and the Ministry of Health and Welfare of the Republic of Korea began to require that medical institutions and coordinators be registered for quality control purposes. To institutionalize MWT formally, the Act on Support for Overseas Expansion of the Healthcare System and Attraction of International Patients was enacted in June 2016. Under this law, medical institutions and coordinators are designated and evaluated annually, their medical expenses and fees are monitored, and they must be insured against medical accidents. Moreover, the central government introduced several other support measures including (1) assistance for upgrading leading medical institutions in other regions (e.g., region-specific technological R&D, promotion and infrastructure): (2) projects for streamlining MWT (e.g., international marketing, infrastructure and online platforms); (3) designation of special zones for MWT (e.g., infrastructure, marketing, health food and networking); (4) refunds of value-added taxes for cosmetic services; and (5) collaboration for more effective support (e.g., forming public-private MWT association co-chaired by director generals of the Ministry of Health and Welfare and Ministry of Culture, Sports and Tourism of the Republic of Korea). Government-affiliated agencies also implement support activities in the sector. First, Korea Healthcare Industry Development Institute (KHIDI) supervises the registration of medical institutions and coordinators, collects and manages data for attracting foreign patients, and publishes reports on domestic and international trends. Second, Korea Tourism Organization (KTO) of the Republic of Korea hosts the Korea International Medical Tourism Convention (KIMTC), promotes MWT within the country to influential international media and celebrities, develops MWT products and operates medical tourism information centers.

The policy suggestions for MWT that can be adopted over the short term are: (1) forming an inter-governmental collaborative organization accommodating agencies and industry; (2) collecting and managing related data; (3) developing an online platform for promotion; and (4) supporting medical institutions for consultation in hospital management including promotion, specialization, service upgrading and improvement of cost-effectiveness. Those achievable over the midterm are (5) providing the institutional foundation for MWT by amending and/or enacting laws and (6) introducing incentives for market stimulation in accordance with law. These are suggested as mid-term tasks not because they are unnecessary immediately but because time is needed for implementation. And over the mid- to long term, the Costa Rican government should consider (7) developing public-private partnerships (PPP) that integrate medical institutions and recreational facilities such as hotels, resorts and eco-parks.

Chapter 1

Development of National DB Center for Transport Planning

Development of National DB Center for Transport Planning

Kang Soo Kim (Korea Development Institute)
Pedro Luis Castro Fernandez (Consultoria e Ingenieria Civil de Centroamerica S.A.)

Summary

This chapter will suggest policy recommendations to make Costa Rica's transportation database more efficient, consistent and reliable. Consequently, the authors will propose suggestions to development DB center for transportation planning based on lessons from the Korean experience. These suggestions are provided base on a diagnostic study on Costa Rica's transportation DB and lessons from the Korean development model.

A. Foundation of National Transport DB Commission

The planning and decision-making processes for transportation infrastructure are highly fragmented among government institutions in Costa Rica. Numerous institutions take part in transportation infrastructure planning, and this leads to excessive policy fragmentation and uncertainty in transportation project implementation.

To overcome fragmentation and raise the coherence of transportation DB policy, a “commission for a national transportation DB” is recommended to be set up under an executive order or the jurisdiction of the Costa Rican Ministry of Public Works and Transportation.

B. Setup of National Transportation DB Center

To overcome institutional fragmentation and raise the specialty for transportation DB development, an agency or unit for this specific purpose is needed. The envisioned center will contribute to a more effective and reliable transportation DB and could better articulate transportation planning mandates.

The prime location for the center is within the Secretary of Sectorial Planning of the MOPT. The secretary has long been active in data collection and works as a liaison with the Ministry of Planning for the execution of the National Transportation Plan. The secretary also has many pre-investment feasibility reports, agreements and project prioritization.

The center should be a politically objective supplier of reliable and statistically sound information used to support decision making in transportation planning. It should also be a gateway to all transportation data and serve as a helpline for each institution in planning. Furthermore, it needs to provide technical assistance for data collection and analysis by the transportation DB.

In addition, the center should produce leading indicators that meet international standards and provide a reliable and statistically sound database used to support decision making in transportation planning.

C. Formation of Solid Legal and Regulatory Framework

To effectively introduce and develop a transportation DB system, corresponding regulatory and institutional DBs need to be prepared. The first priority in the development of the transportation DB is a law enacted specifically for implementation. The law should stipulate well-defined institutional arrangements detailing the roles and responsibilities of main participants since many Costa Rican ministries and institutions in transportation and infrastructure are involved in the development of the transportation DB.

D. Improvement of Decision-making Process for Transport Planning

A reliable and consistent transportation DB will raise the speed and transparency of project prioritization and selection, and enhance the efficiency and credibility of transportation planning. The DB will also strengthen accountability of such planning with the public

An effective and efficient decision-making process boosts transportation investment productivity, and a developed DB is a good instrument to establish the process through consistency and improved accuracy across evaluated projects. The Secretary of Sectorial Planning with the National Transportation DB Center should have the sole authority to oversee the appraisal and selection of investment projects and strive to set up a so-called ”transportation investment management system” through the development of the DB.

1. Introduction

Transportation investment promotes and brings about positive effects on economic growth and social welfare. Done properly, it can trigger higher growth, productivity and long–term national development. The Costa Rican government fully recognizes the importance of such investment and is aware of the shortfall in its transportation infrastructure spending. It is thus seeking to raise such investment by devising the National Transportation Plan 2011–35 (MOPT, 2011) and boosting annual spending on transportation investment to 3.7 percent of GDP by 2035.

Yet transportation investment productivity depends on the effectiveness and efficiency of related planning. Thus ways of project selection and prioritization and a reliable and consistent (standardized) transportation DB are required to enhance the efficiency and effectiveness of transportation planning.

This chapter will suggest policy recommendations to make Costa Rica’s transportation DB more efficient, consistent and reliable, as well as suggest the formation of a transportation DB center based on Korea’s experience. This study first conducted a diagnostic study on the status of Costa Rica’s transportation infrastructure and DB and presented legal and institutional issues to consider when setting up the center through documents and on-site interviews with government officials and stakeholders. Then a case study was done on the Korean experience to offer Costa Rica a benchmark. Good practices and lessons from Korean case studies are provided vis-a-vis the legal and institutional framework and the DB center’s functions and roles are suggested. Law provisions, standards and guidelines for transportation planning, and coordination with other transportation agencies are highlighted. Finally, policy recommendations are offered to implement key priority activities for the development of the DB center as a leading source of timely, accurate and reliable information on Costa Rica’s transportation systems.

2. Current Situation on the Transport Database in Costa Rica

This section will diagnose how data is collected and handled to make decisions on transportation planning within the Costa Rican transportation sector. First is the status of the country's transportation infrastructure.

2.1. A Bird-eye View on Transport Infrastructure

Investment in transportation infrastructure in Costa Rica is close to 1 percent of gross domestic product (GDP). Between 2008 and 2009, however, many important roads were built such as the new road from San José to the Port of Caldera (Pacific shore) and the Pacific shore border road that had been needed for many years. In 2014-15, many other important projects in transportation infrastructure were implemented, including a new port at the Caribbean shore and many road projects funded by InterAmerican Development Bank (IADB) and the Bank of Central American Integration (CABEI).

<Table 1-1> shows transportation investment in Costa Rica over the last ten years. Investment in infrastructure has never reached 4 percent of GDP, which is considered essential to make up for the many years of no investment in infrastructure. Such investment should reach 6 percent of GDP by 2018 based on the National Transportation Plan approved by the MOPT.

〈Table 1-1〉 Investment in Costa Rica's Transportation Infrastructure

Year	Investment (billion colones)	Percent of GDP (%)
2006	59.4	0.52
2007	120.8	0.89
2008	237.0	1.51
2009	327.3	1.94
2010	225.0	1.18
2011	194.3	0.94
2012	225.0	0.99
2013	230.0	0.95
2014	307.4	1.15
2015	368.5	1.31

Note: The exchange rate used was 560 colones per US dollar.
Source: Ministry of Public Works and Transportation, Anuario Estadístico del Sector Transporte e Infraestructura 2015, 2016.

The national road network spans 7,786 kilometers, whereas the rural road network spans 35,496 kilometers. So Costa Rica has an extensive road system at 0.85 kilometer per each square kilometer of land. Consequently, most transportation is done by road, as sea and air transportation focus on external trade. This explains why there is a car for every 4.5 people. As road transportation is by far the preferred and most common transportation mode,[1)] 65.5 percent of investment in transportation infrastructure in 2015 went to roads, whereas only 22.3 percent went to ports, 11.2 percent to airports and just 0.7 percent to trains.

Investment in roads fails to match the condition of Costa Rica's road network. Foreign loans are funding the building of new roads, while most of the network needs rehabilitation or even reconstruction. Of 7,786 kilometers in the national road network, just 4.5 percent is in good or very good condition (based on roughness measurements), 33.4 percent is in regular shape and 62.1 percent is in bad or very bad shape. Of the 35,496 kilometers in the rural road network, 43 percent is in bad or very bad shape.

Costa Rica's number of traffic fatalities is increasing, with 8.3 of every 100,000 people in the country dying in road accidents. The number of traffic fatalities hit a low in 2011 of 289. Afterwards, however, the number increased slowly for a few years, but it reached 359 in 2014 and 398 in 2015. So the pace of growth has sped up over the last few years.

In cargo transportation, statistics show that 1.2 million tons were sent out of the country by land in 2015, whereas 800,000 tons were brought in. Costa Rica's northern border with Nicaragua saw more activity in international trade via roads than its southern border with Panama. Seventy percent of exports were sent through the northern border, whereas 30 percent were sent via the southern border. For imports, 92 percent was brought in through the northern border, whereas only 8 percent came from the southern border. Air transportation is more important for cargo in Costa Rica, as 75 million tons were moved through Juan Santamaría International Airport in 2015. Sea transportation placed second in moving cargo, as the country's ports moved 15 million tons in 2015. Off-course cargo is moved from production units to ports and airports by land only, with few exceptions such as small railroad operations for banana production on the Caribbean shore.

In passenger transportation, 3.7 million people in Costa Rica took the train in 2015, whereas 4.5 million flew. The number of railroad users has increased each year since 2007; that of air passengers arriving in Costa Rica fell between 2012 and 2014 but rose again in 2015.

1) Mode implies means of transportation used for a trip and a trip implies a one-way journey from one place to another.

2.2. Public Institutions in Transport Sector

The Ministry of Public Works and Transportation (MOPT) is Costa Rica's main institution for transportation planning and policy. The MOPT has historically been in charge of project implementation, building, maintenance and operation of transportation infrastructure. Over the last 45 years, however, the ministry has been divided into new institutions, with a few always being autonomous though part of the transportation and infrastructure sector.

A series of institutions have been formed to undertake the MOPT's functions. The national road network is the responsibility of *National Roads Council* (CONAVI)*, Road Safety Council* (CONSEVI)*, National Concession Council* (CNC); *Public Transportation Council* (CTP) for public transportation and airspace administration *Directorate General of Civil Aviation*. Apart from these five, two autonomous institutions handle ports. *Port Management and Economic Development Board of the Atlantic Coast (JAPDEVA)* is in charge of ports on the Caribbean shore and *Costa Rican Institute for Pacific Ports* (INCOP) supervises ports on the Pacific shore. In addition, a relatively new institution runs rail transportation: *National Railway Institute* (INCOFER).

The five institutions have taken over several tasks performed by the MOPT in the past. The autonomous bodies, however, were created to develop specific fields and areas.[2)] JAPDEVA was formed not only to operate the main ports on the Caribbean shore (Moín and Limón), but also to build infrastructure throughout the Caribbean province of Limón to ensure that earnings from port operations are invested in roads, schools and other infrastructure. INCOP was assigned to operate the ports on the Pacific shore, but when Puerto Caldera´s operations were partly privatized as a concession, INCOP was also appointed as the competent authority. Finally, INCOFER was created to build and operate railroads, but is a weak institution since railroads did not operate for nearly 10 years. The recovery of many tracks has led to passenger services in the most important cities in the Central Valley region, and with a few tracks on the Caribbean shore, the railway is used to carry cargo freight.

Another difference between the five institutions and the three autonomous ones is that the former group is headed by a board of directors appointed by the MOPT chief and whose president is the minister or a deputy minister.[3)] The port and railroad institutions have independent boards appointed by their respective presidents.

2) The MOPT has responsibilities related to various transportation activities including issuance of the National Transportation Plan. It still supervises highway patrol, transit engineering, public works machinery and personnel affairs. It also manage loans to finance infrastructure.

3) They enjoy a degree of independence from the MOPT, but the minister is the main link to the institutions. He or she chairs the institutions or can appoint a deputy minister to chair any institution on behalf of the minister. The highest-ranking officials in the institutions are called executive directors or executive secretaries.

〈Table 1-2〉 Key Public Institutions in Costa Rica's Transportation Sector

Name	Year of Inception	Institution Type	Main Tasks
Ministry of Public Works and Transportation (Ministerio de Obras Públicas y Transportes, MOPT)	1860	Ministry	Supports minister as sector head; still supervises highway patrol, transit engineering, public works machinery and personnel affairs; also handles loans to build infrastructure
National Roads Council (Consejo Nacional de Vialidad, CONAVI)	1998	Authority	Designs and builds new roads, conducts road maintenance and handles emergencies; everything related to National Road Network
Public Transportation Council (Consejo de Transporte Público, CTP)	1999	Authority	Manages bus route concessions and other means of public transportation such as taxis
National Concession Council (Consejo Nacional de Concesiones, CNC)	1998	Authority	Bids for and manages concessions for everything, not only roads
Road Safety Council (Consejo de Seguridad Vial, CONSEVI)	1979	Authority	Devises policy and offers education on road safety; finances projects for road safety (such pedestrian crossings)
Directorate General of Civil Aviation (Dirección General de Aviación Civil, DGAC)	1973	Authority	Manages airport concessions and policy toward air transportation
Port Management and Economic Development Board of the Atlantic Coast (Junta de Administración Portuaria y de Desarrollo de la Vertiente Atlántica, JAPDEVA)	1963	Autonomous institution	Runs all Caribbean port operations and conducts development projects such as road construction and maintenance; everything related to Caribbean shore.
Costa Rican Institute for Pacific Ports (Instituto Costarricense de Puertos del Pacífico, INCOP)	1953	Autonomous	Manages port concessions on Pacific shore (main port handled by private company) and runs select small ports
National Railway Institute (Instituto Costarricense de Ferrocarriles, INCOFER)	1958	Autonomous	Operates all passenger (Central Valley) and cargo (Caribbean shore) railroads in Costa Rica

Source: Survey and Written by the Authors.

In giving instructions to institutions in the sector, the MOPT chief has the authority to issue the instructions by signing together with the Costa Rican President.[4)] By co-signing an executive command, such an order can be sent to institutions that must follow. That way, the MOPT can lead the process of data collection, processing and decision making for transportation planning. Yet one or several institutions could question such instructions and thus might delay the process of building the transportation DB.

2.3. Transport Database

This section describes the status of Costa Rica's transportation DB and presents the results of a survey done in Costa Rica; the study is based on interviews with technicians from the MOPT and institutions in transportation and infrastructure.[5)] The survey was done at all institutions to ensure that field research covered all users who might eventually benefit from the country's transportation DB.

The Annex presents a summary of the findings from the interviews and contains more details. All interviews were done between October 28 and November 8, 2016, with the exception of that with COSEVI officials conducted on November 23, 2016.

2.3.1. Types of Data

In Costa Rica, an institution´s annual budget requires certain objectives and a minimum level of goals must be achieved. Under law, all institutions must keep informing select public institutions that monitor goal fulfillment and budget execution. Normally, all institutions are required to submit a report every six months to show their performances in goal fulfillment and budget execution. The report must be sent to Office of the Comptroller General of the Republic (*Contraloría General de la Republica,* CGR), Technical Secretariat of the Budgetary Authority (*Secretaría Técnica de la Autoridad Presupuestaria,* STAP), Ministry of Planning (*Ministerio de Planificación,* MIDEPLAN), and in certain cases Public Services Regulatory Authority (certaincases *Autoridad Reguladora de Servicios Públicos,* ARESEP). Institutions in the transportation sector must send their indicators to the Secretary of Sectorial Planning at the MOPT, which also uses such information to publish an annual report of the sector's performance.

4) In Costa Rica, the executive branch, which consists of the President, vice presidents and ministers, can issue orders to the country's institutions. An order is signed by both the President and a minister who acts as the head of a given sector. So an executive order is a valid instrument for the executive branch to give instructions to every institution, provided that it does not violate the law; an executive order can also be a way to organize the DB center in stating each institution´s responsibility.

5) Institutions include the MOPT, CONAVI, CNC, CTP, CONSEVI, DGAC, INCOFER, INCOP, and JAPDEVA.

Examples of goals from the national development plan include the CTP's duty to rearrange bus transportation in a given area so that fewer buses enter San Jose daily; CNC's target for lowering the number of accidents in San Jose – Caldera (concession) and CONAVI's responsibility to build a set number of roads and bridges every year.

Each institution has other indicators that they are free to collect. Port authorities and the railroad institution often collect data on occupancy and/or operations, such as the number of passengers and volume of cargo moved.

Most institutions say they do not collect enough information, so recommend that new indicators are developed. Planning officials say the institutions in the sector fail to collect sufficient strategic information that could help develop project lists. INCOP and CTP are the only two that believe they collect enough data; all others think they should develop more indicators.

Extremely limited information comes from other institutions, with the exception of pavement distress indicators, such as the international roughness index and falling weight deflections. They are collected by the University of Costa Rica every two years and sent to the MOPT.

Apart from goal fulfillment, data is rarely sent to other institutions. A third party can ask for information but this is just for special projects or general knowledge. Nevertheless, the MOPT publishes annual statistics and information on transportation.

2.3.2. Data Utilization

Planning is a crucial task in all Costa Rican public institutions. Each must follow a national plan approved every four years and define the goals to be achieved.

The MOPT supervises the fulfillment of in transportation goals and the Secretary of Sectorial Planning helps the minister monitor this process, but all institutions still must report all progress to the Ministry of Planning.

Broad differences have been found among units that do planning within the institutions surveyed. Most institutions have a particular department or direction to gather all data with the exception of COSEVI, which has a planning department devoted to goal fulfillment. Yet big differences in size are seen, from 70 people at the Secretary of Sectorial Planning to just a few in most institutions such as INCOFER, JAPDEVA, INCOP and CTP.[6)]

6) COSEVI has two departments for planning: the planning department that mainly follows up goal achievement and the project division that collects and processes data.

Despite their size, certain institutions have managers in planning, whereas bigger institutions like the MOPT have a director. Thus rank does not match the entity's size, which could cause directors and chiefs to lose motivation as lower-ranking positions mean lower wages and fewer chance to reach better positions.

Apart from the MOPT, COSEVI has enough personnel doing data gathering and CONAVI is second to COSEVI in the number of staff. INCOFER and INCOP have the lowest number of employees working in the planning department; INCOFER has no manager or boss of planning (the managing director does all the planning).

Most planning departments are under the authority of the highest operating officer, which is the executive director or executive secretary, though all institutions except the MOPT have a board of directors. The only exception is the planning department of DGAC, which depends on its board.

In Costa Rica, transportation data is used to monitor implementation of national plans. Data is not commonly used for planning new projects or running an institution. Normally, the plan comes first and then data is gathered to confirm or demonstrate that the goals are being achieved.

Institutions in transportation have yet to establish how data can be collected and processed to make decisions[7)] on investment projects. Many efforts have gone toward processing, summarizing and analyzing goal fulfillment indicators, which normally go together with budget execution.

2.3.3. Software and Database

Seven of the nine surveyed institutions have no central database and only CNC and INCOP place all gathered data in a unique database. INCOP uses a commercial spreadsheet, whereas CNC has a data center. JAPDEVA has a storage platform for many of its indicators but the platform is quite old. The information is processed by JAPDEVA's custom-made software, and staff print and retype the data to feed it into more modern systems such as word processors and spreadsheets. CONAVI has several systems to cover certain functions but information is scattered and putting all of it together is apparently hard.

Isolated efforts to process and display important data have been done by CONAVI and CTP. CONAVI has a number of software applications to monitor acquisition status and work development and is working on a geographical information system; CTP has software to handle information on a day-to-day basis. Though certain

7) The list of projects scheduled for every year comes from their boards of directors.

institutions have looked for better ways to obtain and store information, others still use spreadsheets, mainly Microsoft Excel. So wide differences are seen in what institutions do.

CONAVI has several software programs developed for a number of applications and users. For instance, one is for bid timeline control and work execution and another performs goal fulfillment. On the other hand, it also has several databases given its spreadsheets for public tolls and weigh stations. CONAVI's geographical information system is also independent from other databases. So this institution has a large number and variety of platforms employed to handle data.

2.3.4. Data Collections

Any kind of data required by an institution is designed by the institution that needs it, and usually the institution updates and upgrades the ways how information is gathered. The information is sometimes gathered daily at ports and airports or sometimes every three months. Nevertheless, writing reports every year with the inclusion of all kinds of information is common.

COSEVI has developed its own method of data gathering but claims it is based on international standards. COSEVI´s capability to support its data and statistics is said to have received wide recognition and internationally acceptance.

When asked about data collection procedures, most planning officials said they have no guidelines to follow so they developed their own procedures to collect data. Moreover, they could change their procedures at any time, and not all institutions kept track of changes in their procedures. So data can eventually be changed in units or other characteristics without proper notice.

To obtain information to make planning decisions, the MOPT has invested in radar sensors for traffic counting. Twenty-two stations in the country send daily real-time data on traffic count and vehicle distribution.

Most institutions claim to lack sufficient personnel for data collection and processing, but most do have skilled staff, though experienced experts are retiring. Four of nine institutions claimed they had trained and/or skilled personnel. Nevertheless, lack of sufficient staff is a common weakness.

Only the Secretary of Sectorial Planning mentioned the National Transportation Plan as a strength; eight of nine institutions never mentioned it though the plan is considered a guide for planning ahead. For other strengths, CONAVI claims that it had enough computational tools. CNC says it has a powerful platform to handle data and considers its small size an advantage (under 60 people).

The port and railroad institutions were found to have enough raw data, though admitting that the quantity of processed data might be inadequate. Both also have their own IT departments, which can help develop applications and software.

Certain institutions claimed not to have suitable software to process information and others claimed to have an old system. Only CONAVI and CNC said they had advanced and capable software.

Among other weaknesses, bureaucracy was mentioned as slowing down or stopping data collection, processing and sharing. Other institutions complained of insufficient budget to gather data or too few computers and/or software. CONAVI also interestingly mentioned that lack of integration slowed data gathering and led to biased decision making.

2.3.5. Implications from the Interview Survey

The planning and decision-making processes in transportation are highly fragmented among institutions in Costa Rica, leading to excessive policy fragmentation and uncertainty of project implementation. This has a negative impact on the overall coherence of transportation policy.

The institutions that belong to the transportation sector do not develop indicators or data to devise their own plans or decide how they will invest their budget.[8] Data is used only to monitor implementation of national plans.

Transportation plans come first and then data are collected to validate or demonstrate that the goals are being achieved. Data are not frequently used in planning new projects or running an institution. No data or indicators help link strategic planning to transportation infrastructure objectives.

Most institutions lack a central database system and thus accessing or displaying historical data is difficult. The data collection method is also not standardized and changes often. No standard written procedures or protocols exist to collect data.

Every institution heavily relies on a qualitative approach for transportation planning without information and lacks mandatory guidelines and procedures for project selection and prioritization. As a result, decisions on project prioritization and selection are subject to political inference, leading to inefficiency in transportation policy.

8) In Costa Rica, every annual plan and budget are developed from the National Development Plan. Departments and directions of planning usually follow up goal achievement of the national plan, which takes most of their resources including time. Goal fulfillment indicators are updated for the purpose of monitoring every institution´s performance with no consideration of how important and effective their plans are.

3. Korea's Experience and Implications for the Transport Data Base Development

This section looks at a case study using Korea's experience and knowledge for developing a transportation database for benchmarking by Costa Rica. The practices and lessons learned from the Korean experience is based on the legal and institutional framework. Also highlighted are provisions of the law, standards and guidelines for transportation planning, and the importance of coordination with other transportation agencies.[9)]

3.1. Background and Objectives of the Transport DB Development

Reliable and transparent transportation policy requires consistent and systematic data obtained from transportation surveys. In the US, full-scale surveys are done on national transportation and logistics every five years. In Britain, the Transportation (National Travel) Survey is also conducted every half decade. Korea, however, used to conduct a separate transportation survey without an organized foundation for surveys which proposed some challenges.

One of the problems with the national transportation survey was redundancy. Since individual surveys were repeatedly implemented according to each transportation project, budgetary waste was unavoidable and complaints over professionalism and consistency were raised. In addition, the absence of standardized guidelines for survey triggered fears over objectivity of the survey results.

Lack of credibility in transportation investment evaluation also drove the establishment of the national transportation survey and database. The Seoul-Busan High-speed Rail project was an example of this. At the time, the amount of public funds injected into the project was almost triple the initial estimate of KRW 5.5 trillion. Furthermore, among feasibility studies done from 1994–98 on 33 large-scale projects, all except construction of the Ulleungdo airport were found feasible. As a result, the feasibility studies were criticized as seriously flawed in transparency, credibility and objectivity.

The absence of a policy backing a transportation DB was another motivation. The Korean government faced lower reliability of transportation policy due to lack of essential data for effective implementation of such policy. In particular, the absence of data was an impediment to intermodal and sustainable transportation policy.

9) Much of the content of this section is quoted from the MLTM and the Korea Transport Institute (2012), and more details can be found in the report.

Considering the background, the project to build the Korea National Transport Database commenced to efficiently devised and executed national transportation policy through programs such as the National Basic Transportation Network Plan and the Mid-term Investment Plan for Transportation Facilities. The projects were intended to form a system that comprehensively studied and analyzed national transportation data, and to secure the reliability of facility investment in transportation through cooperative use of standardized and consistent time-series transportation data. The Act on National Transportation Efficiency also stipulated the database's purpose as formulating statistics and indicators that can lead to national policy actively support the national decision-making system and establish links to national decision making.

3.2 Establishment of Legal and Regulatory Framework

The Act on Transportation System Efficiency, enacted in February 1999, provided the legal basis for the development of the Korea National Transportation Database. The law sought to improve national competitiveness and the government hoped to devise a national transportation plan to enhance the overall capacity of transportation policy. In July 2001, an amendment to the law required more efficient operation of the national transportation system. In December 2009, a policy requiring an integrated transportation system was emphasized under a unified system, and the law was later renamed the Act on Integrated Transportation System Efficiency.

The Act on National Transportation System Efficiency stipulated the content of the implementation of and guidelines for national transportation surveys and consultations on institutional transportation surveys.

〈Box 1-1〉 Act on National Transportation System Efficiency

Article 11 (Survey and Appraisal of National Transportation and Logistics Competitiveness)

(1) The Minister of Land, Infrastructure and Transport shall conduct a survey and appraisal of the competitiveness of national transportation and logistics on a regular basis to efficiently establish and implement national transportation policies as prescribed by Presidential Decree. <Amended by Act No. 11708, March 23, 2013>
(2) The heads of public institutions shall cooperate in submitting the necessary materials to survey and appraise the competitiveness of national transportation and logistics under Paragraph (1), and endeavor not to repeatedly conduct any survey similar thereto.

Article 12 (Survey of National Transportation)

(1) The Minister of Land, Infrastructure and Transport shall conduct a transportation survey at the national level (national transport survey), as prescribed by Presidential Decree, to

〈Box 1-1〉 Continued

reasonably develop and implement national transportation policy including the national core transportation network plan and the mid-term investment plan. <Amended by Act No. 11708, March 23, 2013>

(2) The Minister of Land, Infrastructure and Transport shall devise a plan for the national transportation survey including survey objectives and strategies, details and methods every five years after deliberation by the National Transportation Commission, to prevent the overlapping of the national transportation survey with an institutional transportation survey referred to in Article 16 (1), conduct an efficient survey of transportation, and promote the joint use of the survey results. <Amended by Act No. 11708, March 23, 2013>

(3) The Minister of Land, Infrastructure and Transport may request the head of a public institution to provide the necessary materials or assistance that could help establish the national transportation survey or related plan provided for in Paragraph (2). In this case, the head of the public institution concerned shall comply with such a request barring a compelling reason not to do so. <Amended by Act No. 11708, March 23, 2013>

Article 15 (Guidelines for Transportation Surveys)

(1) The Minister of Land, Infrastructure and Transport shall prepare and publish guidelines for transportation surveys (transportation survey guidelines) to ensure the objectivity and standardization of transportation surveys. <Amended by Act No. 11708, March 23, 2013>

(2) The Minister of Land, Infrastructure and Transport shall, in preparing transportation survey guidelines, consult in advance with the heads of the administrative agencies concerned. <Amended by Act No. 11708, March 23, 2013>

(3) Coverage of transportation survey guidelines and methods for preparation thereof, the basic matters to be included therein, and other necessary matters shall be prescribed by Presidential Decree.

Article 16 (Consultation on Institutional Transportation Surveys)

(1) Where the head of a public institution intends to conduct an institutional transportation survey to carry out its business affairs (institutional transportation survey), he or she shall prepare a plan for the survey (institutional transport survey plan) in conformity with transportation survey guidelines and consult in advance with the Minister of Land, Infrastructure and Transport: Provided, that this shall not apply to minor institutional transportation surveys as so prescribed by Presidential Decree. <Amended by Act No. 11708, March 23, 2013>

(2) Where it is deemed that an institutional transportation survey plan overlaps with the national transportation survey or any other transportation survey, or otherwise obstructs the efficient conduct of such transportation survey, the Minister of Land, Infrastructure and Transport may request the head of the public institution concerned to take any measures necessary for prevention thereof. In such cases, the head of the institution concerned shall comply with such a request barring a compelling reason not to do so. <Amended by Act No. 11708, March 23, 2013>

〈Box 1-1〉Continued

(3) The head of a public institution shall notify the Minister of Land, Infrastructure and Transport of the results of the institutional transportation survey within 30 days after its completion. <Amended by Act No. 11708, March 23, 2013>

(4) Matters to be included in the institutional transportation survey plan, the deadline for the plan's submission and other matters for consultation with the Minister of Land, Infrastructure and Transport shall be prescribed by Ordinance of the Ministry of Land, Infrastructure and Transport. <Amended by Act No. 11708, March 23, 2013>

Article 17 (Comprehensive Management of Transportation Survey Materials)

(1) The Minister of Land, Infrastructure and Transport shall build and manage a national transportation database to collect, analyze and offer materials and information on the national transportation survey and other institutional transportation surveys in a systematic and comprehensive way, and publish and announce the results of the national transportation surveys on a regular basis as prescribed by Presidential Decree. <Amended by Act No. 11708, March 23, 2013>

(2) In building and managing materials on institutional transportation surveys in the national transportation database pursuant to Paragraph (1), the Minister of Land, Infrastructure and Transport shall comprehensively examine the appropriateness of the surveyed materials, the connection between such materials and those of the national transportation survey, and may, if necessary, adjust them in consultation with the national transportation database council provided for in Paragraph (5), after conducting an additional technical analysis. <Amended by Act No. 11708, March 23, 2013>

(3) The head of a public institution shall utilize the national transportation database and the national transportation survey referred to in Paragraph (1) as a base material when carrying out policies, plans and projects, related to transportation.

(4) The Minister of Land, Infrastructure and Transport may have relevant experts or specialized institutions inspect the national transportation database in a manner prescribed by Ordinance of the Ministry of Land, Infrastructure and Transport to ensure the reliability and objectiveness of the national transportation database. <Amended by Act No. 11708, March 23, 2013>

(5) The Minister of Land, Infrastructure and Transport may organize and operate a national transportation database council consisting of the public institutions concerned as prescribed by Presidential Decree to ensure smooth buildup of a national transportation database. <Amended by Act No. 11708, March 23, 2013>

(6) Necessary matters on the buildup and management of a national transportation database shall be prescribed by Presidential Decree.

Source: http://elaw.klri.re.kr/kor_mobile/viewer.do?hseq=32765&type=sogan&key=4.

The Act on National Transportation System Efficiency also stipulates well-defined institutional arrangements detailing the roles and responsibilities of main participants. The Ministry of Land, Infrastructure and Transport is responsible for devising a mid- to long-term business plan and supervising the management and supervision of consultation facilities. The ministry also oversees the National Traffic DB Management Council. The act also stipulates the roles of the Korea Transport Institute, a government-supported think tank. The institute is responsible for the construction and utilization of the transportation database and analyzing the survey results. Consequently, it acts as a delegate considering the database's specialty and performance.

〈Box 1-2〉 Enforcement Decree of Act on National Transport System Efficiency

Article 114 (Assignment of Work)

Under Article 2 of the Act, the Ministry of Land, Infrastructure, Transport and the Ministry of Oceans and Fisheries of the Republic of Korea shall entrust the Korea Transport Institute to the below.

1. Survey on National Logistics Competitiveness and Evaluation of National Transportation Competitiveness per Article 1
2. Work on the implementation of the National Transport Survey per Article 12 of the Act on Implementation of the National Transportation Survey (except for execution of national port survey)
3. Construction and Operation of National Transportation Database per Article 1
4. Inspection of National Transportation Database per Article 4
5. Collection of Traffic Technology Information and Analysis of Transportation Technology Information

Source: http://elaw.klri.re.kr/kor_mobile/viewer.do?hseq=32765&type=sogan&key=4.

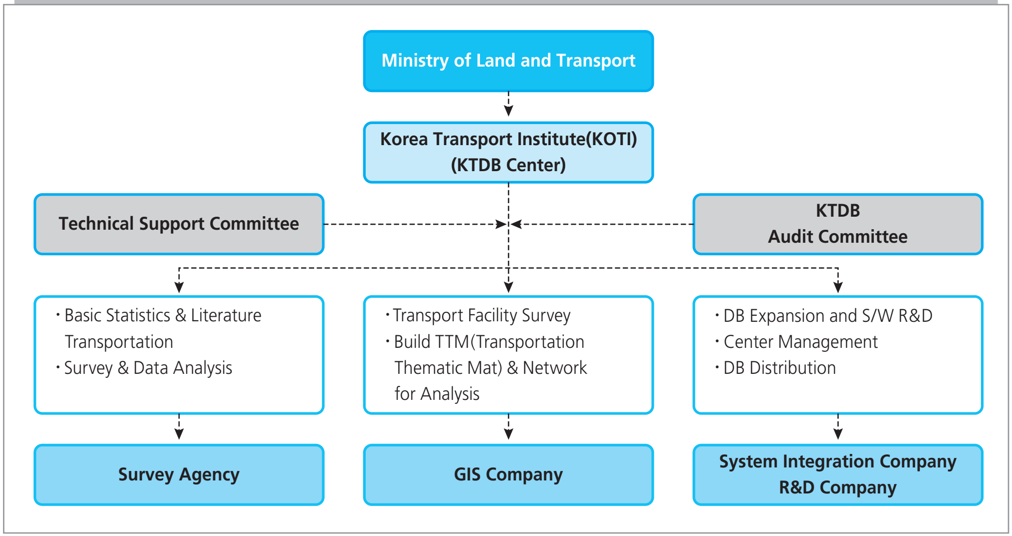
3.3. Foundation of the National Transportation DB Center

The Act on National Transportation System Efficiency prescribes national traffic surveys[10] and the foundation for a national transportation database that manages integrated transportation data, including both a national database and local government-conducted traffic surveys. Per this law, the Korea Transport Database Center was set up within the Korea Transport Institute and entrusted to such works as traffic surveys and analysis, transportation database building, and data provision by the Ministry of Land, Infrastructure and Transport of the Republic of Korea to

10) The National Transportation Survey is institutionally based on the National Transport Survey Plan. The latter aims to devise a systematic plan for planning, accuracy and utilization of planned transportation research projects. Another goal is to improve efficiency in the implementation of national transportation surveys and the deployment of databases in all transportation areas.

build an integrated transportation database. [Figure 1-1] presents the organization of the center.

[Figure 1-1] Organization of KTDB Center



Source: Korea Transport Institute.

The center's mission is to establish and provide an integrated and standardized database on national transportation to support transportation-related policy and planning. To accomplish this mission, the center surveys basic transportation data, passenger-freight O/D[11] traffic, trip[12] generation rates and national traffic cost[13] according to the National Transportation Survey Plan. The following are the center's activities:

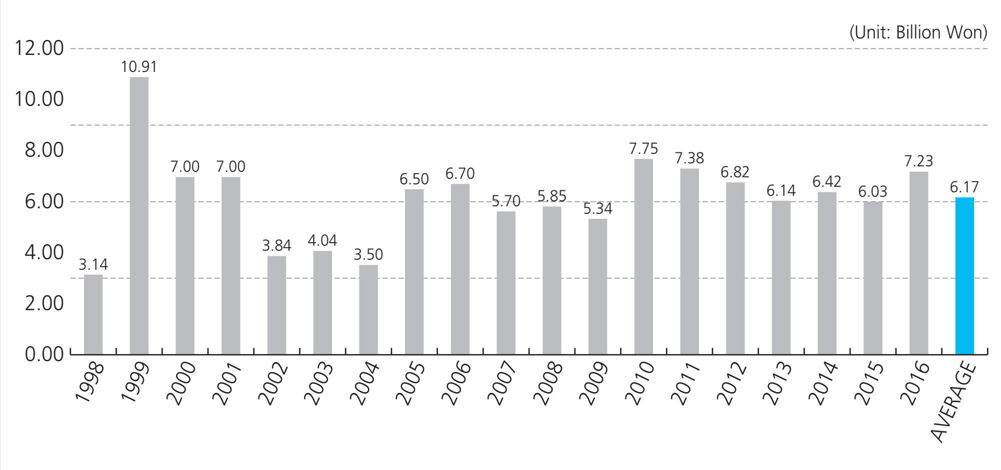
- Examining and providing data on traffic volume of both national and metropolitan areas in number of passengers and freight O/D
- Analysis of traffic status of passengers and freight (by mode and purpose) and trip generation rates
- Survey and analysis of maritime transportation
- Analysis of traffic volume and characteristics between specific areas during special consecutive holidays
- Raising reliability of transportation DB by utilizing state-of-the-art survey method
- Publication of transportation statistical report. Types of transportation statistics include general (area of land, population and GDP), transportation

11) O/D implies matrix of trips from particular origins and destinations.
12) Trip means one-way journey from one place to another.
13) Cost is usually expressed in money, time or distance incurred when traveling from particular origins and destinations.

system (facilities, number of vehicles and vehicles- and ton-km by transport modes) transportation safety (number of accidents and vehicle fatality rate), transportation economy (transportation cost and budget and fare by mode), and energy and environment (energy consumption and greenhouse gas emissions)

In 2016, the center spent about KRW 72 billion for conducting surveys and analysis of the results and management of the National Transportation DB. [Figure 1-2] shows the budget allocated to the center since 1998, with about KRW 62 billion coming from the government.

[Figure 1-2] Trends of KTDB Center's Budget



Source: Korea Transport Institute.

3.4. Key Contents of National Transportation Survey

The National Transportation Survey and DB Construction Project comprise surveys on passenger and freight movement and transportation planning network, transportation statistics, and database management and operation. This section only presents the results of the passenger and freight travel surveys due to limit of report length. More details can be found in the National Transportation Survey Plan and National Transportation Survey Guidelines.

3.4.1. Passenger Travel Survey

The passenger transportation survey is a nationwide preliminary study of surveys on travel by passengers and national passengers, traffic volume and delay function, and travel panel.

The nationwide preliminary survey is conducted to prevent survey error and sets a methodology for selecting the selection and location of the survey. It also sets the proper survey methodology and details the main survey plan, as well as producing the survey manual.

The national passenger travel survey is conducted after the preliminary survey. First, the household travel survey is implemented to understand characteristics, origin and destination, purpose of travel, modes of transportation, and departure and transit times. Public transportation facilities will also be studied to set public transportation planning.

The traffic volume and delay function survey analyzes the relationship between traffic volume and travel time according to road and region type. The function is calibrated with the surveyed traffic volume and travel time data, and future traffic volume is forecast using the calibrated function.

The travel panel survey is responsible for boosting the reliability of demand forecasts and analyzing the effectiveness of transportation policy. Its target is about 3,000 households in large major cities.

3.4.2. Freight Transport Survey

The freight transport survey seeks to enhance the reliability of the freight database and improve its utilities for devising domestic distribution policy. This survey consists of the National Pre-Survey on Freight O/D, Freight O/D Transport Volume Survey and freight vehicle traffic survey.

The National Pre-Survey on Freight O/D presents adequate selections of survey objects and locations. It also sets forth a detailed plan for main surveys and a survey manual for freight origin[14)] and destination[15)] movement.

The Freight O/D Transport Volume Survey studies origin and destination patterns of freight in the country and is applied to transportation policy and project analysis. The survey contains the distribution of infrastructure facilities, unit requirement, and sea and coastal freight O/D.

The surveys on freight vehicle traffic and freight generation facilities track the movement of freight vehicles and study freight vehicle traffic and routes.

14) Origin refers to the place where a trip began.
15) Destination refers to where a trip ended.

3.5. Achievements and Implications

Korea Transport Database (KTDB) has seen steady development with a solid legal foundation. The database was utilized as the basis for devising effective policy and implementing government plans such as those for a national transportation network, railroads and basic plans for road maintenance. The government has conducted rational and objective investment analyses by creating the database. The KTDB leverages the creation, expansion and maintenance of transportation facilities.

The KTDB's achievements include the following. First, the cost savings and efforts toward transportation research can be found by using the one-stop service of analyzed data from the National Transportation Database. The basis data for essential statistics on transportation characteristics of passengers and freight were collected through numerous regular and unscheduled surveys: the database also prevents survey overlapping and decreases the time needed for data gathering and analysis.

More importantly, the decision-making process and the efficiency of transportation investment have both been enhanced through the KTDB. Rational, consistent and transparent evaluation of transportation investment could be performed through the KTDB. For example, the preliminary feasibility system (PFS) was devised in 1999 under legal enforcement, and it prevented infeasible projects from being initiated and avoided budgetary waste. Since the PFS was launched in 1999, the cost savings achieved between 1999 and 2014 amounted to KRW 89,518.8 billion, of which KRW 6,851.2 billion was saved by proposing effective alternatives and KRW 82,667.5 billion by canceling infeasible projects using the KTDB.

Since 1998, Korea has set the foundation for building a national transportation database based on the firm commitment of the central government and active cooperation from municipal and provincial governments and related agencies. The database enabled the implementation of transparent, objective and consistent transportation policy and the foundation for a more rational policy will likely help the development of transportation infrastructure.

4. Conclusions and Policy Recommendations

This chapter's purpose is to suggest policy recommendations to make Costa Rica's transportation database more efficient, consistent and reliable, and establish a database center for transportation planning based on lessons from the Korean experience and model. Based on the diagnostic study and lessons from the Korean case study, the following policy actions are suggested.

4.1. Foundation of the National Transport DB Commission

The planning and decision-making processes for transportation infrastructure are highly fragmented among government agencies in Costa Rica. The numerous agencies involved in transportation planning contribute to excessive policy fragmentation and uncertainty in the implementation of transportation policy.

To overcome such fragmentation and raise the coherence of the creation of a transportation database, one recommendation is to form a "nationa commission for a transportation database" under an executive order or jurisdiction of the Costa Rican Ministry of Public Works and Transportation. The commission should be created with a database center within the legal framework; however, foundation under the jurisdiction of the MOPT is more practical way to implement the policy in the short term.

The database is used directly used to devise the National Transportation Plan, and the envisioned commission shall deliberate on the following matters:

- Establishment and modification of National Transportation Plan
- Establishment and modification of National Transportation Survey
- Establishment and development of transportation indicators
- Establishment of DB center
- Matters on quality, consistency, objectivity and relevance of transportation indicators and analyses collected, supported or disseminated by DB center
- Matters subject to deliberation of National Transportation Commission pursuant to other acts and subordinate statutes
- Matters on DB center operations such as budget and staff
- Other important national policies toward transportation referred by Costa Rican Ministry of Public Works and Transportation

For naming members of the commission, the minister can appoint directors of the board of institutions with specific responsibility for transportation infrastructure.

To carry out the commission’s decisions in transportation planning, the MOPT should clearly explain the purpose of the commission to the institutions. If constituent members agree on the purpose, then the institutions are more likely to comply with the commission’s decisions and instructions.

The enforcement of the commission’s decisions needs to be strengthened by a specific instrument such as the minister’s “executive order.” In Costa Rica, the executive branch, which consists of the President, vice presidents and ministers, can issue orders to institutions and an executive order is a valid instrument for the executive branch to give instructions to every institution, provided that it does not violate the law. An executive order could be a way to organize the envisioned database commission.

4.2. Establishment of National Transport DB center

To overcome institutional fragmentation and advance the development of the transportation DB, an agency or unit for this specific purpose is needed. A DB center will contribute to a more effective and reliable transportation DB and better articulate transportation planning mandates.

The national DB center should be set up under law to secure funding and personnel resources for the sake of sustainable operations; however, this process will take years. An alternative to legislation of a law is to set up the center via a resolution of the National Transportation Database Commission or executive order. This can guide institutions in the sector to gather information, what data to gather that will benefit other institutions, decide which indicators they need for their own use and perform quality control on their own data.

A national database center can be operated immediately as long as the ministry can locate the resources to begin operations. The ministry itself can provide workers, though human resources from government authorities can also join the center if agreements are signed between the authorities and the ministry.

4.2.1. Functions of the National DB Center

The National DB Center for Transportation Planning should be a leading source of timely, accurate and reliable information on transportation planning. The center should be a politically objective supplier of trusted and statistically sound information used to support decision making related to transportation planning. A national transportation survey is one of its duties, and the center should publish guidelines for transportation surveys.

The center should also be a gateway to all transportation data and a help line for each institution in planning. Coordination of transportation planning is also a principal function. Furthermore, it should provide technical assistance in data collection and analysis for the transportation DB. Finally, the center should put out publications such as an annual report on transportation statistics.

4.2.2. Location of the Transportation DB Center

The best location for the database center is within the Secretary of Sectorial Planning of the MOPT. The MOPT dictates transportation policy but is only a channel to coordinate institutions. The law empowering the MOPT chief to supervise transportation stipulates that the secretary shall assist the former to oversee and coordinate activities with other institutions.

The Secretary of Sectorial Planning has long been active in data collection and coordinates with other institutions on data collection and processing. The office works as a liaison with the Costa Rican Ministry of Planning for the execution of the National Transportation Plan.

The secretary has many pre-investment feasibility reports, agreements and project prioritization, so it boasts valuable experience and factual demand of the transportation database in decision making. It can help the database link strategic planning to transportation infrastructure objectives.

Before the agency or unit for this specific purpose is created, the Secretary of Sectorial Planning can begin collecting data and coordinating efforts with all other institutions, provided the MOPT chief supports them. The latter needs to look for additional personnel and resources from other MOPT departments and directions.

4.2.3. Database and Indicators

In Costa Rica, transportation data is used only to monitor implementation of national plans and rarely to plan new projects. A transportation plan comes first and then data are collected to confirm goal achievement.

A national transportation survey is needed to build a trusted and statistically sound database used to support decision making in transportation planning. Data on traffic, geography of passenger and freight movements, a series of economic accounts, and trans-border movement of passengers and freight should be supplied.

The following types of transportation planning data are collected from its own survey:

- Origin/destination flow by means of transportation
- Registration status by means of transportation
- Supply and demand of traffic facilities by means of transportation
- Transportation and logistics expenses
- Traffic congestion

- Energy consumption and efficiency by means of transportation
- CO_2 volume emitted by means of transportation

The national database center should also come up with useful indicators for institutions that meet international standards. The following figure has suggestions for such indicators.

〈Table 1-3〉 Suggested Indicators

Indicators	Unit
Rail freight transport	Million tonne-kilometres
Road freight transport	Million tonne-kilometres
Inland waterway freight transport	Million tonne-kilometres
Oil pipeline transport	Million tonne-kilometres
Total inland freight transport	Million tonne-kilometres
Coastal shipping	Million tonne-kilometres
Rail container transport	Twenty-foot equivalent unit(TEU)
Maritime container transport	Twenty-foot equivalent unit(TEU)
Passenger transport by rail	Million Passenger-kilometres
Passenger transport by private car	Million Passenger-kilometres
Passenger transport by bus and coach	Million Passenger-kilometres
Total passenger transport by road	Million Passenger-kilometres
Total inland passenger transport	Million Passenger-kilometres
Road traffic injury accidents	Number of accidents
Road traffic injuries	Number
Road traffic fatalities	Number
Road traffic fatalities, per million inhabitants	Number
Road traffic casualties(injuries plus fatalities)	Number
Investment in rail transport infrastructure	Million euros
Investment in road transport infrastructure	Million euros
Investment in inland waterway transport infrastructure	Million euros
Total investment in inland transport infrastructure	Million euros
Investment in sea port infrastructure	Million euros
Investment in airport infrastructure	Million euros
Rail infrastructure maintenance expenditure	Million euros
Road infrastructure maintenance expenditure	Million euros
Inland waterway infrastructure maintenance expenditure	Million euros
Sea port infrastructure maintenance expenditure	Million euros
Airport infrastructure maintenance expenditure	Million euros
Total spending on road infrastructure investment and maintenance	Million euros
Total inland transport infrastructure investment as apercentage of GDP	Percentage

Source: OECD, ITF Transport Outlook 2015.

4.3. Establishment of Solid Legal and Regulatory Framework

To effectively introduce and develop a transportation database system, corresponding regulatory and institutional DBs are needed. The proper legal and institutional arrangements are keys to success and ensure a smooth development process in its entirety.

The first priority in the database's development is to enact a law for implementation. For instance, the national center for the transportation database needs to be created by law to secure funding and personnel resources for sustainable operations. Its roles and functions must also be specified in the law, not to mention its location and the establishment and functions of the National Transportation Commission.

The law must also clearly stipulate institutional arrangements specifying the roles and responsibilities of key players since many ministries and institutions in transportation and infrastructure are involved in the database's development. The law should determine the roles and functions of all relevant ministries and institutions to avoid overlapping functions and conflicts of interest. Based on the content of the Republic of Korea's Act on National Transport System Efficiency, the law should include the following:

- Implementation of national transportation survey
- Survey guidelines
- Establishment and functions of National Transportation Commission
- Content of national transportation survey
- Establishment and location of national transportation database center
- Institutional arrangements specifying roles and responsibilities

Also needed is a legal basis for the collection of traffic data, navigation and mobile information in preparation for the introduction of high technology in transportation surveys.

4.4. Improvement of Decision-Making Process in Transport Planning

Costa Rica heavily depends on qualitative appraisal in transportation planning and lacks a reliable project pipeline for execution. Data's role is only to monitor implementation of national plans, and data are not commonly used in project planning. Furthermore, the lack of a standard selection procedure and project prioritization raises susceptibility to political inference.

A reliable and consistent transportation database supplied by the center will boost the speed and transparency of project prioritization and selection, as well as raising the efficiency and credibility of transportation planning. The database will also strengthen accountability of transportation planning with the public. In the Republic of Korea, the preliminary feasibility system (PFS) using the standardized database, part of the reform of the public investment system, was devised in 1999 by law, and the system prevented inefficient projects from being initiated and removed budgetary waste. The establishment of a national transportation database center is also an opportunity for the Costa Rican government to improve its processes and methods of transportation planning. A rational evaluation process for transportation planning can be arranged through the use of a consistent and transparent database.

An effective and efficient decision-making process bolsters transportation investment productivity, and a developed transportation database is a good instrument to set the process through consistency and improving accuracy across evaluated projects. The Secretary of Sectorial Planning, along with the database center, should have sole authority to supervise the appraisal and selection of investment projects and strive to create a “transportation investment management system” via the development of the database.

References

Costa Rican Ministry of Public Works and Transportation, Anuario Estadístico del Sector Transporte e Infraestructura 2015, 2016. [In Spanish]

Korea Development Institute, 2011 Modularization of Korea's Development Experience: Construction and Utilization of National Transport Database, 2012.

Ministry of Land, Transport and Maritime Affairs, Final Report on Korea National Transport Survey and DB Project, 2010. [In Korean]

Ministry of Land, Transport and Maritime Affairs, 1st National Transport Survey Plan, 2008. [In Korean]

Statues of Republic of Korea, Enforcement Decree of Act on National Transport System Efficiency.

Statues of Republic of Korea, Act on National Transport System Efficiency.

OECD, ITF Transport Outlook, 2015.

Appendix*

Summary of Interviews (1)

	Institution Type	Staff for Minister	Unique Platform
MOPT	Direction (sector secretary)	Minister	No [1)]
INCOFER	Management of administration [2)]	Executive vice president	No
JAPDEVA	Planning management	Executive vice president	Yes
CONAVI	Planning dept.	Executive director	No
CNC	Planning management	Executive secretary (Director)	Yes
INCOP	Planning dept.	Executive vice president	Yes
DGAC	Planning management	Executive director	No
CTP	Planning dept.	Board of directors	No
COSEVI	Project division / planning dept.	Executive director	No

Summary of Interviews (2)

	Platform Details	Use of Compiled Indicators in Planning
MOPT	Various databases depending on users.	None; planning based on National Transportation Plan and available budget.
INCOFER	Word and Excel / Every 5 years stored in files.	For operations such as fares and budget for small investment (self-generated).
JAPDEVA	So old that data are printed then retyped and processed.	Projections for annual budget planning.
CONAVI	- SIGEPRO (DB for bids and work execution) - DELFUS (goal fulfillment) - Spreadsheets for public tolls and weigh stations. - Geographical information system under development with work location and status - SAEP (bridge structure management system)	None; with exception of select bridge works based on management system.

* Please refer to Appendix Note for footnotes within the tables.

CNC	Data center with custom-made software	Goals based on indicators from previous year (i.e., road accidents)
INCOP	Spreadsheet	Select goals and projects based on indicators
DGAC	Movements (passengers and cargo) gathered in spreadsheet	Select goals and projects based on indicators
CTP	DB used for day-to-day information such as fleet substitutions; also developing system for budget execution and goal fulfilment. The Financial Department is developing a system.	Special surveys for special situations, no advance planning
COSEVI	1st database included license permits and infractions, now many Excel spreadsheets used; unique central database under development. It takes up to two years to gather all the information based on highway police infractions and field studies.	Each project based on required data, before and after implementation.

Summary of Interviews (3)

	Institution Type	Staff for Minister	Unique Platform	Platform Details
INCOP	Planning dept.	Executive vice president	Yes	Spreadsheet
DGAC	Planning management	Executive director	No	Movements (passengers and cargo) gathered in spreadsheet.
CTP	Planning dept.	Board	No	Database for day-to-day information used, such as fleet substitutions. Also developing system for budget execution and goal fulfilment. Financial dept. developing system.
COSEVI	Project division of / Planning dept.	Executive director	No	1st database included license permits and infractions; now many Excel spreadsheets used Now developing unique central database. Up to two years needed to gather all information based on highway police infractions and field studies.

Summary of Interviews (4)

	Goal Fulfillment Indicators	Collection Frequency	Destination of Information
MOPT	Sectorial goals [3] and budget execution [4]	Every 6 months then annually	CGR, Estado de la Nación, MIDEPLAN, STAFF of MOPT [5]
INCOFER	Sectorial goals [6] and budget execution.	Every 6 months then annually	CGR, MIDEPLAN, STAP, ARESEP, MOPT
JAPDEVA	Sectorial goals [7] and budget execution	Every 6 months then annually	CGR, MIDEPLAN, STAP, ARESEP, MOPT
CONAVI	Sectorial goals and budget execution	Every 6 months then annually [8]	CGR, MIDEPLAN, STAP, MOPT
CNC	Sectorial goals and budget execution	Every 3 months, then every 6 months and annually	CGR, MIDEPLAN, STAP, MOPT
INCOP	Sectorial goals and budget execution	Every 6 months then annually	CGR, MIDEPLAN, STAP, ARESEP, MOPT
DGAC	Sectorial goals and budget execution	Every 6 months then annually	CGR, MIDEPLAN, STAP, ARESEP, MOPT
CTP	Sectorial goals [9] and budget execution	Every 6 months then annually	CGR, MIDEPLAN, STAP, ARESEP, MOPT
COSEVI	Sectorial goals and budget execution.	Every 6 months then annually	CGR, MIDEPLAN, STAP, MOPT

Summary of Interviews (5)

	Methodology	Other Indicators	Frequency of Collection
MOPT	By institutions requiring information	Traffic counts every 15 minutes in 22 locations.	Daily
INCOFER	By institutions requiring information	No. of passengers, total cargo moved, equipment statistics, accidents	Monthly
JAPDEVA	By institutions requiring information	Overall operation statistics	Monthly, summarized in annual report

CONAVI	Each institution states it; similar data required but different methodologies and reports; Even MOPT has separate requirements.	Works status, investment per year, no. of work executions	Annually
CNC	Each institution must make 3 reports with same information because of differences in manner of request.	No	-
INCOP	By each institution; different requirements by institution for same information	Operations such as occupation, movement	Monthly
DGAC	By institution; different requirements by institution for same information.	Operations – movements of passengers and cargo	Monthly
CTP	By institution	Other indicators estimated on daily basis [10)	As needed
COSEVI	By institution	No. of accidents and deaths; various statistics such as no. of penalties.	As needed Not set Depends on project

Summary of Interviews (6)

	Manner of data Dissemination	Methodology	Indicators from Other Institutions
MOPT	Just by request	By itself, upgrade every year	Transportation sector [11) plus universities [12), and third parties [13)
INCOFER	Just by request	By itself	No
JAPDEVA	Published on homepage	Self-correction, sometimes indicators added based on same data	No
CONAVI	Just by request. Usually required by local governments [14)	By itself	From LANAMME: road deflections, roughness index and skid resistance From ITCR: bridge condition.
CNC	-	-	INEC information considered [15)

INCOP	Published every year Usually given to anyone by request.	By itself and coordinated with private concessionary companies	From its concessionaire [16]
DGAC	Requested by airlines, media, Banco Central, COMEX, ICT, and INEC. Also OACI and CLA	By itself	No. of fumigation operations, fuel consumption by RECOPE, police operations by air
CTP	Board to make decisions	By itself	ARESEP sends service demand [17]
COSEVI	Published and sent to board to allow decisions on specific project	By itself, based on international standards and policies	Highway patrol, MOPT (average daily traffic), INEC (poverty indexes by zone)

Summary of Interviews (7)

	Adequacy of Indicators	Other Required Indicators
MOPT	Not enough	Travel time, user cost, among other
INCOFER	Not enough	Potential passengers, indicators of operations such as travel time
JAPDEVA	Not enough but raw data sufficient [18]	More indicators based on same raw data
CONAVI	Not enough; more technical indicators required	Better pre-investment studies, including social indicators
CNC	Yes	Information to aid implementation of most important projects
INCOP	Not enough	Indicator list prepared [19]. Also operative indicators to help decide how to invest, what concessions to give.
DGAC	Not enough	Operations by product type (import and export)
CTP	Yes	-
COSEVI	Not enough	Full coverage of all accident types

Summary of Interviews (8)

	Strengths	Weakness
MOPT	Qualified personnel / sufficient no. of professionals/ cameras to count vehicles / guidance from National Transportation Plan	Not enough technicians / bureaucracy / budget shortfall / trained professionals retiring.
INCOFER	Qualified personnel / most information gathering focused on training right of way	Personnel near retirement, outdated institutional structure [20)
JAPDEVA	Flexibility in information handling/ experienced personnel/ sufficient volume of raw data / adequate human resources	Outdated platform to gather and present data / old institutional structure / human error common when retyping data
CONAVI	Trained human resources / resources to hire and develop computational tools / lessons learned	Information technologies dept. not strong counterpart when hiring software developers /lack of integration among departments / tendency not to release information / dependency heads changed too quickly /outdated institutional structure
CNC	Existing software allows data gathering and processing / small organization eases data gathering /new projects registered	Internal organization needs upgrading yet experiences frequent changes / Certain areas deficient in personnel and resources
INCOP	Investment in computer system allows easier access to information /Easy to make reports based on gathered information	Indicators not used in decision making
DGAC	Raw data available	Lack of technology to handle information/ No central database
CTP	Tools being developed /experienced personnel	Experience based on practice rather than academia / insufficient budget to invest
COSEVI	Sufficient budget and resources to gather latest information / Internationally known as trustworthy data source	Inadequate no. of personnel to gather more information

Summary of Interviews (9)

	Opportunities	Problems
MOPT	Int'l cooperation available /most institutions cooperate to release information.	Certain institutions fail to release information swiftly / Ministry of Treasury restricts hiring and investment.
INCOFER	Strong new law allows INCOFER to acquire debts by itself and form trusts.	Intermodality of public transportation not working.
JAPDEVA	-	-
CONAVI	Financial institutions usually offer technical support and donations in consulting.	Changing methodologies from institutions that control goal execution / court changes plans. [21)]
CNC	Private initiative allows project development via concessions.	Change in law could eliminate organization / popular misconception about concessions.
INCOP	Good cooperation with private concessionaires.	No feedback from COMEX / Many institutions ask for same information in different ways.
DGAC	Operation of SIAR system to monitor technical indexes.	Airlines occasionally delay release of information.
CTP	-	Certain law projects might eliminate CTP/ service providers part of board / Service providers reluctant to give data.
COSEVI	-	Other institutions pay little attention to road safety /no wide assessment of impact of traffic fatalities.

Appendix Notes

1) There are several databases. Traffic information gathered by cameras is stored in one, and a project is developing a central database with all indicators and another seeks to develop a geographic information system Data are received from autonomous institutions and included in every year´s progress report. The MOPT receives information from management units for works on their way, such as Bajos de Chilamate – Vuelta de Kooper, Programa de Infraestructura Vial (IADB funded), Programa de InfraestructuradelTransporte (IADB funded) and a BCIE-funded program.
2) Planning is now part of the Management of Administration. The position of institution planner means just one person responds to the Manager of Administration.
3) Goals contained in "Plan Nacional de Transportes(National TransportationPlan)", for instance, requires CTP to arrange a public transportation zone to go in and out of San Jose through only one bus route.
4) Every year´s budget has goals, and the ministry like every other institution must demonstrate how such goals are being fulfilled.
5) Budget execution is supervised by STAP (Costa Rican Ministry of Treasury) and CGR (government auditor), whereas goal fulfillment is supervised by MIDEPLAN (Costa Rican Ministry of Planning). Estado de la Nación is a non-profit organization that publishes the annual report on the state of the nation.
6) For instance: the new updated railroad system and network, rehabilitation of 20 kilometers of railroad tracks every year.
7) For instance: average time without activity at the port will be reduced two hours every year.
8) Information is updated every month, though the reports are due every six months.
9) Example of sectorial goals: conduct survey to estimate public transportation demand
10) Special surveys are often needed and conducted by CTP together with bus companies.
11) All organizations in the sector must send information to the MOPT, usually just annual figures and goal achievements; such institutions include CONAVI, COSEVI, CNC, CTP and DGAC, as well as INCOP and JAPDEVA (autonomous institutions).
12) The University of Costa Rica by law has to gather information on the National Road Network (7,800 kilometers)that includes pavement deflections, international roughness index and skid resistance. InstitutoTecnológico de Costa Rica feeds the Bridge Structure Management System. The former reports to the MOPT and the latter to CONAVI, but both also copy the direction of bridges from the MOPT.
13) RITEVE also supplies information (fleet condition), INS (quantity of operating vehicles) and cars through toll roads and load trucks by CONAVI.

14) The local governments of Belen, Desamparados and Heredia are among the biggest requesters of information.

15) General statistics for Costa Rica

16) A company that has the concession supplies much information.

17) Every three months, ARESEP sends people to take buses. Information is supplied by the same bus companies.

18) Raw data covers operations at their own ports.

19) Indicators that INCOP believes should be gathered: surface of available storage areas, use of terminal by containers

20) For instance, the institution’s organigram is old and needs updating. Certain functions are no longer required, and new ones are being done by people who need not do it.

21) Sala IV is a special court in which people can ask for their constitutional rights to be upheld. Normally people who want their roads to be paved can file a complaint saying dust is hurting their health. Sala IV then orders CONAVI to pave their road within a few months, making CONAVI change its plans and cutting its budget for other projects.

Chapter 2

Long-term Employment Projections and Manpower Planning for Research Personnel in Science and Technology of Costa Rica

Long-term Employment Projections and Manpower Planning for Research Personnel in Science and Technology of Costa Rica

Jae Min Park (Konkuk Univeristy)
Roberto Cruz Romero (University of Costa Rica)

Summary

Costa Rica is seeing growing opportunities for FDI specifically in technology and ecotourism. Over the past several decades, American technology, electronic and medical service companies as well as those from other countries and industries have set up operations in Costa Rica. Several leading multinational companies, including Hewlett Packard, IBM, Intel, Procter and Gamble and Western Union have also started operations in the country. In addition, more Costa Ricans have set up their own companies to provide products and services globally.

This has resulted in a shortage of Costa Rican workers with the necessary knowledge and skills to work in the tech industry (Mata, Matarrita, & Pinto, 2012). Several factors constrain the country's capacity to keep up with the growing demand for qualified and trained personnel: (1) the nation's small population and reduced access to upper secondary and tertiary education; (2) the limited capacity of private universities to produce IT professionals with graduate degrees; and (3) weak technical and para-academic education.

In addition, R&D investment accounted for just 0.57 percent of GDP in 2014, and the participation of the private sector is low. The rate of return on R&D for Costa Rica is 34 percent, far higher than the 6-percent return on investment from physical capital (Lederman and Maloney, 2003). Most tech-oriented countries have three to five times more researchers, especially those specifically for R&D, than Costa Rica

(Monge-González, 2016). The country's number of researchers dedicated to R&D activities per million people puts Costa Rica in the middle of the world rankings. In the ratio of R&D expenditures to GDP, Costa Rica's standings is similar to those of Mexico, Chile and Uruguay but relatively lower than most tech-oriented countries, which invest three to eight times more in R&D than Costa Rica does.

The purpose of this study is to understand the status of science and engineering human resources in Costa Rica, improve the government's capacity to nurture them, and forecast supply and demand for S&T R&D personnel to make recommendations for policy. Yet many challenges and obstacles are expected, and they include:

- Forecasting human resource development (HRD) requires skilled staff and an organizational base under a team approach. Researchers with many required areas of expertise remain in short supply in Costa Rica;
- Even if the information generated is of great value to planning, training and management, task and functional arrangements among related institutions are sometimes considered too complex and costly to execute;
- HRD forecasting has traditionally suffered from merely focusing on surveying a variety of workforce numbers while ignoring the long-term process. Proper forecasting requires a long-term perspective that includes survey and DB design, tentative model development and pilot studies;
- Getting an exact picture of the structure and distribution of specific knowledge that a researcher or technician holds is difficult.

This study compares the supply and demand for R&D personnel and researchers. Demand was analyzed by examining researchers employed in a number of sectors. Past trends and productivity were considered. The number of researchers required in each R&D sector was computed using sectoral output, R&D investment and research productivity. The number of researchers was computed by projecting future R&D expenditures, sometimes by extrapolating the previous level of sectoral R&D and multiplying the employment coefficient, which is the reciprocal of labor productivity.

The next step is to estimate the demand based on the R&D personnel projection using the employment coefficients of Costa Rica (2010-20). Demand can be divided into expansion and replacement. Expansion demand is the difference between the two points in the R&D personnel projection obtained above. Replacement demand is incurred by an incumbent to replace his or her position due to retirement because of old age or transfer to a business or other occupation. The assumption is that an annual average of 4 percent will be eliminated. The two demand types were added up to yield recruitment (total) demand.

Supply forecasting begins with consideration of trends in sociodemographics and labor market participation. The gross birth rate has declined and the annual death rate is expected to increase. Given both trends, student enrollment at the tertiary level is assumed to be stable. This study estimates the number of graduates from 2015-20 for each sub-field using STEM graduates in Costa Rica by sub-field from 2000-14. The next step is to convert supply forecasts by municipality into those by degree. Ideally, this step should look at the degree structure by major. Based on these ratios and the overall number of STEM graduates, graduates from 2015–20 for each degree were yielded. As a final step, recruitment demand and the overall number of graduates given above as supply were compared.

In a tentative analysis, supply and demand for STEM graduates were projected for the 2015–20 period. Overall, the supply of STEM doctorate holders in Costa Rica is expected to hinder research needs by 2020. If researchers mean only those with PhDs, then a considerable shortage in the near future can be expected. The number of researchers will see no significant change, going from 290 in 2015 to 281 in 2020, with demand for 1,748 of them expected over this period. The supply of doctorate holders, however, is expected to reach only 450. On the other hand, if the qualification required for a researcher is met with a master's degree based on the study's content or difficulty, supply could be considered sufficient quantity-wise.

Another conclusion is that the supply of doctoral candidates is also insufficient to stably perform R&D in Costa Rica. Demand for such candidates is expected to reach 422 in 2015–20 and rising. Assuming that dissertation preparation is required for three years after a doctoral student completes the final qualification exam and proposal process and that two-thirds of them graduate, 900 doctoral candidates will be supplied. When comparing these two figures, supply is about twice the demand.

In conclusion, the supply of STEM doctorate holders in Costa Rica is expected to significantly hinder research needs by 2020. Also, the supply of doctoral candidates is expected to be insufficient to perform stable R&D in Costa Rica. The biggest fear, however, is that the gap between supply and demand will widen if the analysis is conducted at sub-major levels even if aggregate supply and demand seem fairly balanced.

Many obstacles and challenges remain for Costa Rica. As supply-and-demand forecasts go through stages of estimation, the data-binding problem at each stage undermines the model's coherence. The lack of a centralized body that processes data and keeps it updated, coordinating with government and public institutions, private sector representatives or chambers, and the heads of higher education institutions (public and private), hinder the application of the forecasting model.

Yet because this is a meaningful process for devising an effective human resource policy, and considering the Korean experience, the Costa Rican government needs to make efforts. The first step is to collect and integrate data on STEM enrollment and graduation from public and private universities and form and operate a small research group to perform analysis on supply-and-demand forecasting from the most basic stages. Nurturing experts and devising a mid- to long-term roadmap are also important. Furthermore, advantages can be gained by organizing committees with the heads of relevant ministries and agencies and task forces with those responsible for their work. Also, a structured and multi-level national qualification system, with professional engineers at its highest level, is the most effective way the Republic of Korea used to quickly provide high-quality technicians and engineers for its fast-growing economy. On a broader context, the creation of a top decision-making body chaired by the president to coordinate science policy was a successful example of the Republic of Korea's attempt to overcome low investment in R&D and university STEM fields.

Looking at history, the Republic of Korea's industrialization experience can be said to have been successful. But the country still needs innovation and is driving it in many areas. In the end, S&T policy should be seen as destiny to change via the process of innovation. Costa Rica is a latecomer in science and technology and innovation, but countries that get more advanced are more likely to see success, and thus a new innovation model from Costa Rica is arousing keen interest.

1. Introduction

The Republic of Costa Rica is in Central America and borders Nicaragua to the north and Panama to the south. It lies between the Caribbean Sea and Pacific Ocean. Costa Ricans, or Ticos as they call themselves, have the highest standard of living in Central America with purchasing power based on per capita income of about US$ 11,500 (US Department of State, 2012). Life expectancy in Costa Rica also trumps that of the US than Americans (Firestone, Miranda, & Soriano, 2010). Several reasons could explain this. Costa Rica has no military, requires primary education that is free, has universal health care and offers a generally stress-free life (Firestone, Miranda, & Soriano, 2010).

Costa Rica is also a prime spot for growing opportunities for FDI, specifically in technology and ecotourism. Over the last several decades, American technology, electronic and medical service companies as well as those from other countries and industries have started operations in Costa Rica. Several leading multinational companies, including Hewlett Packard, IBM, Intel, Procter and Gamble and Western Union, have set up business in the country. In addition, a growing number of Costa Rican companies have appeared to provide products and services globally.

Costa Rica faces a shortage of domestic workers with the necessary knowledge and skills to work in tech industries (Mata, Matarrita, & Pinto, 2012). Several factors constrain the country's capacity to keep up with the growing demand for qualified and trained personnel: (1) the nation's small population and reduced coverage of upper secondary and tertiary education; (2) the limited capacity of private universities to produce computer professionals with advanced degrees; and (3) weak technical and para-academic education.

In addition, R&D investment in this country was just 0.57 percent of GDP in 2014, and participation of the private sector is low. R&D's rate of return in Costa Rica is 34 percent, far higher than the 6-percent return on investment in physical capital (Lederman and Maloney, 2003). Most tech-oriented countries have three to five times more researchers, specifically those dedicated to R&D activities, than Costa Rica (Monge-González, 2016). The number of researchers in Costa Rica dedicated to R&D activities per million people places the country in the middle of the world rankings. In the ratio of R&D expenditure to GDP, Costa Rica is similar to Mexico, Chile and Uruguay, but significantly inferior to most tech-oriented countries, which invest three to eight times more in R&D than Costa Rica does.

Of course, not all innovation needs to rely on formal R&D spending. Importing capital equipment, licensing, worker training, recruitment of more skilled labor, management retooling and efforts to enter (or reposition in) production value chains can also promote innovation. Cohen & Levinthal (1990), however, found that a company's absorption capacity determines utilization of this knowledge and that such capacity itself depends on the company's own R&D. In other words, R&D might not be an essential element of innovation but achieving innovation is difficult when R&D is deficient. This lack of innovation culture helps explain the low number of basic researchers per capita in Costa Rica and why investment in R&D there is poor.

Oppenheimer (2014; 283) said:

> "… a climate that produces a collective enthusiasm for creativity, and glorifies productive innovators in the same way that the great artists or great sportsmen are glorified and that challenges people to take risks without fear being stigmatized by failure …"

Also, Monge-Gonzales, Rivera, and Rosales (2010: 7) said:

> "… for the most part, government failures rather than market failures have been the main justification for PDPs (productive development policies). Even in the presence of market failures, the instruments applied in the policy design are not necessarily the most efficient (according to economic theory), but rather the most politically feasible options (lower political cost) ..."

Under these circumstances, this study sought to understand the status of science and engineering human resources in Costa Rica, improve its capacity to nurture them, and forecast supply and demand for S&T research personnel to make policy recommendations to Costa Rica. More specifically, this study specifically focused on (1) identifying the issues and obstacles that hinders the development process; (2) finding the proper analytic and planning methods or techniques; and (3) recommending which methods or techniques should be developed further for Costa Rica.

- Yet many challenges and obstacles should be expected. They include:
- Human resource development (HRD) forecasting requires skilled staff and an organizational base under a team approach. Researchers with many required areas of expertise remain in short supply in Costa Rica;
- Even if the information generated is of great value to planning, training and management, task and functional arrangements among related institutions have occasionally been considered too complex and costly to execute;
- HRD forecasting has traditionally suffered from being focused on merely surveying workforce numbers while ignoring the long-term process. Proper forecasting requires a long-term perspective that includes survey and DB design, tentative model development and pilot studies;
- Getting an exact picture of the structure and distribution of specific knowledge that a researcher or technician holds is difficult.

Fortunately, Costa Rica provides abundant information conducive to this study. The number of reports and studies on the subjects, relevance and prospective vision of R&D in Costa Rica has increased in recent years, though the field remains highly opaque. MICITT, the country's governing body for science, technology and innovation, has exerted significant efforts from a policy standpoint to keep a systematic record of all data pertaining to this important issue. Yet its datasets are not fully available for independent analyses and need constant updates. Currently available data and reports both share problems due to constraints inherent in existing primary sources.

Despite that data might not always exist for empirical analysis or other quantitative studies, a number of related reports focus on R&D for development. From what this paper has reviewed, a few of the most prominent examples stand out thanks to their systematic approach, technical coherence and academic value.

For instance, Programa Estado de la Nacion (2016), or the State of the Nation Program think tank, has a research agenda that focuses on the political, environmental and economic issues that characterize Costa Rica's context. It has the view that we must find elements that impede the long-term development of society. Thus S&T problems are a transversal element in the analysis of economic possibilities for sustainable development. This year's report specifically covers innovation and its benefits for expanding economies, as well as a means to stimulate the education system and its link to the productive (manufacturing and services) sector. The report also hints at the relation between academia and the private sector as a key factor toward a more dynamic economy and society.

On this matter, MICITT's own report, centered on national S&T indicators (2014), closely examines this relation from a number of perspectives, one being scientific production within academia. This is particularly important given that this is where most top-level applied and basic research is done. This document also poses an indirect question to the problem of employability of Costa Rica's scientific community. Despite evolving into an innovation-based economy, the country still offers little incentive to its technological and scientific experts with highly specialized skills, usually referred to as the diaspora, to return to their country and seek jobs in their fields (limited offer) and/or develop startups.

This affects the Costa Rican R&D ecosystem since highly qualified professionals are mainly located within university research units, with little room for human resource expansion and accounting for the private sector's demand for more technical-oriented personnel, with few options for researchers and experts.

The aforementioned is another issue problematized by State of the Nation's specialized research groups State of the Education (2015) and SSTI (2014). Though each focuses on specific topics, all agree that R&D personnel is severely lacking, particularly considering the country's intention to drastically transform its productive framework into an innovative economy. Furthermore, another factor is the origin and destination of funding and output vis-a-vis human resources (education and specialization) and research projects and areas. The public sector is the main contributor to national R&D but does not execute most of the funds and gets little in return. Again, public HEIs are the ones leading the way in this area.

The World Economic Forum (2016), as well as Costa Rican researchers (Herrera and Gutierrez, Eds., 2011) also agrees the country has fertile ground for innovation and that efforts in this direction must be aligned between academia and industry. Despite having the preconditions necessary for an innovation-driven economy, much room for improvement exists especially in applied research. This will fuel more practical production of goods and services that provide economic stability and growth (strengthen academia-industry links, stimulate STEM research and promote the development of patent-oriented projects).

All these documents and reports are based on papers and workshops that help disseminate this knowledge and, primordially, the importance of emphasizing the R&D sector in Costa Rica. Since most of these are endogenous reports, the main objective is to shed light on opportunities and obstacles, reflecting the potential benefits for sectors, the economy and Costa Rica.

Under these circumstances, this paper will first assess the status of the supply and demand for research personnel in Costa Rica and analyze their competitiveness in Section 2. Then policies and strategies will be proposed aimed at development of a forecasting model using the Republic of Korea's experience and other successful case studies as benchmarks in Section 4. Section 3 introduces cases and examples from the Republic of Korea as references for assessing a tentative model proposed for Costa Rica. The results of the supply-and-demand study are also discussed in Section 3.

2. Status of Supply and Demand for Costa Rica's Research Personnel

2.1. Overview: Population and Employment

This section explores Costa Rican society through its educational advances and employability record. This overview will raise understanding of the possibilities and limitations when modeling and forecasting available research personnel in science and technology.

2.1.1. Demographics

Costa Rica's national statistics agency is INEC (National Institute of Surveys and Census), which collects annual data on the most basic social and economic factors for families and households. For example, it conducts an annual survey on household income nationwide and also measures employment and schooling indicators for families. INEC uses the most up-to-date statistical tools available for these topics.

INEC also produces a comprehensive national census every decade not only to account for population growth, but also to understand social and economic changes occurring in society. The census also helps produce better models of population growth as well as financial cycles.

Thanks to data from both the National Census and Household Survey, INEC has made available the estimated projections for population growth in Costa Rica. Given that the last census was in 2011 and this year's Household Survey is on random sampling, INEC forecast the country's population at 4,890,372 in 2016, and 4,947,490 in 2017. By gender 2016 saw 2,467,825 males and 2,422,547 females and 2017 saw 2,495,770and 2,451,720, respectively.

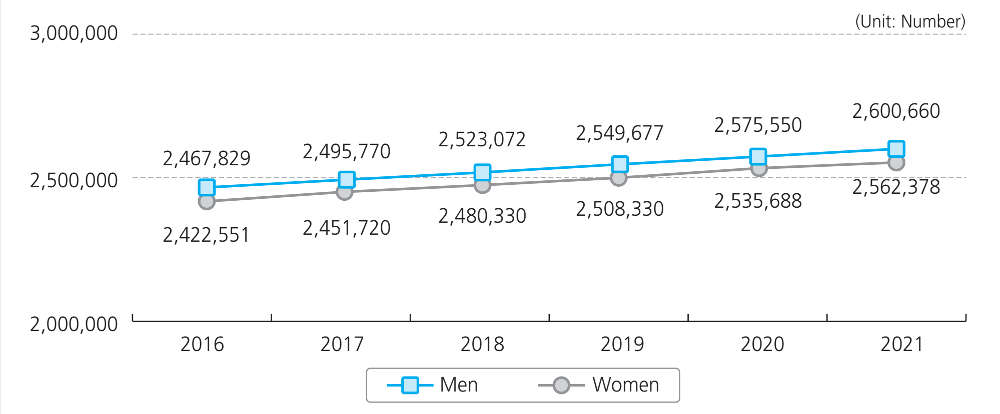
〈Table 2-1〉 Costa Rican Population by Gender and Territorial Distribution

Population	Costa Rica	San José	Alajuela	Cartago	Heredia	Guanacaste	Puntarenas	Limón
Total	4,890,372	607,170	975,023	525,724	497,805	371,375	747,262	439,013
Male	2,467,825	797,959	496,180	264,549	249,865	189,120	243,150	227,002
Female	2,442,547	809,211	478,843	261,175	247,940	182,255	231,112	212,011
Territorial size (km^2)	51,100	496,590	975,753	312,467	265,698	1,014,071	1,126,569	918,852
Population density (per km^2)	95.7	323.6	99.9	168.3	187.4	36.6	42.1	47.8

Source: Author's elaboration with of INEC data, 2015.

<Table 2-1> shows the population distribution by gender and territorial distribution; it also shows population density, which is about 96 people per km^2, with San José accounting for 324 people per km^2. This indicates that life in Costa Rica is heavily concentrated in and around the capital both politically and socially, with all major public institutions in its capital. Out of the estimated overall population of 4,890,379, 1,607,170 live in or around San José. This is an early indication of the dynamics of the country's work and employability landscape, in which centralization of the job market determines intra-national migration to the capital.

[Figure 2-1] Costa Rica's Estimated Population by Gender and Year



Source: Author's elaboration with INEC data, 2016.

[Figure 2-1] shows population growth trends in Costa Rica for 2016-21, according to INEC estimates. It also shows the gender breakdown of the population to precisely determine how the social composition is shifting. Similarly, <Table 2-2> shows a detailed view of sociodemographic indicators for assessing the shift in population growth. For instance, a clear trend is shown in the slowing down of population growth, effectively displaying the social phenomenon observed worldwide: repopulation is insufficient as people grow older and fewer births are seen every year.

〈Table 2-2〉 Sociodemographic Estimates for Costa Rica, 2015-25

(Unit: Number, %)

Indicator	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Annual births	73,831	73,483	73,027	72,478	71,867	71,204	70,513	69,823	69,156	68,519	67,895
Gross birth rate (per thousand)	15.3	15.0	14.8	14.5	14.2	13.9	13.7	13.4	13.1	12.9	12.7
No. of annual deaths	21,187	21,647	22,129	22,631	23,155	23,701	24,269	24,861	25,476	26,117	26,786
(per thousand)	4.4	4.4	4.5	4.5	4.6	4.6	4.7	4.8	4.8	4.9	5.0
Annual growth	52,644	51,836	50,898	49,847	23,238	23,784	24,353	24,944	25,560	26,201	26,870
Growth rate (per hundred)	1.1	1.1	1.0	1.0	1.0	0.9	0.9	0.9	0.8	0.8	0.8
Annual migration	6,841	6,652	6,433	6,220	6,025	5,851	5,695	5,555	5,429	5,316	5,215
Migration rate (per thousand)	1.4	1.4	1.3	1.2	1.2	1.1	1.1	1.1	1.0	1.0	1.0
Annual growth	59,484	58,488	57,331	56,067	29,263	29,635	30,048	30,499	30,988	31,517	32,085
Growth rate (per hundred)	1.2	1.2	1.1	1.1	1.0	1.0	1.0	0.9	0.9	0.9	0.8

Source: Author's elaboration with INEC data, 2016.

2.1.2. Employment

Data from the National Institute of Surveys and Census (INEC) show that Costa Rica's employment rate is 51.8. This figure represents the number of people working per every 100 people of working age (over 15). Given that not every person over age 15 is fit or seeking to work, the unemployment rate is only 9.4 percent (i.e., the number of people out of work for every 100 employed).

In absolute terms, the number of people above age 15 in Costa Rica is 3,832,748 and the working population reaches 1,954,756. The vast majority of this workforce (1,366,509) is employed in commerce and the service sector; in contrast, only 229,038 and 356,145 work in the primary (agriculture, cattle farms and fishing) and secondary (manufacturing and building) sectors, respectively.

In addition, around 87 percent of Costa Rican jobs are in the private sector, thus showing how influential this sector is in the economy. Yet according to data from the Costa Rican Ministry of Science, Technology and Telecoms (MICITT), this sector's participation in R&D and innovation practices is the least accounted for (MICITT, 2016). In worker qualifications, more than half (51 percent) of the active workforce holds jobs requiring mid-level qualifications; 26 percent work jobs needing low-level qualifications and only 22 percent have positions requiring high-level qualifications.

〈Table 2-3〉 Overview of Costa Rica's Active Workforce, 2016

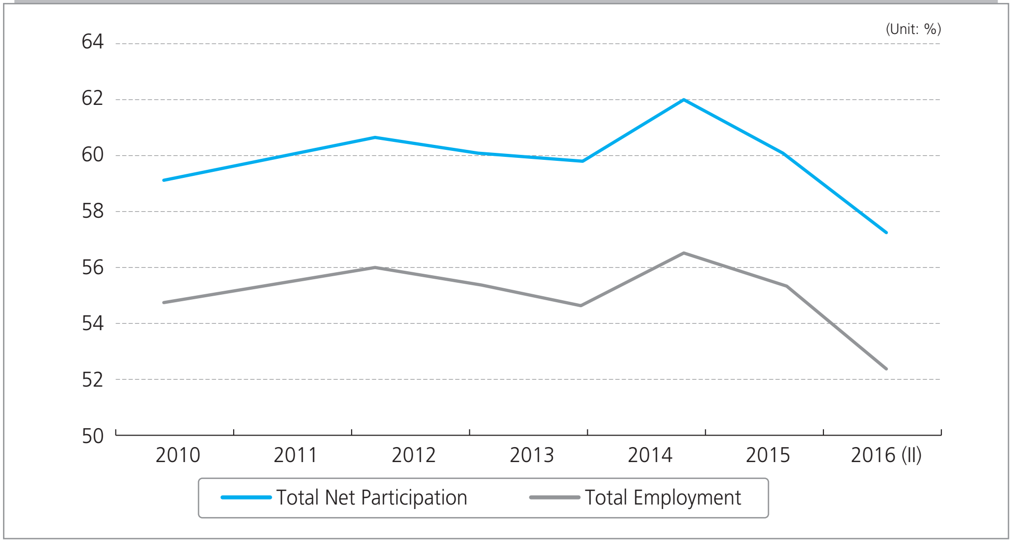
(Unit: Number)

Sector	Estimates		
	Men	Women	Total
Primary	203,498	25,540	229,038
Secondary	290,225	65,920	356,145
Commerce and services	738,332	628,177	1,366,509
Unspecified	2,226	838	3,064
Qualifications			
High	247,573	191,874	439,447
Mid	638,752	357,504	996,256
Low	345,151	169,482	514,633
Unspecified	2,805	1,615	4,420
Sector			
Public	134,018	126,705	260,723
Private	1,100,263	593,770	1,694,033
Unspecified	-	-	-

Source: Author's elaboration with INEC data, 2016.

These figures seem promising but the reality is that the Costa Rican job market has wildly fluctuated over the last past years. [Figure 2-2] and [Figure2-3] show the way those employed in Costa Rica have shifted, mostly toward growth, since 2010, spiking in 2014 and receding over the past two years. Both political and economic reasons have triggered this behavior, but the truth is that 2016 showed lower employment than 2010. This historical description shows the instability of the job market, particularly in sectors that require low-level qualifications (e.g., services, retail and certain mid-qualification jobs such as middle management) (INEC, 2016).

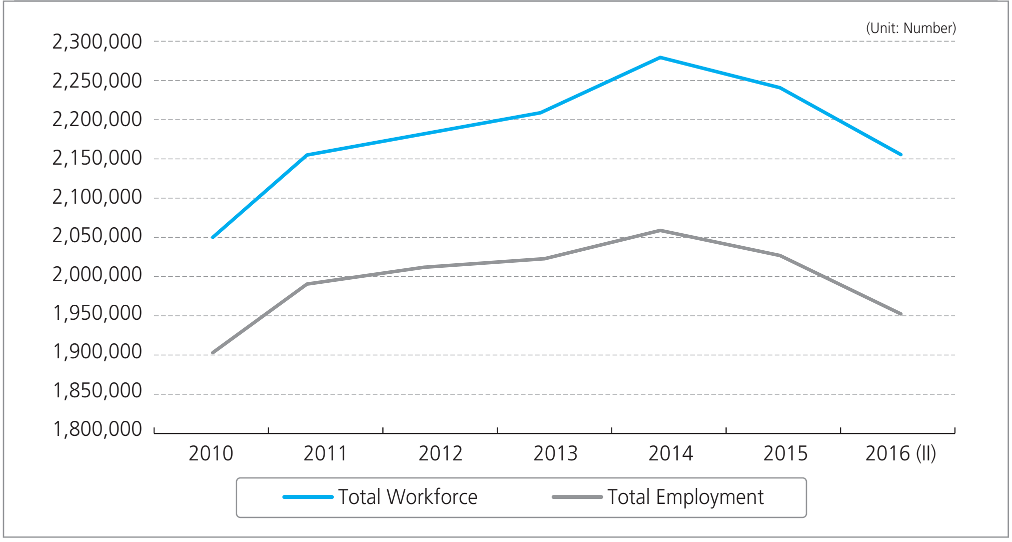
[Figure 2-2] Total Net Participation and Employment Rates in Costa Rica, 2010-16



Note: At the time of collection, data for 2016 was only given for trimesters I & II.
Source: Author's elaboration with INEC data, 2016.

Additionally, the number of people that form the workforce has decreased in absolute figures. Again, after the 2014 spike, nearly 100,000 fewer people were in the age group designated fit to work (over age 15) in 2016. Migration, death and other sociodemographic reasons might explain this shift, but 2016 saw fewer people working than in the previous five years.

[Figure 2-3] Total Workforce and Employment Rates in Costa Rica, 2010-16



Source: Author's elaboration with INEC data, 2016.

2.2. Population and School Enrollment

2.2.1. Education

According to the Costa Rican Investment Promotion Agency (CINDE), "The Costa Rican workforce is recognized for its high education standards and outstanding productivity levels" (CINDE, 2016, p.2). Historically, Costa Rica has received global attention for its outstanding performance in education indicators, especially in Latin America. The main reason for this is the transcendental decision from the 1948 Costa Rican government to permanently abolish the army and other military institutions. Thus financial resources were redirected toward education and health services nationwide.

In Costa Rica, education is a constitutional right and has the same rank to receive financing. The Constitutional Bill of 1949 stipulates that at least 8 percent of GDP must go toward education yearly (this includes primary and secondary schools, as well as higher education institutions). This requirement, however, has not been fully enforced.

Public education is also free and mandatory for every citizen age 5 and above. This also has contributed to expanded access for rural communities across the country as well as for disadvantaged social groups like single mothers, the elderly and indigenous people. This historical trend has resulted in a literacy rate recognized globally as the highest in Latin America and among the top 30 in the world. Costa Rica ranks 28th worldwide in quality of education system (World Economic Forum, 2016) and its adult literacy rate is 97.4 percent (United Nations, 2015). See <Table 2-4> for more details.

〈Table 2-4〉 Costa Rica's Global Competitive Indexes, 2015-16

Indicator	Value	Rank (/140)
4th pillar: Health and primary education		
4.09 Quality of primary education	4.6	39
4.10 Primary education enrollment, net %	90.0	101
5th pillar: Higher education and training		
5.01 Secondary education enrollment, gross %	108.9	14
5.02 Tertiary education enrollment, gross %	47.6	56
5.03 Quality of education system	4.5	28
5.04 Quality of math and science education	4.3	55
5.05 Quality of management schools	5.1	27
5.06 Internet access of schools	4.7	53
5.07 Availability of specialized training	5.1	25
5.08 Extent of staff training	4.5	31

Source: Author's elaboration with World Economic Forum data, 2016.

The Costa Rican education system has an intense focus on the bilingual abilities of students at all levels, thus English has been mandatory in primary and secondary school. Additionally, the National Institute for Technical Education (INA) has implemented several courses to promote practical and advanced knowledge of English through practical experience under a public-private partnership with contact centers, graduating 1,000 students every year since 2005 (CINDE, 2016c).

Education in Costa Rica consists of three main levels: a) primary or elementary school that starts with kindergarten and ends in sixth grade. Graduates mostly continue onto secondary level; b) high school usually receives graduates from elementary school between the ages of 11-15, but exceptions exist for adults and the elderly. This level consists of five years of education in the academic format and six years in the technical format. Both systems conclude with the student taking standardized tests to gain admission into higher education. The main distinction between both formats is that technical students need to take courses alongside a specific specialization in their sixth year, usually on something practical for a partner company. Students can choose from over 55 specialization tracks.

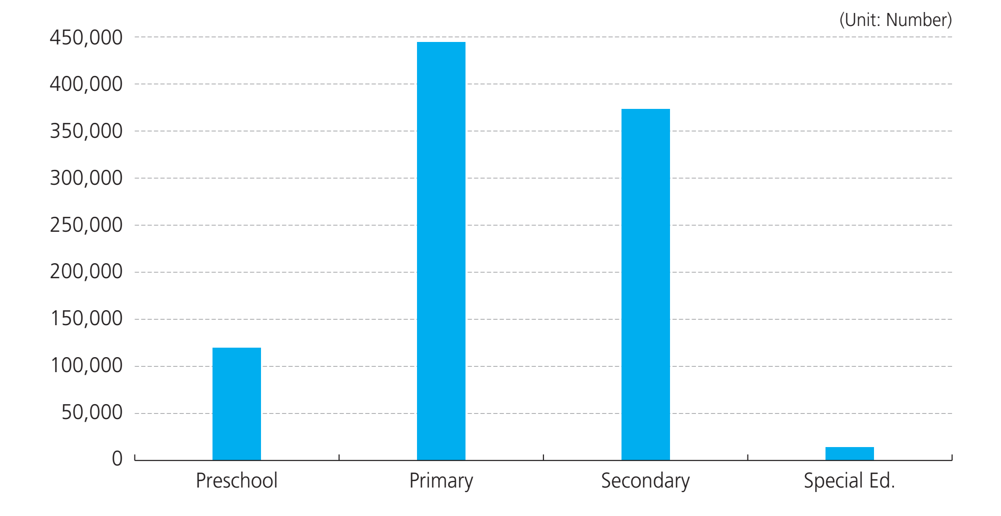
Finally, c) higher education is the tertiary study level of the Costa Rican system. Particularly, most research is done within public universities. The reason for this is that public higher education institutions (HEIs) receive government funding (part of the 8-percent GDP mandatory budget, or precisely 1.5 percent) to invest in the three main pillars of the public university system: education, social outreach and research. This special funding is a constitutional right and needs separate negotiations and approval.[1)] HEIs are divided into public and private; the top five are public - University of Costa Rica (UCR), Costa Rican Technological Institute (TEC), Costa Rican National University (UNA), National Distance Learning University (UNED) and National Technical University (UTN).

2.2.2. School Enrollment

Official records by the Costa Rican Ministry of Public Education Ministry (MEP), say 951,227 students are enrolled in the national education system, including at public (4,516 schools and high schools) and private institutions (686 schools and high schools[2)]) (MEP, 2016, p.1). See [Figure 2-4] for a detailed view of school distribution. This population is nearly to a fifth of the country's total. The majority of students are enrolled at the primary level (444,616), followed by those at the secondary level, both academic and technical (372,512). In line with a previous topic, the estimated budget for the 2016 school year was 7.9 percent of GDP over that same period (which in the Costa Rican currency colon was CRC 2,362.194 million or close to US$ 4.3 billion), showing the limitation that the public school system still sluggish until the present day.

1) The Special Fund for Superior Education (FEES) is an extraordinary budget allocated to the five public universities and negotiated by representatives of each university and the ministers of education, science, technology and education, and treasury.
2) Figure from 2015. Includes semi-private schools that receive financial benefits from the government.

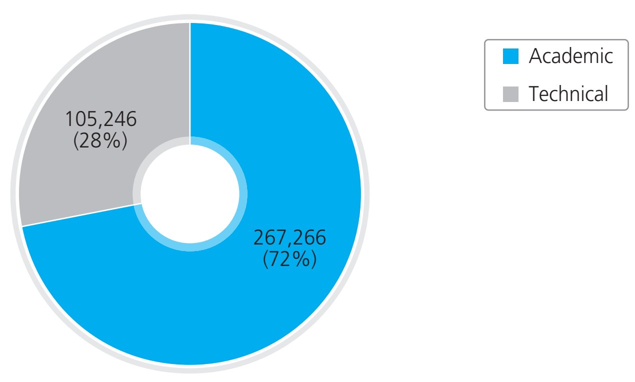
[Figure 2-4] Number of Students Enrolled in Costa Rican Education System, 2016



Source: Author's elaboration with MEP data, 2016.

More specifically, the vast majority of secondary level students enrolled opt to pursue the academic curriculum (72 percent) versus technical programs (28 percent) as shown in [Figure 2-5]. This phenomenon is set to shift systematically as the country deepens its focus on industrial and manufacturing processes, but this contrasts with the nation's ambition to become an innovation-driven economy, which requires a highly qualified workforce.

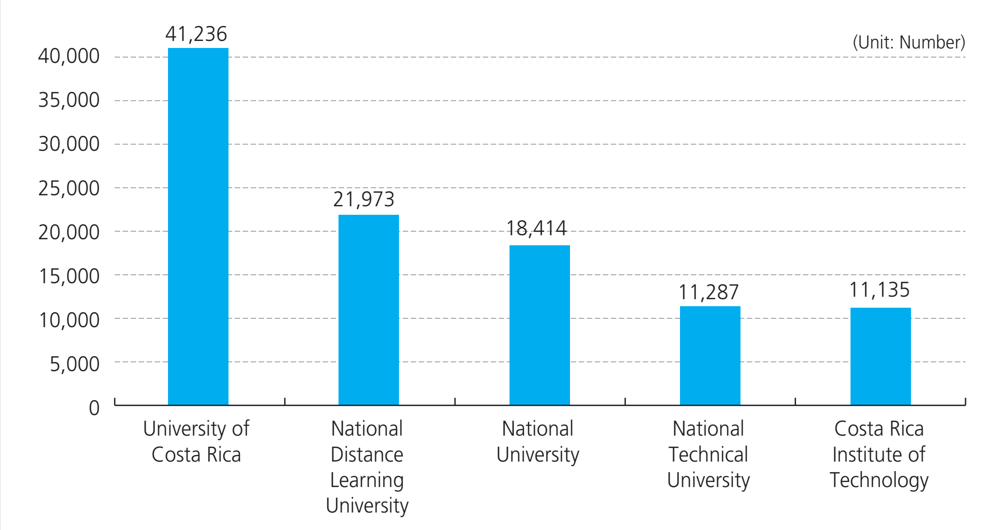
[Figure 2-5] Number of Secondary Level Students in Costa Rican Education, 2016



Source: Author's elaboration with MEP data, 2016.

According to data from each public university's administration and registrar's office, 111,301 active students are in the public HEI system. UCR has the biggest number with over 40,000, from undergraduates to postgraduate and doctoral students. UNA has a student population of nearly 20,000, the third most in the country but second in the number of students living on campus. TEC is the smallest public HEI with over 10,000 students enrolled, but maintains a steady increase in enrollment due to the attraction of STEM students and creation of decentralized campuses. UTN, Costa Rica's newest university, has over 10,000 students thanks to rapid growth since opening in 2010. Lastly, UNED's student enrollment exceeds 20,000, with the caveat that this HEI works under a different academic structure given its nature. It facilitates education to specific social groups but remains accessible by the general public. It serves as a bridge for some to acquire new knowledge or balance existing capabilities.

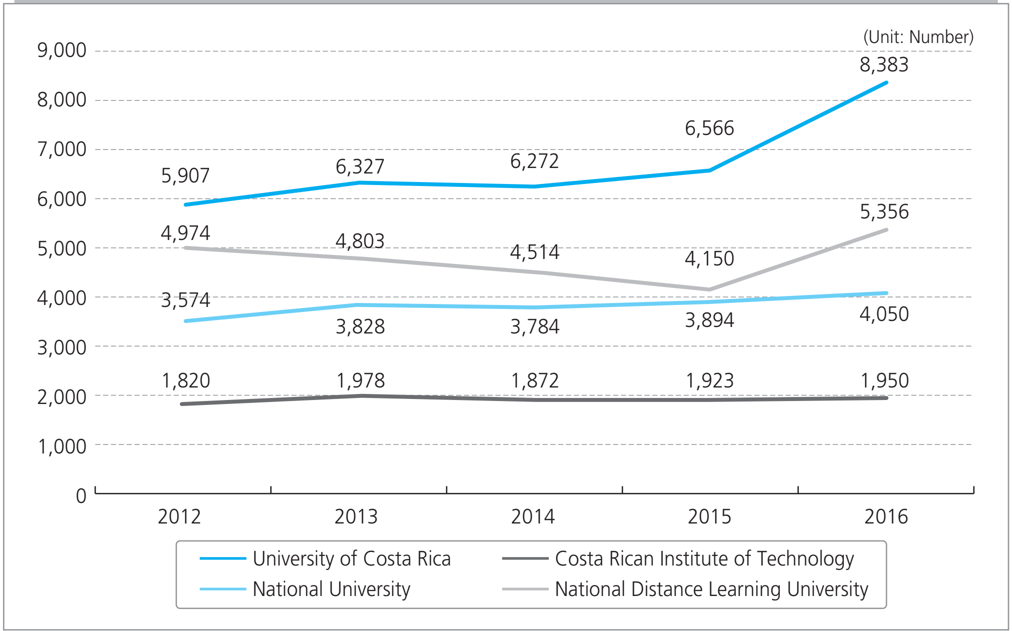
[Figure 2-6] Number of Students Enrolled at Costa Rican Public HEIs, 2016



Source: Author's elaboration with data from CONARE and each university's admission records, 2016.

For public HEIs, in 2016 figures, enrollment was consistent with the data shown in [Figure 2-6]. UCR had the largest incoming class (over 8,000 first-year students), while TEC had the least (just under 2,000). UCR also has nearly three times more campuses than TECacross the territory, covering more potential newcomer students. Only UNED surpasses UCR in this regard (with 34 sites), but given the distance learning modality, such locations are more of a decentralized administrative entity. [Figure 2-7] shows the differences in enrollment among freshmen at the four main public universities (UTN lacks data for the period). As shown, UCR has more than double UNA's admission figures. This alone explains the uneven distribution of the FEES budget (see the following sections), but also creates an imbalance in supply and demand in education.

[Figure 2-7] Number of Freshmen at Costa Rican Public HEIs, 2012-16



Source: Author's elaboration with CONARE data, 2017.

Additionally, next to the five public HEIs are a significant number of private universities (53) accredited by their governing body CONESUP (National Council for Private Higher Education). This entity is located within MEP, thus following certain quality controls on curricular arrangements and institutional obligations needed to operate. The model of private higher education has proven successful, at least from a matriculation perspective, since the number of these institutions has grown constantly since 1995, when the first opened in Costa Rica.

Much discussion and debate have gone toward the quality of education received by students at these universities, considering the number of these institutions still operating. In certain cases, the validity of its titles has been called into question due to shady professional and ethical practices of individuals. However, these private universities offer not only a very diverse range of majors but also more students than public universities on average in the 2010–14 period (State of Education, 2015). According to the State of Education (2015) think tank and CINDE's overview (2016b; 2016c), 201, 602 students were enrolled at public and private HEIs in 2014. That same year, the proportion between public and private enrollment was close (51.4 to 49.6 percent in favor of private), showing growth in student enrollment at private HEIs as seen in <Table 2-5>.

〈Table 2-5〉 Comparison of Enrollment at Costa Rica's Public and Private HEIs, 2000-14

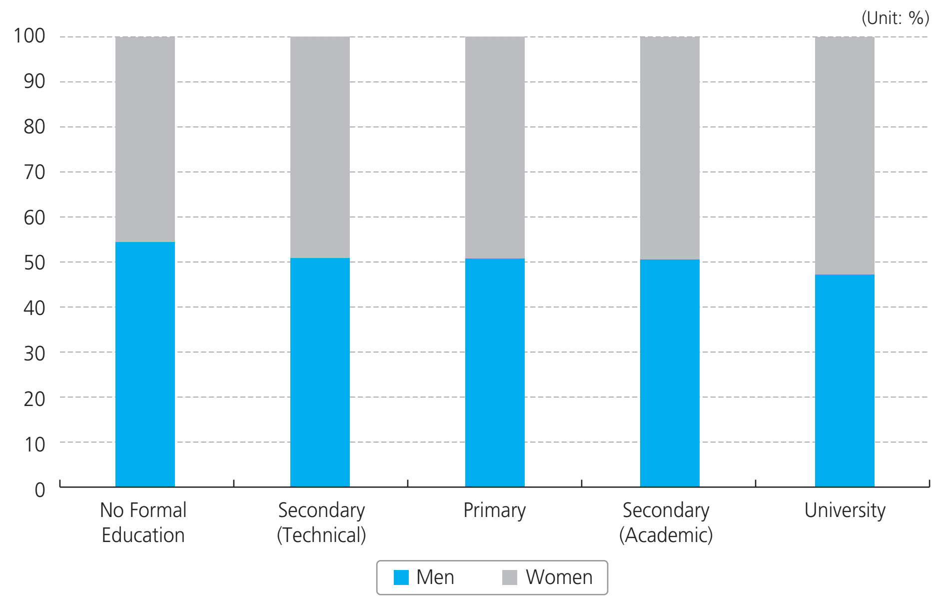
(Unit: Number)

	2000	2005	2010	2014	2000-14 Avg.
University Matriculation					
Public university matriculation (first semester)	60,960	71,878	81,288	101,547	78,918
Private university matriculation	...	...	95,399	100,055	97,727

Source: Author's elaboration with State of Education data, 2015.

In addition to these figures, how the education system has impacted society through its various stages requires oversight. To do this, a look at the education levels of the workforce (or economically active population or EAP) by gender is warranted. For example, Costa Rica sees higher literacy in women than in men, and this trend appears especially when knowledge specialization becomes greater, that is, when advancing in the education system. This means the country has more illiterate men than women; conversely, more women are enrolled in or graduated from university. [Figure 2-8] shows more about this trend.

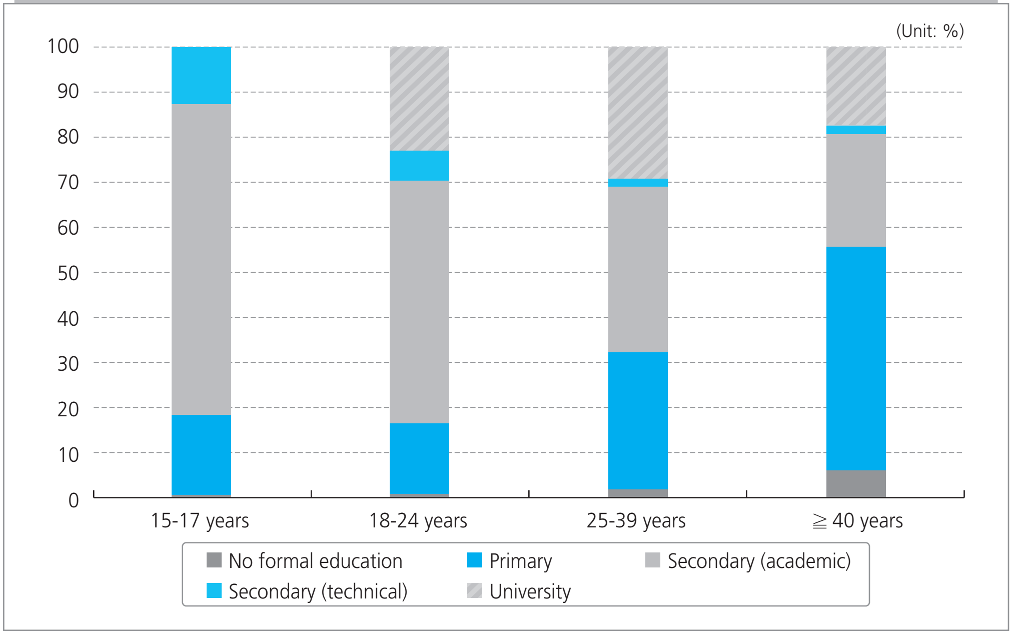
[Figure 2-8] Education Level of EAP in Costa Rica by Gender, 2015



Source: Author's elaboration with INEC data, 2016.

Another significant factor is the education levels of the population, specifically among age groups that shape society as a whole. Reflecting the EAP again, university education is clearly greater in the younger segments of the population (ages 18-39). On the contrary, higher education is not popular among older groups, as under 20 percent of those age 40 or older have attended university. And given the nature of Costa Rica's social advances in education and the relatively newness of HEIs, close to 60 percent of those age 40 or older only have finished primary education (see Figure 2-9).

[Figure 2-9] Education Level of Costa Rica's EAP by Age Group, 2015

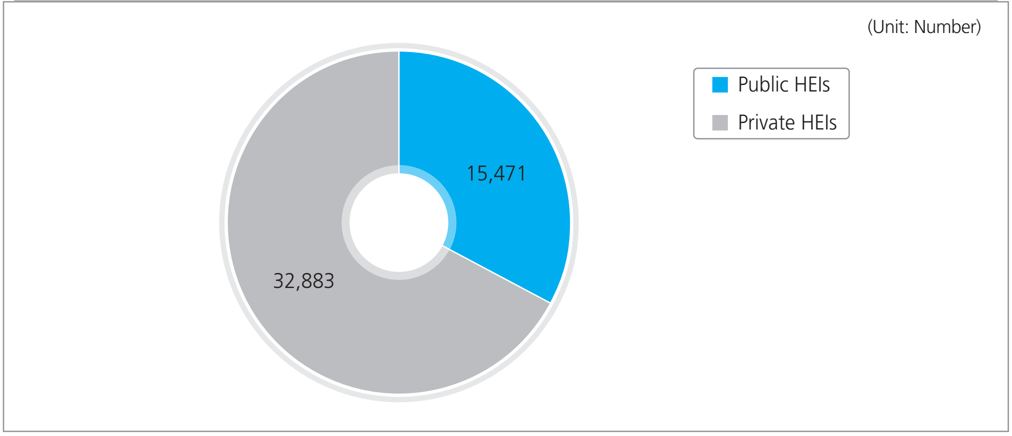


Source: Author's elaboration with INEC data, 2016.

Nearly 84 percent of Costa Rica's population ages 18-24 have been or are enrolled in the education system, be it secondary or tertiary level. That reflects an optimistic landscape where highly qualified personnel can flourish and develop a more sophisticated workforce, fulfilling the objective of becoming an innovation-based economy in the not-so-distant future.

Thus the overall number of graduates in Costa Rica merits attention. This leads to a broader picture of the state of higher education in evaluating the impact of education-related policy, especially in science and technology. As previously mentioned, private universities do not perform research so public HEIs carry all the weight in that area; private HEIs, however, do have the majority of the population at this level of education. To exemplify this, [Figure 2-10] shows the number of university graduates in Costa Rica and the relation to either public or private institutions. The country has 53 private HEIs with varying levels of scientific commitment and academic rigorousness, partly adding to the reason of the notable offset in graduate output (notwithstanding the previous statement about ethical issues and professional practices).

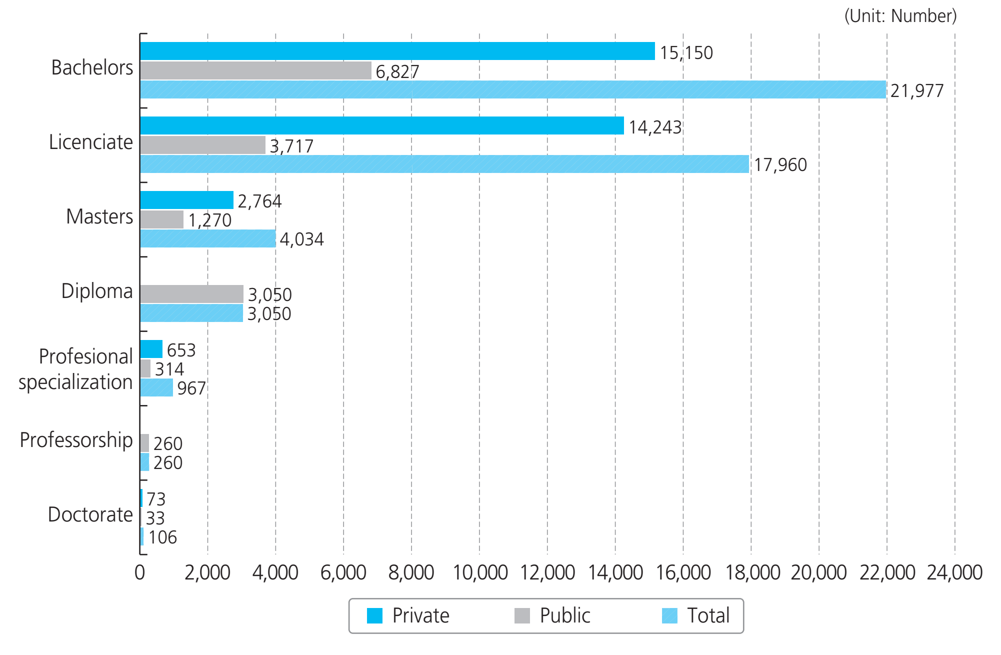
[Figure 2-10] Number of Diplomas Given by Costa Rican HEIs, 2015



Source: CONARE, 2017.

A glaring weakness of Costa Rica's higher education landscape is the relative lack of doctorate (Ph.D.) holders. In contrast, the higher education system seems to promote low-level specialization. This might not be the case for R&D activities or S&T areas, but technical-level personnel outnumber highly specialized researchers or doctoral candidates. This could cause problems in the near future (or now) as lower-level specialization leads to lower added value. Thus innovation-based products and services are less likely to appear in such an ecosystem. This data also sets the foundation for a scenario in which few Ph.D.-level researchers conduct a limited number of R&D projects, most of them within academia. [Figure 2-11] shows the number of diplomas awarded in Costa Rica , as well as distribution per sector (public and private).

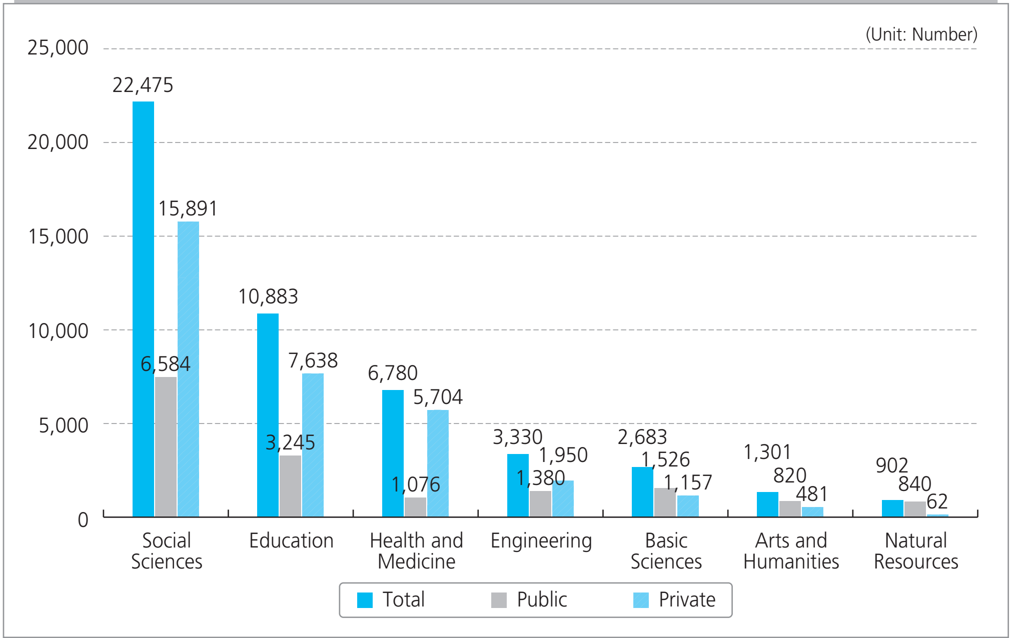
[Figure 2-11] Number of Diplomas Awarded in Costa Rican Higher Education by Level, 2015



Source: Author's elaboration with CONARE data, 2017.

In line with the last data shown, the main fields of study when completing a degree in Costa Rica requires attention. As will be discussed later, Costa Rica's research ecosystem has been mostly driven by social-related issues. In other words, the social sciences show the largest output of diplomas at both public and private HEIs. Though desirable to a degree, a glut of students and graduates in fields exceeding their demand equilibrium in the number of graduates is troubling. Health and medicine, however, seem to have a greater share of the professional output of HEIs. Incidentally, science and engineering considerably lag behind the former sector. This, parallel to what [Figure 2-15] shows on the relation of a master's and Ph.D. to engineering and technology, appears to be counterproductive, creating an R&D dependence on a few people conducting a small number of research projects. [Figure 2-12] shows this distribution in greater detail.

[Figure 2-12] Number of Diplomas Awarded by Field in Costa Rica, 2015

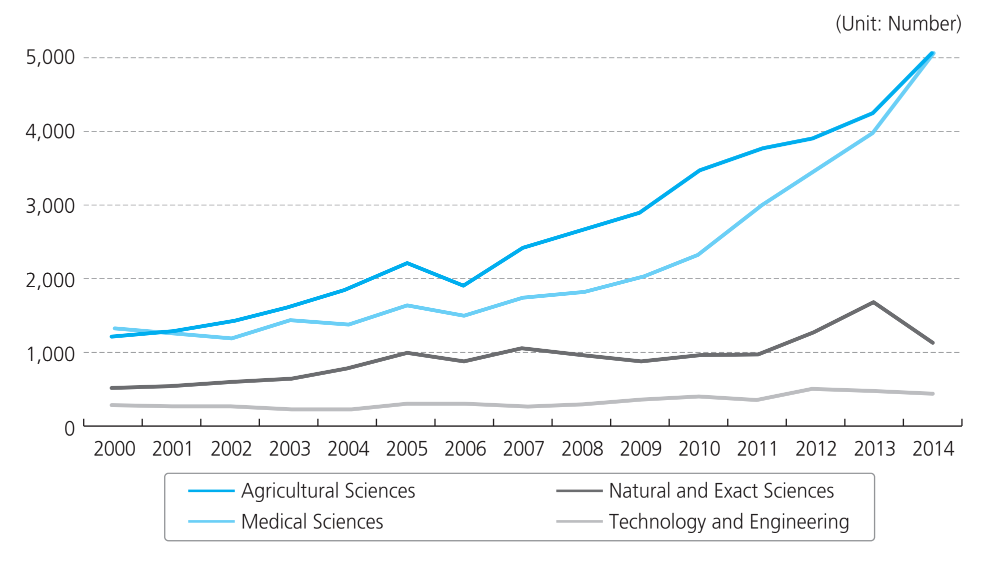


Source: Author's elaboration with CONARE data, 2017.

Following the last idea, State of the Nation's think tank HIPATIA has produced a series of statistical records specifically centered on science, technology and innovation called State of Science, Technology and Innovation (SSTI) in 2014. These records try to systematically arrange the available information on these areas to serve as input to stakeholders and top-level decision makers in the country, aiming to strengthen scientific production, spending on innovation and development into a more dynamic economy.

[Figure 2-13] presents valuable insight into the evolution of STEM fields in Costa Rica by considering the number of graduates from programs in these areas. The period between 2000 and 2014 showed continuous growth in most of these fields, especially medical science and technology and engineering.

[Figure 2-13] Number of STEM Graduates in Costa Rica by Sub-field, 2000-14

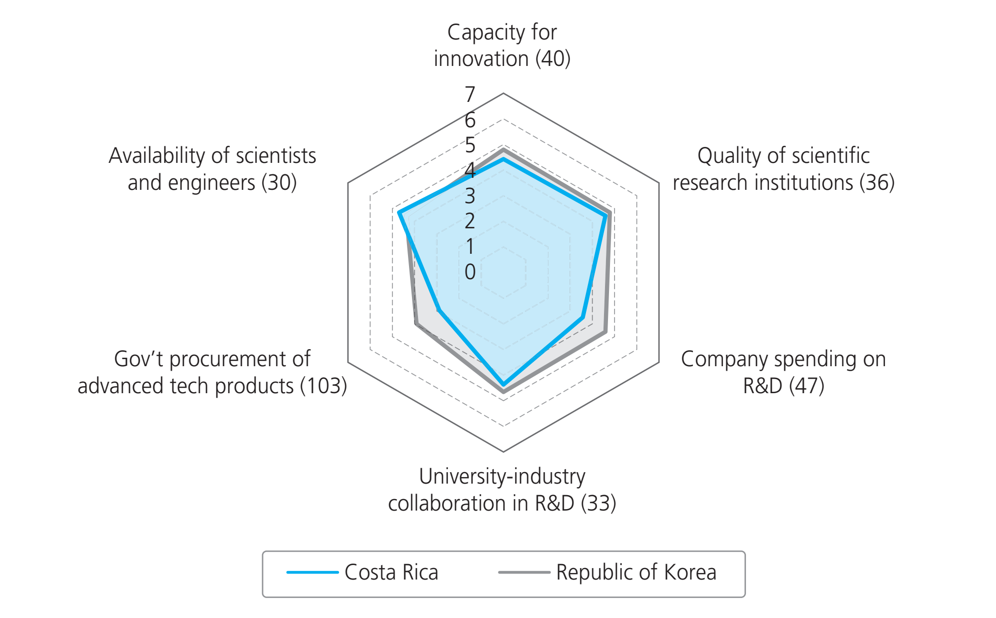


Source: Author's elaboration with data from State of Science, Technology and Innovation, 2016.

Finally, Costa Rica has good upside in competitiveness on a global scale. Data gathered by the World Economic Forum (2016) enables a detailed view of this. For example, considering the 12th pillar of the innovation-focused Global Competitiveness Report, Costa Rica shows impressive results with most of its indicators in the global top 40. This is a major achievement considering the country's institutional and economic limitations. To put things into perspective, [Figure 2-14] displays the data for the innovation pillar for Costa Rica and the Republic of Korea. This allows comparative observation of the situation and prospective advances for Costa Rica to become an innovation-driven economy, such as the Republic of Korea. Costa Rica has also remarkably established itself within that range despite limited R&D funding (see the following sections) and highly specialized research personnel.

The Republic of Korea has an overall better score than Costa Rica (scores are graded on a scale of 1-7), but similarities between the two exist. For example, both countries have a significantly close score in the indicator for quality of scientific research institutions, as well as that for university-industry collaboration in R&Ds. Costa Rica, however, surpasses Korea in the indicator for availability of scientists and engineers, which speaks both good and bad about the Central American country's employment situation. Despite the global diaspora of Costa Rican scientists and engineers, opportunities offering job security and conditions in Costa Rica are scarce. This is an unresolved issue prioritized by public HEIs and corporations to create top-level research and innovation, causing a brain drain in more critical and specialized fields such as physics, biochemistry, biotechnology and applied computation.

[Figure 2-14] Comparison of Innovation Indicators of Costa Rica and Republic of Korea



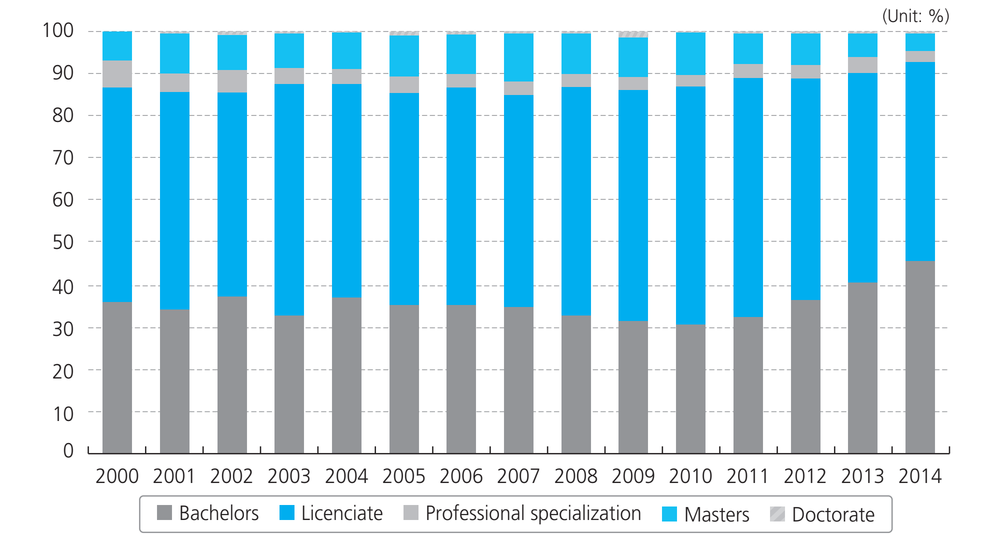
Source: Author's elaboration with World Economic Forum data, 2016.

2.3. Research Personnel by Sector

R&D figures and statistics in Costa Rica are widely dispersed and not standardized among bodies and institutions. The multiplicity of actors in the promotion of sci-tech activities make it difficult to obtain and systematically process this information. But efforts from specialized think tanks and public institutions have gone toward offering the most up-to-date data available. Institutions like MICITT and the State of the Nation think tank Hipatia (SSTI) are the key actors in analyzing R&D practices in Costa Rica over the past few years and their prospects.

A key finding in research personnel, derivate of the number of HEI graduates in Costa Rica, is degree of specialization. This is reflected in the last academic title obtained and, according to INEC data, just a fraction of the EAP (2 percent) has obtained a post-graduate degree or is enrolled in a program leading to one (e.g., specialization, master's or doctorate). This is particularly similar when observing STEM graduates. [Figure 2 -15] shows the distribution of degrees obtained by graduates working in STEM fields in Costa Rica who make up the national scientific registry. As presented, under 15 percent of all graduates in all areas have a master's, doctorate or even a professional specialization.

[Figure 2-15] Distribution of Degrees Held by STEM Professionals in Costa Rica, 2000-14



Source: Author's elaboration with data from State of Science, Technology and Innovation, 2016.

As mentioned in the previous section, Costa Rica had over 11,000 STEM graduates as of 2014. Nonetheless, according to MICITT data, only 6,370 (54 percent) professionals were working in R&D in the country over the same period.

The disaggregation of this figure shows a persistent gender gap in this area, as well as a predominance of research and technical personnel and disregard for doctoral candidates, who are a clear minority per the previous figure. An important aspect is the decline in the number of R&D personnel over the past few years, falling from a record 7,708 to the mentioned 6,370 in 2014. <Table 2-6> shows this data in greater detail.

〈Table 2-6〉 R&D Personnel in Costa Rica by Occupation and Gender, 2010-14

(Unit: Number)

Occupation and Gender	2010	2011	2012	2013	2014
R&D Personnel, Total	6,156	7,708	6,483	7,193	6,370
Researchers	3,384	3,970	3,414	3,884	3,776
Men	1,896	2,172	1,876	2,185	2,118
Women	1,401	1,636	1,538	1,699	1,658
Disaggregate	87	162	0	0	0
Doctoral Candidates	185	417	216	407	296

⟨Table 2-6⟩ Continued

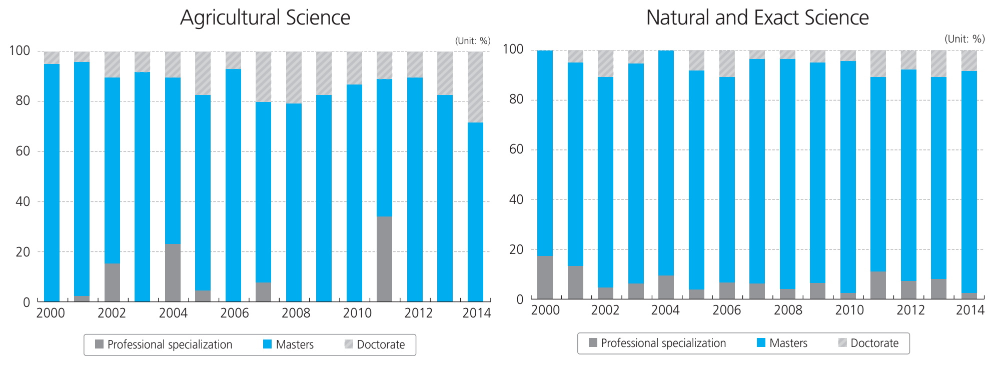
(Unit: Number)

Occupation and Gender	2010	2011	2012	2013	2014
Men	111	235	136	185	151
Women	74	185	80	147	145
Disaggregate	ND	ND	ND	75	0
R&D Technical Support Staff	2,587	3,321	2,853	2,902	2,298
Men	1,336	1,676	1,297	1,503	1,213
Women	864	1,253	871	1,022	708
Disaggregate	387	392	685	377	377

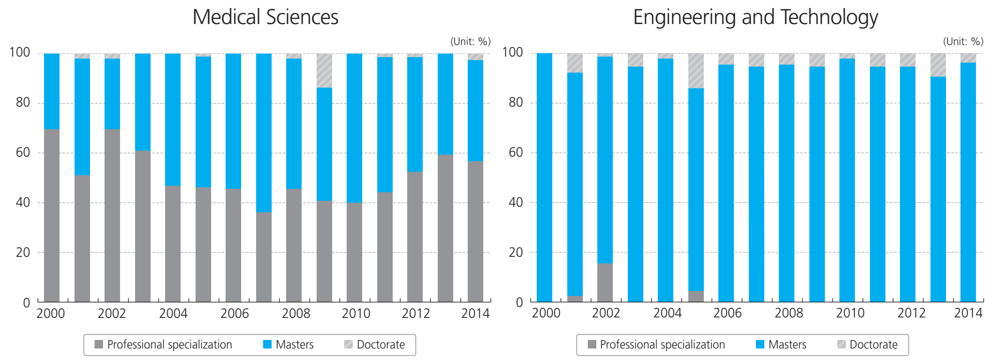
Source: MICITT, 2016, p.46.

This presents another peculiar trait of the Costa Rican R&D system: a deficiency of professionals with postgraduate education and, in turn, the sector's use of technical staff to implement R&D agenda. The ratio of researchers to technical staff is 3:2, meaning researchers and support staff work hand-in-hand in scientific and innovation projects. This is good for knowledge transfer and cooperative work. Given Costa Rica's drive toward becoming an innovation-driven economy, a highly specialized workforce should be a principal asset in the R&D ecosystem. In Costa Rica, unfortunately, this is not the case. [Figure 2-16] shows the proportion of postgraduate degrees held by STEM professionals in agricultural, medical, natural and exact sciences, engineering and technology. What this shows is a clear indication of the lack of incentive in these fields to get a degree beyond a master's, as just 3 percent (in engineering and technology) of professionals hold a doctorate.

[Figure 2-16] Distribution of Postgraduate Degrees Obtained by STEM Professionals in Costa Rica by Area, 2000-14



[Figure 2-16] Continued



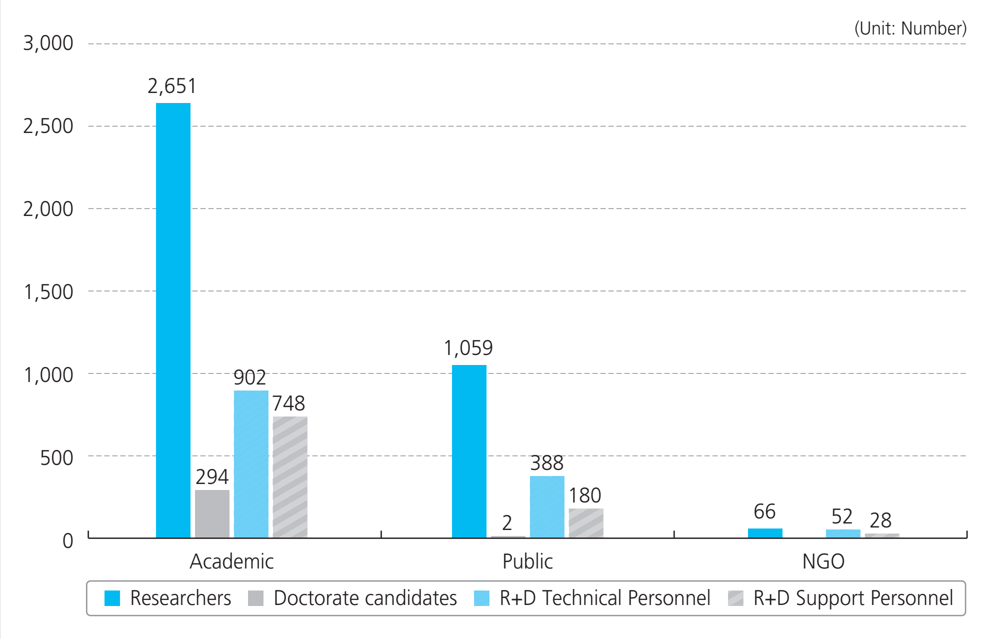
Source: Author's elaboration with data from State of Science, Technology and Innovation, 2014.

A reason for the dearth of highly specialized professionals, as mentioned before, could be lack of incentives for R&D personnel in Costa Rica (SSTI, 2014) due to a relatively small ecosystem for innovation that requires skills and expertise. In addition, disconnection between clusters of research and S&T activities is perceived as a negative sign of an underdeveloped environment. This is mostly due to a large chunk of national R&D spending coming from the government directly through its institutions or from public HEIs.

Due to this situation, the job market for R&D specialists is highly concentrated in academia. This is why a major portion of R&D is done at public universities and why almost 40 percent of highly qualified professionals go abroad for jobs, usually to countries where they earned their degrees or where demand for specific professionals is high, typically the US or Europe.

So research personnel tend to be classified in four categories (for which data is available for three): academic, public and non-government organization (NGO). The fourth category is the private sector, but due to the dispersion of companies doing R&D as well as the lack of systematic information and data, this sector is not counted in any report on or analysis of human capital.

[Figure 2-17] R&D Personnel in Costa Rica by Occupation and Sector, 2014

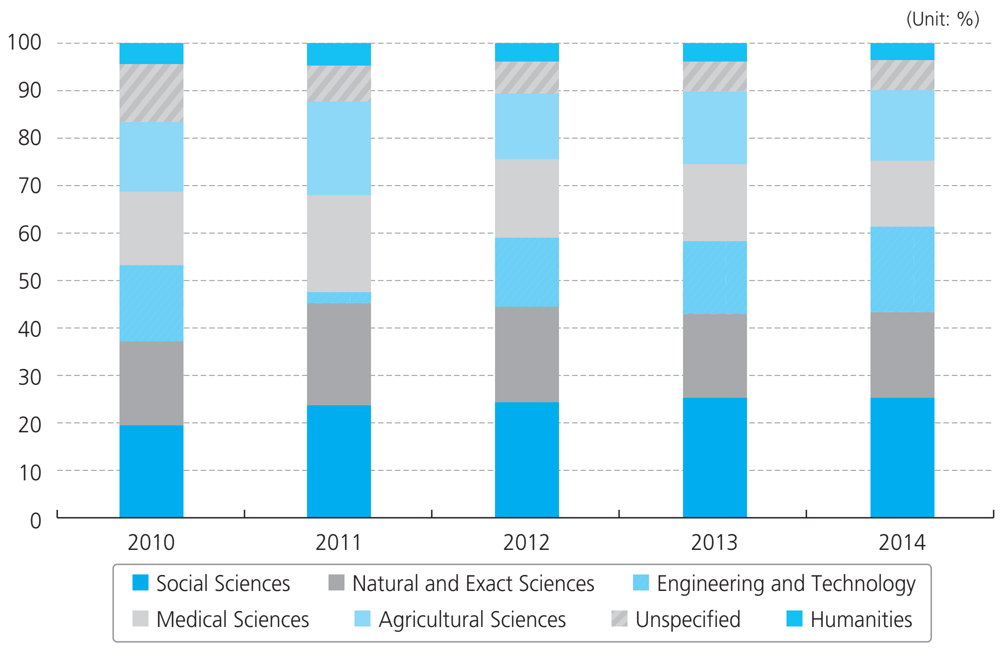


Source: Author's elaboration with MICITT data, 2016.

[Figure 2-17] shows the distribution of R&D personnel by specific duties in the three aforementioned sectors from a comparative perspective. In absolute figures, the number of researchers decreased, as did that of R&D staff, from 7,193 in 2013 to 6,370 in 2014. Per MICITT (2016) a big reason for this was the fall in the number of research projects carried out. The number of researchers working in academia increased but fell among public institutions. One clear trend is the lower number of support personnel in the public and NGO sectors. Again, this might be partially explained by the general decrease in R&D projects.

Another relevant factor is the distribution of these researchers by their respective areas of specialization, or the majors they pursued in earning postgraduate degrees. As seen in [Figure 2-18], most R&D professionals are well distributed along all areas of knowledge. Interestingly, a predominance of social scientists is seen working in research fields, next to natural and exact science graduates. The main issue of this trend is that most research carried out by professionals in these areas are mainly theoretical and basic. Areas that tend to produce empirical and applied research and consequently development have fewer researchers. [Figure 2-18] illustrates this in more detail.

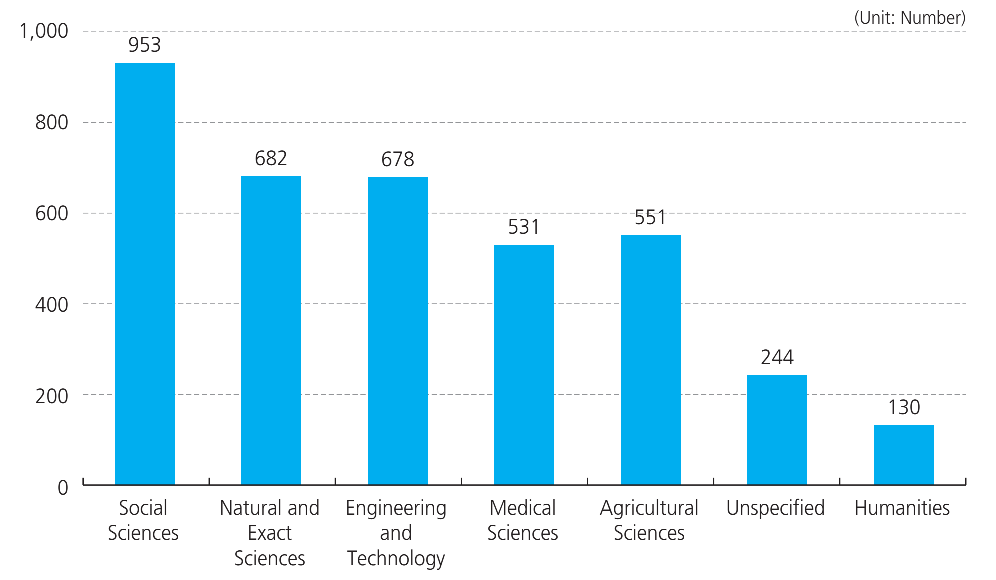
[Figure 2-18] R&D Researcher Distribution in Costa Rica by Specialization, 2010-14



Source: MICITT, 2016, p.49.

In the last year available for this data (2014), the distribution of researchers by specialization merits attention. This sheds light and reinforces the R&D paradigm that the Costa Rican research ecosystem has nurtured. As previously mentioned, the country's R&D is based primarily on academic projects, most of which have no real-world application or innovative value. Parallel to that, private sector research is done by SMEs that get funding from external bodies (government and other institutions), with little observable impact on society. Additionally, academic R&D is based primarily on non-key areas for innovation-based development such as the social sciences. For instance, nearly 1,000 researchers were in the said field in 2014 and a combined 1,360 researchers in natural and exact sciences engineering and technology. This puts heavy pressure on the higher education system to readjust itself and pursue other goals that better align with the country's development objectives. [Figure 2-19] shows the number of researchers per field in 2014.

[Figure 2-19] Number of R&D Researchers in Costa Rica by Specialization, 2014



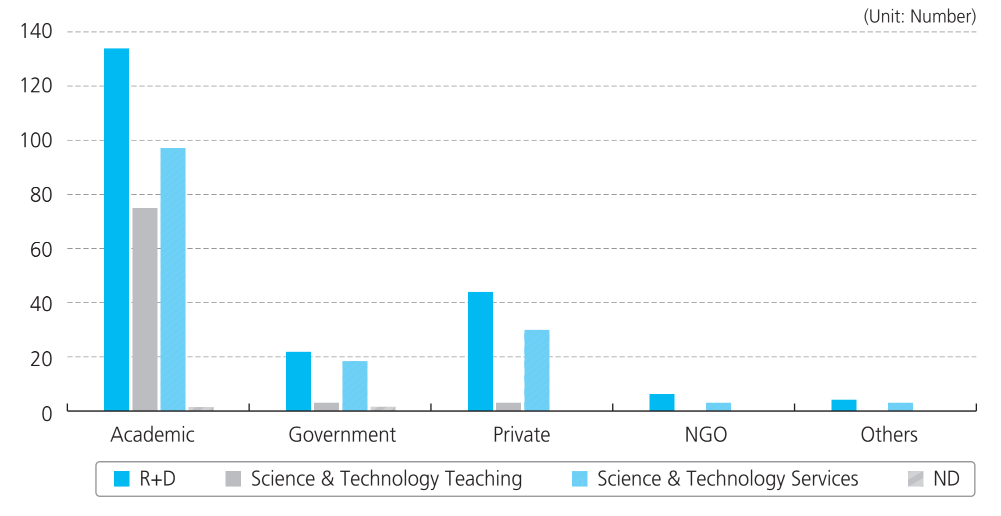
Source: MICITT, 2016, p.49.

2.4. R&D Expenditures

2.4.1. R&D Sectors and Activities

As mentioned before, R&D is mainly done within the public sector, whether at public institution or HEI. In that sense, public R&D budgeting is mostly directed toward public education, or more specifically public universities and specialized research organisms within them. Private R&D investment, on the other hand, primarily goes into three main subsectors: manufacturing, energy and telecommunications; and the service industry and agriculture. Despite the major impact private R&D had on the country's overall R&D expenditure during 2014 (MICITT, 2016), no disaggregated records show just how exactly these figures weigh on the overall industrial landscape.

[Figure 2-20] R&D Units in Costa Rica by Sector, 2015



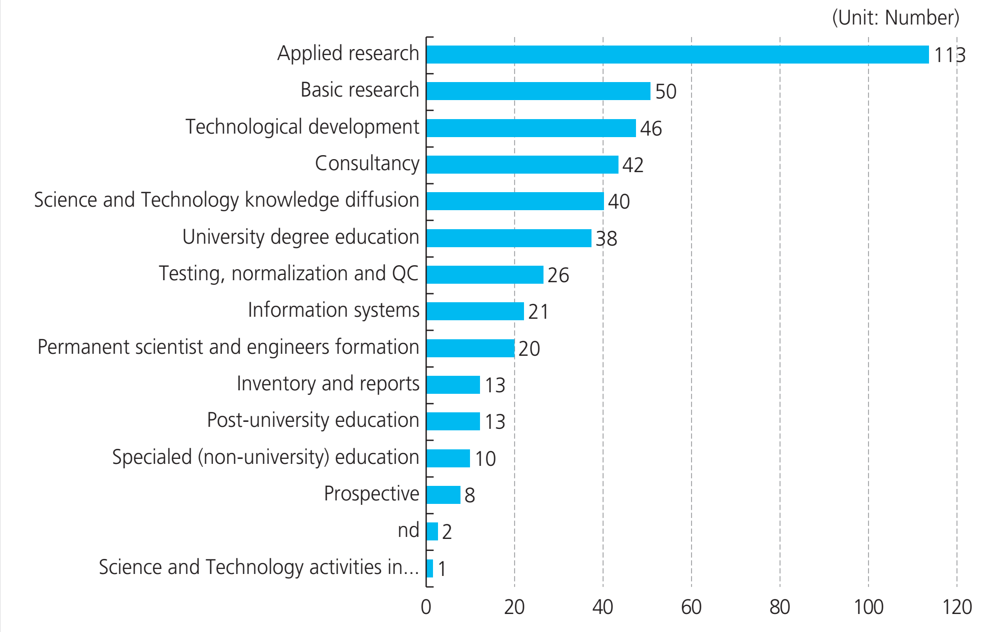
Source: Author's elaboration with Hipatia data, 2016.

Recent data from the SSTI think tank Hipatia (2016) for 2015 shows a slight uptick in the number of R&D units in Costa Rica from that registered by the State of Education in 2014 (130). This in line with the trend of academia carrying most of the weight in absolute participation (see Figure 2-20). But private industries are getting more active in the expansion of Costa Rica's R&D ecosystem, either via direct investment or promotion of indirect means of R&D and S&T activities.

Yet the registered participation of the private sector remains limited to company-level innovation (processes), whereas academia specializes in generating services and knowledge transfer of research results. According to the same dataset (State of Science, Technology and Innovation, 2016) about 307 R&D units are in the academic sector, far more than the 77 in the private sector. Conversely, the government seems to lag in R&D, often outsourcing these activities to other sectors (including NGOs), registering only 44 R&D units in 2015.

Especially in STEM fields (the ones made available by Hipatia), applied research is the principal activity these R&D units focus on, with more than double the activities of basic research and technological development. This attests to the kind of recent efforts put into R&D, with applied research (typically constant in medical and agricultural sciences and engineering) a major trend (see Figure 2-21). This is in contrast to the aim of effective application of this research, namely an increase in the number of patents. Nonetheless, Costa Rica has low production of only 1.4 patents per million people for 64th in the world, far lower than the Republic of Korea, whose patent rate exceeds 200 per million people (World Economic Forum, 2016).

[Figure 2-21] Activities of Costa Rican R&D Units, 2015



Source: Author's elaboration with Hipatia data, 2016.

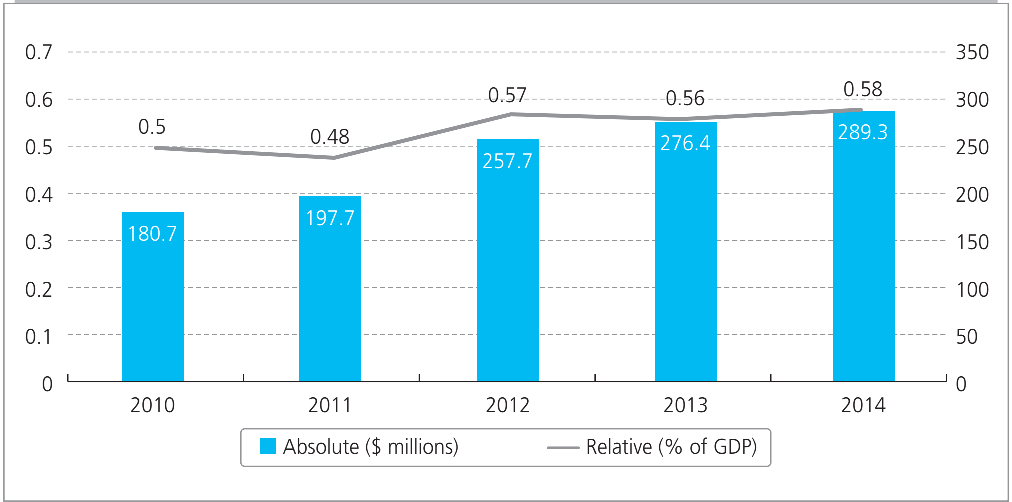
2.4.2. R&D Expenditures in Costa Rica

R&D spending could be distorted according to each information source. The main reason is lack of uniformity in data systematization across and within sectors. Plus private investment in R&D is sometimes impossible to attain given the secrecy with which companies treat their data. Both national and international entities have close approximations of R&D expenditures in proportion to GDP, with slight differences in sector weight and absolute numbers.

Additionally, data remain out of date and despite the information available, represent a limitation in understanding reality and prospective actions. This will be discussed in a further section.

Costa Rica has a number of data sources on R&D expenditures; one of the most accurate and trustworthy is MICITT, which is in charge of systematizing this information. Many of the other sources use data from MICITT to delve into the subject. According to MICITT (2016), the estimated R&D budget (all sectors included) in 2014 was about US$ 289 million, or just 0.58 percent of Costa Rica's GDP for that period (see Figure 2-22). The figure is considerably low compared to those of member countries of the Organization for Economic Cooperation and Development (OECD), whose average is 3 percent, and even lower than the Latin American average (0.75 percent) (MICITT, 2016).

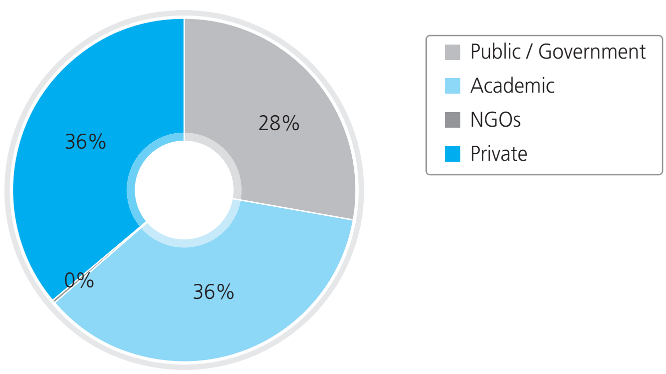
[Figure 2-22] R&D Expenditure in Costa Rica in Proportion to the GDP, 2010-14



Source: Author's elaboration with MICITT data, 2016.

A few caveats to this estimation are in order. The budgets invested in R&D can be known only in terms of the total amount, and are not classified by sub-fields. Other sources such as Hipatia (2016) disaggregate this figure to see the effective weight of sectors such as public institutions, academia and private industry. The same principle is followed by the Science and Technology Indicators Network (RICYT). This considers two sectors that help understand the R&D ecosystem and its growth or contraction: funding and performance.

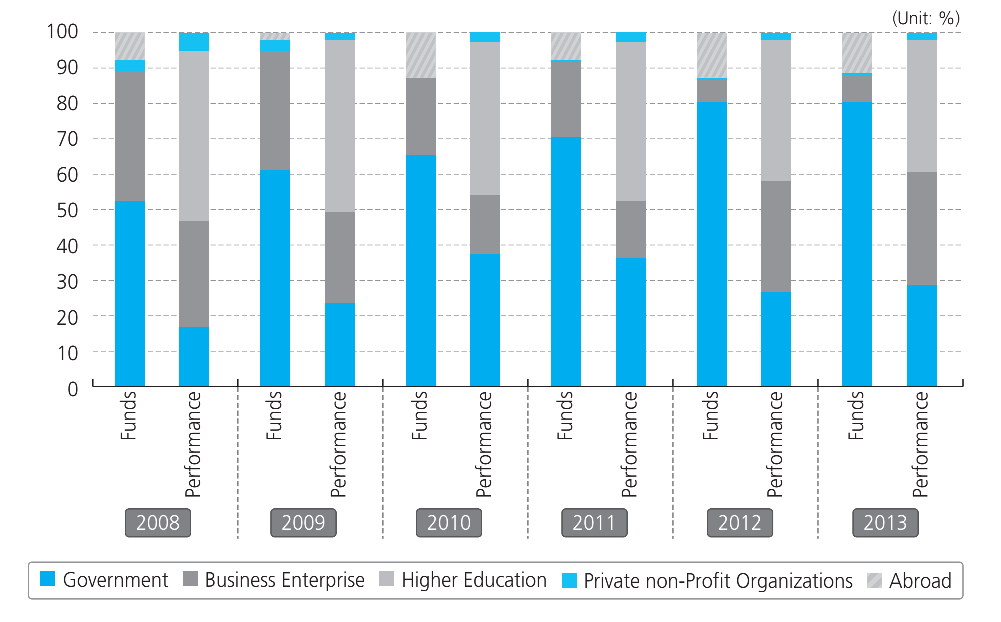
[Figure 2-23] R&D Expenditure in Costa Rica by Performance Sector, 2014



Source: Author's elaboration with MICITT data, 2016.

[Figure 2-23] visualizes the latest dataset available (2014) on the performance sectors of R&D resources in Costa Rica. This refers to the bodies executing the funding acquired through research projects, contracts or other means. Both academia and the private sector share the weight in relation to the use of R&D resources available over that period. Yet both sectors appear to be the lesser contributors in funding the R&D ecosystem. As [Figure 2-24] shows, the usual pattern of funding is to have big government input, with limited resources coming from abroad (in the form of small-scale venture capital) as well as little contribution from non-profit organizations. Another clear trend is the consistent decline in R&D funding from private businesses, yet conversely, recent years have seen a rise in the private sector's participation in this sector vis-a-vis the execution of available funds.

[Figure 2-24] Costa Rica's R&D Funding and Performance by Sector, 2008-13



Source: Author's elaboration with RICYT data, 2016.

This is partly explained by the incentives private companies can obtain from the government. Basically, given that big tech companies do virtually all of their R&D in-house, public institutions have opted to provide applied research grants. So government entities such as MICITT allocate public funds (more recently international cooperation funding) to programs for assisting small and medium enterprises (SMEs). One example of this is the funding programs available through MICITT focused on S&T SMEs and entrepreneurs. The intention is to promote the development of an endogenous R&D ecosystem that links other productive sectors, thus generating a more dynamic S&T environment. This explains the private sector's higher participation in R&D performance.

Academia's role in R&D expenditures features a bit of ambiguity in its categorization. Public HEIs receive funds equal to 1.5 percent of GDP and part of the 0.58 percent of domestic R&D investment. This indicates that public HEIs merely allocate small fraction of their annual budget to R&D, showing a misalignment between budgeting and real expenditures within these institutions. For example, CONARE has data on each university's R&D budget. For obvious reasons, public HEIs refrain from allocating all of their budgets into research activities, as administrative and other continuing expenses take up most of the budget. <Table 2-7> shows this R&D expenditure ratio within public HEIs.

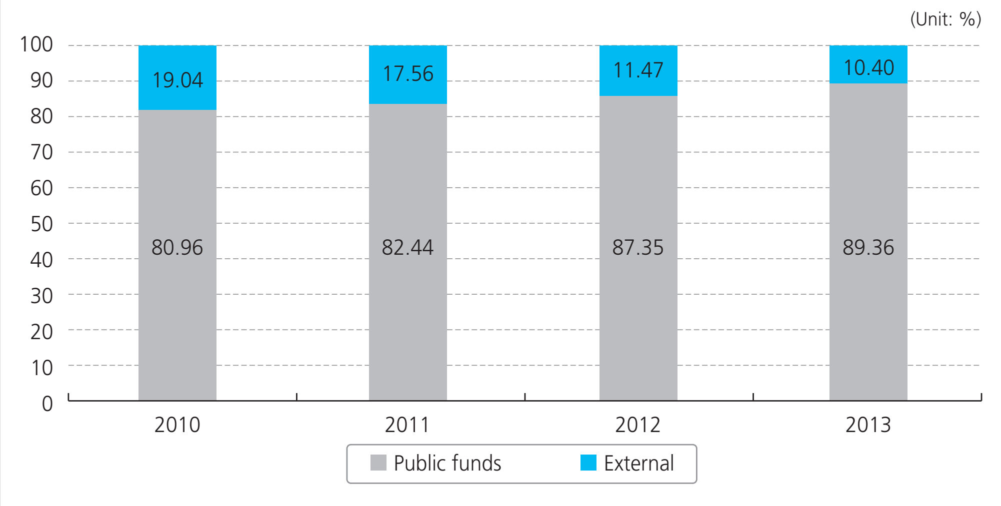
〈Table 2-7〉 Total R&D Expenditure for Costa Rican Public HEIs (USD), 2010–13

	2010	2011	2012	2013
UCR	70.56%	70.40%	73.33%	70.91%
UNA	19.20%	17.93%	17.69%	18.15%
TEC	8.53%	9.55%	7.12%	9.36%
UNED	1.68%	2.12%	1.85%	1.58%
Total (USD)	57,090,909	64,276,292	79,224,598	81,520,499

Source: Author's elaboration with CONARE data, 2015.

Additionally, public HEIs also have secondary funding since they have outreach commercial entities that work as foundations or other external bodies. The money allows universities to commercialize their services to third parties with few constraints from fiscal and other administrative controls. Accounting for 2013 (the last year where data is available), this external funding comprises 10.4 percent of public HEIs' R&D budget (CONARE, 2015). This means R&D at public universities is greatly financed through each institution's ability to sell its academic production, though mostly in the form of consulting and other knowledge-based products. [Figure 2-25] shows how public universities have distributed their R&D budget for the 2010–13 period (on public budget and private and external funding). Based on the data for the available period, a steady decrease is seen in external funding being allocated to R&D. This may be partly explained due to the annual rise in the FEES budget and the numerous research units that depend directly on these funds, and/or a decrease in the commercialization of university services.

[Figure 2-25] R&D Funding Sources of Public Universities, 2010-13

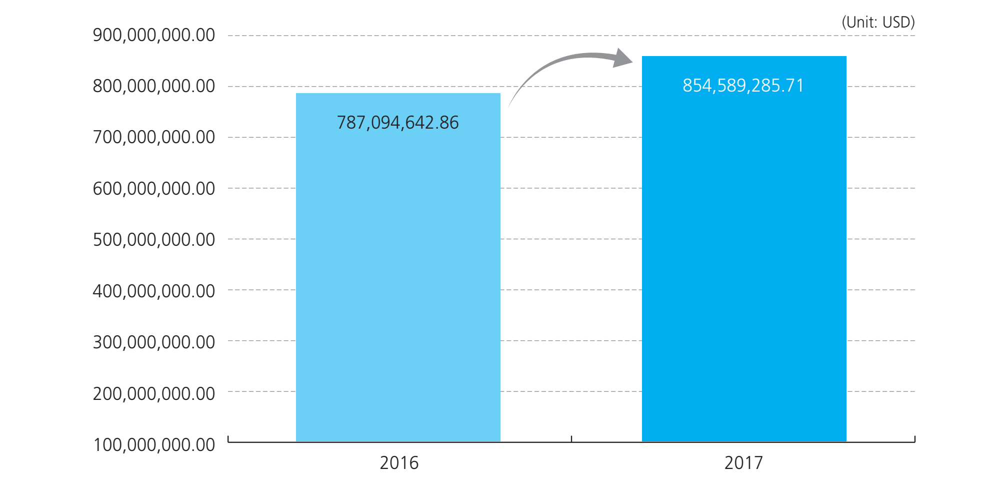


Source: Author's elaboration with CONARE data, 2015.

Finally, public universities negotiate FEES funding every five years, but this can be revised by an executive order and renegotiated within the five-year period. These terms usually mean an inter-annual hike in the relative and absolute budgets allocated to public higher education. Though the FEES budget has never reached the constitutionally set quota of 1.5 percent of GDP, it tends to get closer to that figure every year. This means that universities can only project future spending based on their last year's budget, since FEES can see revision and renegotiation every year under fiscal or political pressure, leaving room for raises or cuts.

For example, UCR, Costa Rica's largest public university, had a budget of nearly US$450 million in 2014, US$70 million of which were research-specific funds (about 14 percent of the university's budget). Today, this amount would equal 0.49 percent of GDP and a little under a third of the overall FEES budget. As mentioned before, FEES should amount to 1.5 percent of GDP, which would represent a hike of 8–10 percent in university funding (specifically for UCR) (UCR, 2015). This figure does not contradict previous data, as the country's budget has experienced sustained contraction over the past two years, meaning that the proportion of GDP for research funding is similarly affected. Another example is the FEES amount for 2017, which was 8.6 percent higher than that of 2016. This means that (as presented by Figure 2-26) public HEIs have an available budget of US$854 million. If one considers the UCR example, 15 percent of the budget for research activities amounts to US$128 million for all five public HEIs.

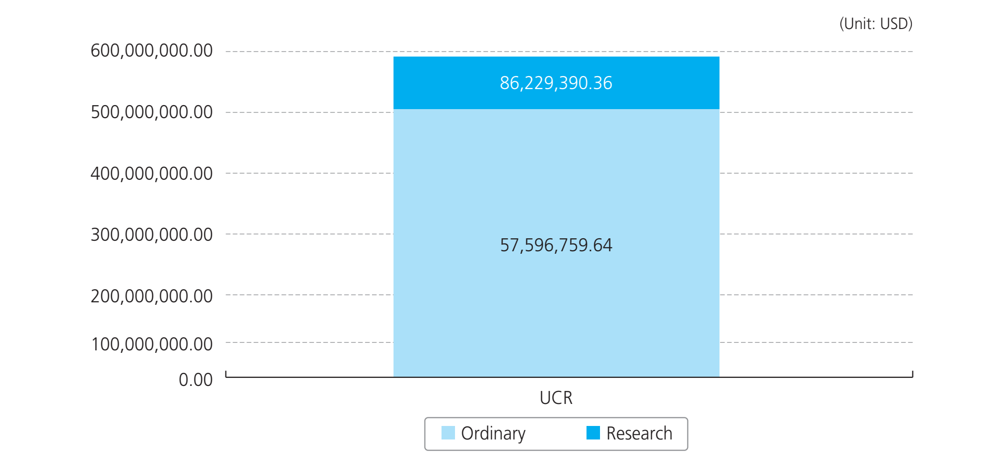
[Figure 2-26] FEES Budget for Public HEIs, 2016-17



Source: UCR, 2016.

In another example, UCR's budget for 2017 is about US$590 million, while the amount allocated to research activities (including services and other continuing expenses) is around US$86 million (as shown in Figure 2-27). Such figures, however, fail to truly represent overall R&D investment as they include non-research expenses such as pension, building and grounds keeping costs, security and rental payments. The subcategory for this budget, titled research support, accounts for about US$31 million, a far more realistic figure, considering all of the previously mentioned factors. All in all, national funding for public universities, despite showing little growth last year (difference of 8.6 percent in the 2016–17 period), remains one of the main R&D drivers in Costa Rica.

[Figure 2-27] UCR Budget for Research-related Activities, 2017



Source: UCR, 2017.

In budget stability, the national budget (from where FEES stems) has a similar or even worse landscape. Public spending is controlled by the legislature, thus leaving room for political pressure to overweight fiscal or monetary factors. And since public R&D funds emanate from this budget, its volatility leaves virtually no room to project or plan public research agenda. This is another key factor considering the lack of prospective academic and national policies toward R&D, especially in science and technology. Particularly, cuts to institutional budgets have been seen year by year.[3)]

3. Developing Supply-Demand Forecasting Model in the Context of STEM Promotion

3.1. Definition of S&T Personnel

For the sake of more concrete modeling, this paper will first define the concept of human resources in science and technology. The term "science and technology (S&T) personnel" is used in a variety of ways depending on research purpose and type. In general, the scope of S&T human resources is determined by job type and qualification. Jobs are deeply related to demand and utilization and qualifications are related to training and supply. There are three international definitions of S&T personnel. UNESCO uses "S&T personnel" and the OECD "R&D personnel" in classifying such workers by occupation. The term human resources of science and technology (HRST) in the OECD Canberra Manual is classified by occupation and qualification.

First, UNESCO's definition of S&T personnel by occupation is as follows.

> "... the total number of people participating directly in S&T activities in an institution or unit, and, as a rule paid for their services. This group should include scientists and engineers, technicians and auxiliary personnel…"

This definition is based on S&T activities like an S&T occupation irrespective of qualification level.

Next, the definition of R&D personnel and researchers according to the OECD Frascati Manual is:

> "Research and development (R&D) personnel consists of all individuals employed directly in the field of R&D, including persons providing direct services, such as managers, administrators and clerical staff."

3) MICITT, Costa Rica's leading body for science and technology, has the second-smallest budget within the central government, and the FEES budget is constantly under political pressure with little room to enlarge it.

> "A R&D researcher can be employed in the public or the private sector - including academia - to create new knowledge, products, processes and methods, as well as to manage the projects concerned."

While these two definitions are relatively simple, the definition of HRST in the OECD Canberra Manual is rather complex.

> "HRST refers to those persons who fulfill one or the other of the following conditions; (a) successfully completed education at the tertiary level, (b) not formally qualified as above, but employed in an S&T occupation where the above qualifications are normally required."

As described above, however, this definition consists of a union of two conditions, so the following four additional definitions (subset) are possible.

- HRSTE: Human resources in science and technology by level of education. Those people who have successfully completed a tertiary level education (until 2013, ISCED97 - levels 5A, 5B, 6; starting with 2014, ISCED2011 - levels 5 to 8);
- HRSTO: Human resources in science and technology by occupation. Those people not formally qualified as above but employed in an S&T occupation where the above qualifications are normally required (ISCO-08 major groups 2 and 3);
- HRSTC (core): Those people who have successfully completed a tertiary level education AND are employed in an S&T occupation;
- SE: scientists and engineers. Those people who work in ISCO-08 groups 21 science and engineering professionals, 22 health professionals, 25 information and communications technology professionals;

Once the objects of analysis as described above are defined, the next task is to refine qualifications and occupations. In other words, to define S&T personnel according to the above qualifications and occupational standards requires the definitions of "occupation" and "job occupation with a certain degree of scholarship in science and technology." First, according to UNESCO's International Standard Classification of Education 2011, academic ability can be defined as follows. Here, the applicability of ISCED levels 5–8 is assumed. Next, a definition of occupation is required; in the Republic of Korea, this is defined in the『Korean Standard Classification of Occupations』as shown below. So in Costa Rica, selection could be required based on the country's own standard classification of occupations. One additional process for the labor force and employment of S&T personnel remains: selection of an S&T major. In the Republic of Korea, six subjects in natural science, 10 in engineering, medical science, and agriculture, forestry and fisheries science are classified into two categories according to the『Science Technology Research Activity Report』and『Education Statistics Yearbook』. Per Costa Rica models, however, such classification and definition can be selected according to the country's situation.

3.2. Tentative Model Application: R&D Personnel and Researchers[4)]

The next task is to implement supply-and-demand forecasts for R&D personnel and researchers in Costa Rica using the data presented in Section 2. As in many previous studies, the supply and demand outlook for such staff is divided into supply-and-demand outlooks.

Some of them will be reviewed for demand forecasting.

Section 2 looked at gross birth rate (per thousand), annual death rate (per thousand) and population growth rate (per hundred). Gross birth rate is expected to decline and the annual death rate is set to rise with a focus on trends. This suggests that the composition of the population cohort is changing toward a higher average age. As a result, the population growth rate (per hundred) will fall from 1.2 percent in 2015 to 0.8 percent in 2015. Total net participation and employment also declined until 2014 and will continue to fall, which suggests that Costa Rica's labor supply capacity will gradually decline.

Comparing Costa Rica to the Republic of Korea is useful using indicators in determining the supply and demand outlook. <Table 2-8> below shows school enrollment at the tertiary level. Costa Rica's rate was 46.7 percent in 2012, up from 44.5 percent the previous year but still less than half of the Republic of Korea's figure of 98.4 percent. Costa Rica's rate, however, is expected to continue an upward trend.

4) The analytical process of Korea's previous and recent studies on supply-and-demand forecasts are summarized in the Appendix. It could be removed from the final copy if the report's volume is judged too large, but in this case, it can be provided on request.

〈Table 2-8〉 Tertiary School Enrollment in Costa Rica and Republic of Korea

Country	2008	2009	2010	2011	2012
Costa Rica	…	…	…	44.5	46.7
Republic of Korea	101.8	101.6	101.0	100.8	98.4

Note: 1) … = data not available.
2) Gross enrollment ratio (GER) for tertiary (ISCED 5 and 6) is total enrollment in tertiary education (ISCED 5 and 6), regardless of age and expressed as a percentage of the population of the five-year age group following the completion of secondary education.
Source: Monge-González (2016).

Comparing the average number of years of formal education in both countries, Costa Rica's figure was 8.4 years in 2013, considerably lower than Korea's 11.8 years. Data from 2000-13 showed that it fell again in 2005 and 2006 but gradually rose from 2007.

〈Table 2-9〉 Average Number of Years in Formal Education in Costa Rica and Republic of Korea

(Unit: Year)

Country	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013
Costa Rica	8.0	7.9	7.9	8.0	8.2	8.3	8.2	8.3	8.4	8.4
Republic of Korea	10.6	11.4	11.4	11.5	11.6	11.7	11.8	11.8	11.8	11.8

Source: Monge-González (2016).

The percentage of graduates from tertiary science programs represents the share of science students in tertiary education. This is the de facto supply capability of science majors. As of 2011, Costa Rica trailed the Republic of Korea in this category 5.7 percent to 7.3 percent. In both countries, however, this figure was declining.

〈Table 2-10〉 Percent of Graduates from Tertiary Science Program in Costa Rica and Republic of Korea

(Unit: %)

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Costa Rica	6.0	…	…	…	…	6.9	…	…	5.7	5.7	…
Republic of Korea	10.1	10.6	10.2	7.4	7.3	7.4	7.6	7.5	…	7.3	7.1

Note: … = data not available.
Source: Monge-González (2016).

The percentage of tertiary graduates in engineering, manufacturing and construction represents the proportion of engineering students enrolled in HEIs. The table below shows the supply capability of engineering majors. As of 2011, the percentage was 6.2 in Costa Rica and 24.6 in the Republic of Korea, or a four-fold difference. In other words, Costa Rica's engineer supply capacity in higher education is far lower than that of the Republic of Korea, though this proportion is decreasing in the latter country. In Costa Rica, whether to blame data limitations for the increase or decrease is difficult.

〈Table 2-11〉 Percent of Tertiary Graduates in Engineering, Manufacturing and Construction in Costa Rica and Republic of Korea

(Unit: %)

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Costa Rica	6.0	…	…	…	…	6.2	…	…	5.7	6.2	…
Republic of Korea	30.0	28.4	27.5	29.5	28.1	26.4	24.8	23.4	…	24.6	23.9

Note: … = data not available.
Source: Monge-González (2016).

For the number of researchers per million inhabitants, Costa Rica in 2011 had 1,868, a huge leap from just 291 in 2002, but the Republic of Korea went from 4,093 to 7,699 over the same period. Similar trends can be seen in the number of R&D researchers per million people.

〈Table 2-12〉 Researchers per Million Inhabitants / R&D Researchers per Million People in Costa Rica and Republic of Korea

(Unit: Number)

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Researchers per Million Inabitants											
Costa Rica	291.0	281.0	253.0	334.0	720.0	789.0	754.0	1,570.0	1,669.0	1,868.0	…
Republic of Korea	4,093.0	4,253.0	4,487.0	4,990.0	5,426.0	6,077.0	6,268.0	6,710.0	7,139.0	7,699.0	…
R&D Researchers per Million People											
Costa Rica	…	131.4	108.1	121.9	…	…	257.0	973.4	1,199.0	1,289.0	…
Republic of Korea	3,059.0	3,246.0	3,337.9	3,823.1	4,228.9	4,665.0	4,933.1	5,067.5	5,450.9	5,928.3	…

Note: … = data not available.
Source: Monge-González (2016).

The ratio of R&D expenditures to GDP is the leading indicator of a country's devotion to R&D and often referred to as "R&D intensity." In 2011, the ratio for Costa Rica was 0.5 percent and that of the Republic of Korea 4 percent. Costa Rica was at 0.4 percent from 2003 to 2007 but has remained at 0.5 percent since 2008. The Republic of Korea, on the other hand, has seen an annual increase since posting a ratio of 2.4 percent in 2002.

〈Table 2-13〉 Ratio of R&D Expenditures to GDP in Costa Rica and Republic of Korea

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Costa Rica	…	0.4	0.4	…	0.4	0.4	0.4	0.5	0.5	0.5	
Republic of Korea	2.4	2.5	2.7	2.8	3.0	3.2	3.4	3.6	3.7	4.0	

Note: 1) … = data not available

2) R&D spending comprises current and capital expenditures (both public and private) for creative work undertaken systematically to increase knowledge, including that of humanities, culture and society, and the use of knowledge for new applications. R&D covers basic and applied research and experimental development.

Source: Monge-González (2016).

In the case of the number of global patent applications by residents, the gap between both countries is enormous. Costa Rica had just 10 in 2012, while the Republic of Korea had 148,136, around double the 76,570 filed in 2002.

〈Table 2-14〉 Number of International Patent Applications by Residents in Costa Rica and Republic of Korea

(Unit: Number)

Country	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Costa Rica	…	…	…	…	…	…	…	…	8.0	14.0	10.0
Republic of Korea	76,570	90,313	105,250	122,188	125,476	128,701	127,114	127,316	131,805	138,034	148,136

Note: Worldwide patent applications field per the terms of the Patent Cooperation Treaty or with the national patent office for exclusive rights to an invention.

Source: Monge-González (2016).

Academia plays a key role in Costa Rica's R&D investment by sector (as a percentage of GDP). The investment accounts for 0.45 percent of GDP, of which academia and the public sector take 0.35 percent and companies 0.09 percent, or about 20 percent of the country's R&D investment.

〈Table 2-15〉 R&D Investment by Sector in Costa Rica (as Percent of GDP)

(Unit: %)

Sectors	2006	2007	2008	2009	2010	2011
All	0.43	0.36	0.40	0.54	0.50	0.45
Public sector	0.06	0.06	0.07	0.13	0.18	0.14
Academia	0.16	0.18	0.19	0.26	0.21	0.22
NGOs	0.02	0.02	0.02	0.01	0.01	0.01
Companies	0.19	0.11	0.12	0.14	0.09	0.09

Source: Innovation Surveys, Ministerio de Ciencia, Tecnologia y Telecomunicationes (MICITT).

Section 2 presents STEM graduates by subfield. In particular, looking at growth rates from 2010-14 is important for predicting structural changes. The average annual growth rate for that period was 3.4 percent for agriculture, 6.6 percent for natural and exact sciences, 10.9 percent for medicine and 11.5 percent for technology and engineering. Considering that the number of graduates in 2014 was 461 in agriculture, 1,165 in natural and exact sciences, 5,084 in medicine and 5,086 in technology and engineering, the share of medicine and technology and engineering will increase and that of natural and exact science is expected to shrink. A positive sign, however, is that the annual average increase will reach 10.1 percent in the number of STEM graduates as a whole.

Next is a comparison of the supply and demand for R&D personnel and researchers with the data presented above and the information presented in Section 2. Demand was analyzed by studying researchers employed in different sectors. Past trends and productivity were considered. The number of researchers required in each R&D sector was computed using sectoral output, R&D investment and research productivity. The overall number of researchers was computed by predicting R&D expenditures, sometimes by extrapolating previous sectoral R&D levels, and multiplying the employment coefficient, which is the reciprocal of labor productivity.

To forecast demand, R&D expenditures in 2010–20 in US$ were estimated first. The value for 2015–20 was calculated by extrapolation using the average growth rate of R&D spending for 2010–14.[5] This is a partial correction through additional

5) In general, predicting time series data can be done by using models for time series regression, ARIMA (autoregressive integrated moving average) and exponential smoothing. For forecasting via time series regression analysis, however, it is possible to calculate an excellent predicted value with minimum error when an optimal model is established, but not possible to find an independent time series with high explanatory power for the dependent time series given the massive time and efforts required.
Forecasting using the ARIMA model was judged not useful for supply forecasting in this study because

regression analysis. The estimates show that such spending rose from US$189 million in 2010 to US$294 million in 2014; the forecast is US$579 million by 2020.

〈Table 2-16〉 R&D Expenditures in Costa Rica, 2010-20

(Unit: Million USD)

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Costa Rica	189	209	233	262	294	331	372	418	467	521	579

Source: Author's calculations using MICITT data, 2016.

at least 35 data sets are needed to build the model. In other words, the data used in this study's supply forecasting are from 1990-92 provided by the Korea Educational Development Institute and biennial data for 1990, 1992, 1994 and 1996. Thus eight years of data including four years of data available.
The exponential smoothing model used in this study has a statistical and mathematical logic structure that is poor in theory development but allows ease of applying the model. This model can obtain highly accurate predictions compared to the simplicity of calculations, and its accuracy is why analysts often use this model.

The exponential smoothing model used in this study is a double exponential smoothing model based on a simple exponential smoothing model. The simple exponential smoothing model is a predictive model that assumes a constant model $Z_t=b_0+e_t$ when the time series has no trend and only maintains a certain level.

The simple exponential smoothing model can be expressed as $F_{t+1}=\alpha Y_t+(1-\alpha)F_t$ Where F_{t+1} is the predicted value at time t+1, Y_t is the actual observation at time t, and α is a weighting value between 0 and 1, which is called the smoothing constant. The larger α is, the more weight is given to the current observation.

In other words, the predicted value of the next period is the weighted average of the period's observations and predicted value, and the latter is the weighted average of past and present forecasts. If it is $F_1=Y_1$ it can be expressed as follows $F_{t+1}=\alpha Y_t+(1-\alpha)\alpha Y_{t-1}+(1-\alpha)^2\alpha Y_{t-2}+(1-\alpha)^3\alpha Y_{t-3}+\cdots+(1-\alpha)^{t-1}Y_1$

In other words, predictions for the next period can be calculated as the weighted average of all observations from past and present.

So the predicted value depends entirely on the value of α, and a predicted value with the smallest mean square error (MSE) is selected using α = 0.1, 0.3, 0.5 and 0.9.

In the case of the double exponential smoothing model used to estimate the supply of science personnel in this study, it can be expressed as $F_{t+k}=L_t+kT_t$. In other words, the forecast value F_{t+k} at time t+k can be regarded as the sum of the level estimate L_t and the trend estimate T_t at time t. Level estimates can be calculated as follows , $L_t=S'_t+(S'_t-S''_t)$, $S'_t=\alpha Y_t+(1-\alpha)S'_{t-1}$, $S''_t=\alpha S'_t+(1-\alpha)S''_{t-1}$. In this equation, S'_t is the smoothed value of the observed time series (Y_t) and S''_t is the smoothed time series (S'_t) and again smoothed values.

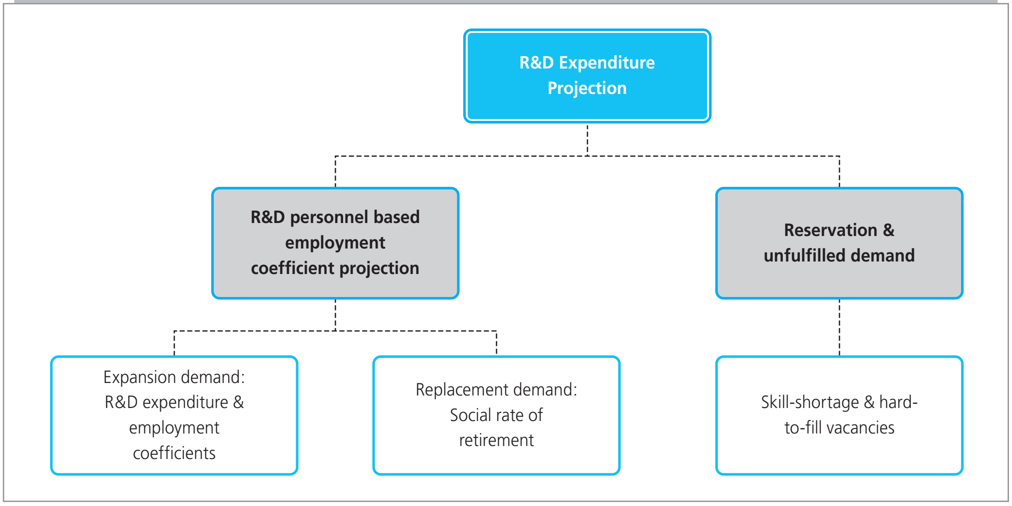
In this case, if Y_t shows the trending form, the first smoothed value S'_t is different from Y_t, and the second smoothed value is the difference between S''_t and S'_t

The level estimates of the observed time series are calculated based on the first and second smoothed data thus obtained.

Next, the trend estimate can be expressed as $T_1=\left(\frac{\alpha}{1-\alpha}\right)(S'_t-S''_t)$ In other words, if the time series shows a trend type, the level is adjusted so as to fluctuate by the trend influence value to obtain a better prediction value. Though the exponential smoothing model has an advantage, it is not useful in this study. Supply-and-demand forecasts for this study are available only for the 2010–14 period.

So considering the comprehensive evaluation of these constraints, this study adopted an extrapolation method using the annual growth rate. And to reflect nonlinear trends, a time series regression analysis model was applied to the time series data that were expanded extensively.

[Figure 2-28] STEPI Framework: Demand Projection



Source: Author.

The next step in demand forecasting is to project an employment coefficient based on R&D personnel. In other words, R&D spending and data on R&D personnel and researchers are used to determine the number of R&D staff needed to perform US$1 million worth of R&D. To do this, the first action is to calculate the employment coefficient for 2010-14. Next, the value of 2015-20 is estimated by using coefficients obtained from 2010-14. This process is also extrapolated using the average growth rate based on the coefficient trends of 2010-14, such as the outlook for previous R&D expenditures. This estimation process was conducted for the three categories of R&D personnel: researchers, doctoral candidates and technical support staff. The coefficient values for R&D personnel are used as the sum of the three coefficients.

〈Table 2-17〉 Employment Coefficient in Costa Rica based on R&D Personnel, 2010-20

(Unit: Million USD)

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
R&D Personnel	32.53	36.85	27.78	27.48	21.64	19.61	17.78	16.16	14.70	13.39	12.21
Researchers	17.88	18.98	14.63	14.84	12.83	11.81	10.87	10.00	9.20	8.47	7.79
Doctoral candidates	0.98	1.99	0.93	1.55	1.01	1.01	1.02	1.03	1.03	1.04	1.05
Technical support staff	13.67	15.88	12.23	11.09	7.81	6.79	5.90	5.13	4.46	3.88	3.37

Source: Author's calculations using MICITT data, 2016.

The scale of R&D personnel is estimated by multiplying the expected R&D expenditures and employment coefficients based on R&D personnel by the year 2020. The number of such personnel in Costa Rica is expected to increase from 3,776 in 2014 to 4,511 in 2020. The number of researchers is seen to rise from 3,776 in 2014 to 7,067 in 2020 and that of doctoral candidates from 296 to 607 over the same period. On the other hand, the number of technical support staff is seen to fall from 2,298 in 2014 to 1,950 in 2020. Such personnel had gone from 2,587 in 2010 to 3,321 in 2011, but their number is believed to have gradually decreased since then. If changes in number occur even if the time series is short, the more limited the forecast based on the trend gets.

〈Table 2-18〉 Employment Coefficient in Costa Rica based on R&D Personnel Projections, 2010–20

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
R&D personnel	6,156	7,708	6,483	7,193	6,370	6,493	6,620	6,745	6,863	6,971	7,067
Researchers	3,384	3,970	3,414	3,884	3,776	3,910	4,044	4,175	4,298	4,410	4,511
Doctoral candidates	185	417	216	407	296	335	380	429	483	542	607
Technical support staff	2,587	3,321	2,853	2,902	2,298	2,248	2,196	2,141	2,082	2,018	1,950

Source: Author's calculations using MICITT data, 2016.

The next step is to estimate demand based on the employment coefficients in Costa Rica (2010–20) based on R&D personnel projections. Demand can be divided into expansion and replacement. First, expansion demand is the difference between the two points in the R&D personnel projections above. In other words, expansion demand in 2011 was the difference between the number of R&D personnel in 2011 and overall employment the year before. This means new demand that increased as employment grew. Replacement demand is incurred by the departure of existing staff due to retirement because of old age or transfer to a business or other occupation. In Costa Rica, the age structure of R&D personnel is unknown, and assuming no information on retirement rates, an annual average of 4 percent in turnover is assumed We summarize the two demand types to estimate recruitment (total) demand.

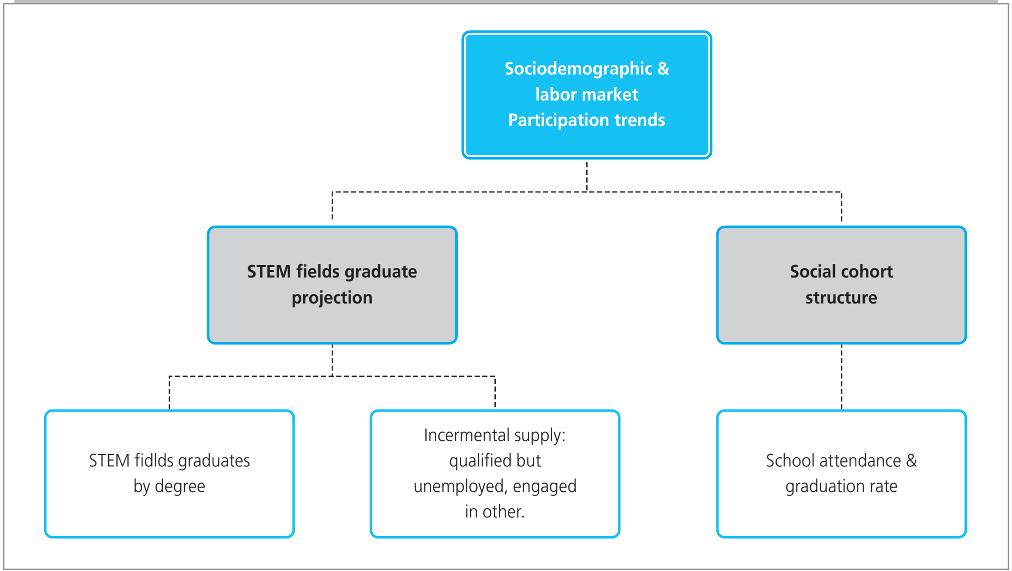
〈Table 2-19〉 Expansion, Replacement & Recruitment Demand for R&D Personnel in Costa Rica, 2010–20

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Expansion Demand for R&D Personnel in Costa Rica, 2010–20											
Researchers	…	586	-556	470	-108	134	135	130	123	113	100
Doctoral candidates	…	232	-201	191	-111	39	44	49	54	59	65
Technical support staff	…	734	-468	49	-604	-50	-52	-55	-59	-64	-69
Total	…	1,552	-1,225	710	-823	123	127	125	118	108	96
Replacement Demand for R&D Personnel in Costa Rica, 2010–20											
Researchers	135	159	137	155	151	156	162	167	172	176	180
Doctoral candidates	7	17	9	16	12	13	15	17	19	22	24
Technical support staff	103	133	114	116	92	90	88	86	83	81	78
Total	246	308	259	288	255	260	265	270	275	279	283
Recruitment Demand for R&D Personnel in Costa Rica, 2010–20											
Researchers	…	745	-419	625	43	290	296	297	295	289	281
Doctoral candidates	…	249	-192	207	-99	53	59	66	74	81	89
Technical support staff	…	867	-354	165	-512	40	36	31	24	17	9
Total	…	1,860	-966	998	-568	383	392	395	392	387	379

Note: … = data not available.
Source: Author's calculations using MICITT data, 2016.

Next comes the stage of supply forecasting. Supply forecasts should begin with a consideration of trends in sociodemographics and labor market participation. The gross birth rate has declined and that of annual deaths is expected to increase. As a result, the population growth rate (per hundred) fell from 1.2 percent in 2015 to 0.8 percent in 2020. Total net participation and employment also declined until 2014. But tertiary-level school enrollment rose to 44.5 percent in 2011 and 46.7 percent in 2012. Given these two trends, school enrollment at the tertiary level is deemed stable.

[Figure 2-29] STEPI Framework: Supply Projection



Source: Author.

The following are statistics of graduates from 2015–20 for each subfield using data on STEM graduates in Costa Rica by subfield from 2000–14. The growth rate of technology and engineering graduates was the highest at 10.7 percent, followed by those of medicine with 10.1 percent, natural and exact sciences 6 percent and agriculture 3.1 percent, and the results are shown in <Table 2-13>.

〈Table 2-20〉 STEM Graduates in Costa Rica by Subfield, 2010-20

(Unit: Number)

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Agriculture	408	383	532	510	461	475	490	506	522	538	555
Natural & exact sciences	980	995	1,286	1,708	1,165	1,235	1,309	1,387	1,470	1,558	1,652
Medicine	2,342	2,975	3,507	4,020	5,084	5,597	6,161	6,783	7,467	8,220	9,050
Technology& engineering	3,488	3,769	3,945	4,268	5,086	5,629	6,230	6,895	7,632	8,446	9,348
Total	7,218	8,122	9,270	10,506	11,796	12,936	14,191	15,571	17,091	18,763	20,604

Note: … = data not available.
Source: Author's calculations using MICITT data, 2016.

The distribution of academic degrees from 2015-20 is based on degree structure from 2000-14. The next step is to convert the supply forecasts by municipality into those by degree. Looking at the degree structure by major is ideal in this step. And if this is possible, assuming of course that demand forecasts should also be made in this format, supply-and-demand forecasts (by major x degree) are also possible. In data constraints, however, the supply forecasts for all STEM fields were conducted from 2015-20, and the results are shown in the table below.

〈Table 2-21〉 Distribution of Degrees Obtained by STEM Professionals in Costa Rica, 2010-20

(Unit: %)

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Doctorate	0.3	0.5	0.5	0.5	0.4	0.4	0.5	0.5	0.5	0.4	0.5
Master's	10.1	7.4	7.7	6.1	5.0	7.3	6.7	6.6	6.3	6.4	6.6
Professional specialization	2.4	3.0	3.0	3.4	2.3	2.8	2.9	2.9	2.9	2.8	2.8
Licenciate	55.4	55.8	51.8	49.2	47.0	51.8	51.1	50.2	49.9	50.0	50.6
Bachelor's	31.8	33.2	36.9	40.8	45.3	37.6	38.8	39.9	40.5	40.4	39.4

Note: … = data not available.
Source: Author's calculations using MICITT data, 2016.

The figures in the above table are estimated to be moving averages based on the average of 2000–14 after 2015. So a degree of break exists between the 2014 and 2015 figures. The reason for this assumption is that the trend is unclear. For example, the number of bachelor's degree earners declined until 2010 but has risen since then. On the other hand, the number of people earning licenciates, professional specializations, master's degrees and doctorates has repeatedly seen rises and dips. If recent trends are reflected in 2010-14, the estimation results could be considered excessive overshooting or undershooting.

Based on these ratios and the number of STEM graduates mentioned above, the following table shows the number of graduates from 2015–20 for each degree. The interpretation of this figure as total supply does have a limit, however. In other words, the figures presented in this table refer to graduates, and those who do not advance to research or who have the same academic qualifications as those who already graduated could return to research. This can usually be reflected in the estimation process by examining or collecting data on the employment distribution for graduates and information on the proportion of fresh graduates who are newly registered as researchers or technical support staff. Because this information is not available, the report assumes that both are absent or on the same scale.

〈Table 2-22〉 STEM Graduates in Costa Rica by Degree, 2015–20

(Unit: Number)

Country	2015	2016	2017	2018	2019	2020
Doctorate	57	66	72	78	83	93
Master's	939	950	1,020	1,080	1,194	1,368
Professional specialization	365	412	449	489	517	586
Licenciate	6,706	7,255	7,816	8,523	9,383	10,427
Bachelor's	4,864	5,500	6,209	6,916	7,580	8,122

Source: Author's calculations using MICITT data, 2016.

The final step is the comparison of recruitment demand and the number of graduates given above as supply.[6] This requires a review of the STEM fields below and recruitment demand comparison in Costa Rica by degree from 2015–20. Researchers in Costa Rica are expected to see no significant change in number, going from 290 in 2015 to 281 in 2020, with demand of 1,748 seen over this period. If researcher here means a doctorate holder, then a considerable shortage will ensue because the number of Ph.D. holders is expected to be only 450 over this period. On the other hand, inclusion of master's holders in the study is fine, or on the quality level (in certain areas, a master's level is considered sufficient), the supply may be considered at least quantitative. Next, demand for doctoral candidates is expected to rise to 422 people by 2015–20, and is rising. Assuming that the dissertation preparation period is a required three years after students complete the final qualification exam and proposal process and that two-thirds of them graduate, the number of doctoral candidates will reach 900. When comparing these two figures, supply is about twice the demand. There is no exact figure, but the assumption that at least half of doctoral candidates will participate in R&D is excessive. What is more worrying is the overall supply-and-aggregate demand, and the supply-demand gap will increase if subdivided by a sub-major. That is to say, with this level of supply (when a master's holder confirms the signal on the R&D marker and then gains admission and completes the coursework, then takes the time to become a doctoral candidate), a serious shortage is possible. One conclusion is that the supply of doctoral candidates is insufficient to perform stable R&D in Costa Rica. In the same analysis process, the

6) Of course, certain things are not considered at this stage, including the impact of the outflow of personnel abroad. In Costa Rica, excellent STEM graduates tend to study or work abroad. This effect can be greater as the number of graduates is relatively small. In the case of R&D personnel, the impact of this problem on the supply-and-demand outlook is even more probable. Based on the Republic of Korea's experience of previously seeing high outflow, the impact of overseas outflow is not considered a big constraint on extracting policy implications from the supply and demand outlook. Even so, acknowledgement is needed of the omission of outflow and inflow from this model of forecasting supply and demand. Thus reflection of the model through data identification is a must for the future.

supply of technical support staff will not be a problem (at least quantitatively) when looking at those earning a master's, professional specialization, licenciate and a bachelor's.

〈Table 2-23〉 Comparison of STEM Graduates and Recruitment Demand in Costa Rica by Degree, 2015–20

(Unit: Number)

Country	2015	2016	2017	2018	2019	2020	Sum (15–20)
Costa Rica's STEM Graduates by Degree							
Doctorate	57	66	72	78	83	93	450
Master's	939	950	1,020	1,080	1,194	1,368	6,551
Professional specialization	365	412	449	489	517	586	2,818
Licenciate	6,706	7,255	7,816	8,523	9,383	10,427	50,111
Bachelor's	4,864	5,500	6,209	6,916	7,580	8,122	39,191
Recruiting of Costa Rica's STEM Graduates by Degree							
Researchers	290	296	297	295	289	281	1,748
Doctoral candidates	53	59	66	74	81	89	422
Technical support staff	40	36	31	24	17	9	157
Total	383	392	395	392	387	379	2,328

Source: Author's calculations using MICITT data, 2016.

4. Conclusions and Recommendations

4.1. Preliminary Conclusions

Overall, the relatively low supply of STEM doctorates in Costa Rica is expected to greatly hinder research needs by 2020. If researchers all need PhDs, then a considerable shortage in the near future could arise. The number of researchers will see no significant change, going from 290 in 2015 to 281 in 2020, with demand for 1,748 expected over this period.

The supply of doctorates over the period, however, is expected to be only 450. On the other hand, if the qualification required for a researcher is met with a master's degree according to the content or difficulty of the study, the Ph.D. supply could be considered sufficient at least in quantity.

Yet the conclusion is that the supply of doctoral candidates is also insufficient to perform stable R&D in Costa Rica. Demand for them is expected to be around 422 in 2015-20 and rising. Assuming a dissertation preparation period of three years after students complete the final qualification exam and proposal process and that two-thirds of them graduate, the number of doctoral candidates is expected to reach 900. When comparing these two figures, supply is about twice the demand. There is no exact figure, but to assume that half of doctoral candidates will participate in R&D is excessive.

4.2. Challenges and Obstacles

As mentioned more than a few times in previous sections, lack of the latest and up-to-date information is the main obstacle and limitation, with certain cases of no information at all. Despite MICITT being Costa Rica's central institution for science, technology and innovation, its operating capacity is far from optimal in the collection, systematization and dissemination of data in these areas. This leads to an atomization of data that follows different standardization and methodological goals, making it more complicated to obtain and analyze.

Consequently, a number of public, non-government and private institutions have various datasets (on education, employment, expenditures and other areas) of varying availability. Public institutions and non-government organizations can be accessed with a variable level of effort, but due to the nature of the information requested, it is always accessible. Private organizations, on the other hand, are more secretive, with limited channels of communication and a poor culture of cooperation despite clarifying the objective and nature of research.

Consequently, the ensuing institutional barriers (mainly attributed to pre-established bureaucratic practices) need to be overcome. Public information must be freely accessible for the most part and ideally in digital formats. The foundational limitation, however, is the lack of a centralized body that processes this data and keeps it updated, coordinating with government and public institutions, private representatives or commerce chambers and the heads of HEIs (public and private). Having such a body will not only shorten times for data collection, but also constitute a more transparent and open means for all parties involved to analyze their efforts and even propose policy-oriented actions.

Such a body will also serve as a think tank that shows through empirical evidence the need to promote alignment between market forces and academia, as well as help incentivize a true research-based higher education system, develop its curricular excellence and focus on key areas of national development.

In this manner, universities, both private and public, will feel an organic stimulus to do research (particularly the former), publish it and apply for external funding. Another idea is to formulate a national policy through which funds can be transferred to HEIs according to research done. This measure will consider the reality of private universities and their lack of (current) regulation and create a merit-based system. For public universities, however, constitutional-level autonomy grants these institutions the self-governing right to allocate public funding where considered. In many cases, research funding does respond to a practical need, meaning that engineering and scientific fields are involved though most of the research and researchers being funded through FEES budget are social scientists or specialists in other subjects that have saturated the labor market (particularly law and psychology).

Also lessening the impact of research-based scientific education is the inequality by which FEES budget is assigned. Traditionally, UCR received nearly all of these funds (since it was for a time the only HEI in Costa Rica), leaving marginal funding for UNA, TEC, UNED and UTN. Since the four other universities have experienced rapid growth over time, their need for more resources has also increased but allocation of this budget is mainly justified by enrollment figures. UCR still has more students (and more new ones) than the rest. One argument could be that an institution like TEC,– Costa Rica's main S&T university, should receive more funding but it consistently gets a smaller slice of the pie.

This represents a weakness not only in education funding, but also the overall research ecosystem. As mentioned earlier, Costa Rica's research investment as a proportion of GDP is considerably small compared to countries that have based national development primarily on science and technology (even four times less than, for example, the Republic of Korea or Finland).

Additionally, Costa Rica has a palpable lack of direction in its research ecosystem; no entity has the institutional rank to direct STEM research toward specific or emphatic objectives. In part, this is due to the absence of a normative background, namely the lack of a specific S&T policy. Though MICITT is a key actor, its efforts toward the subject are limited as most public funding requires legislative approval. Thus the slow process is constantly interrupted by special interests and plain policy incompetence.

A preliminary suggestion might be to view STEM policy from a legislative perspective to not only secure funding but also make the policy a national development priority. Consequently, a public institution might house a body that focuses on labor forecasting, education and job market behavior, and analysis of the S&T ecosystem.

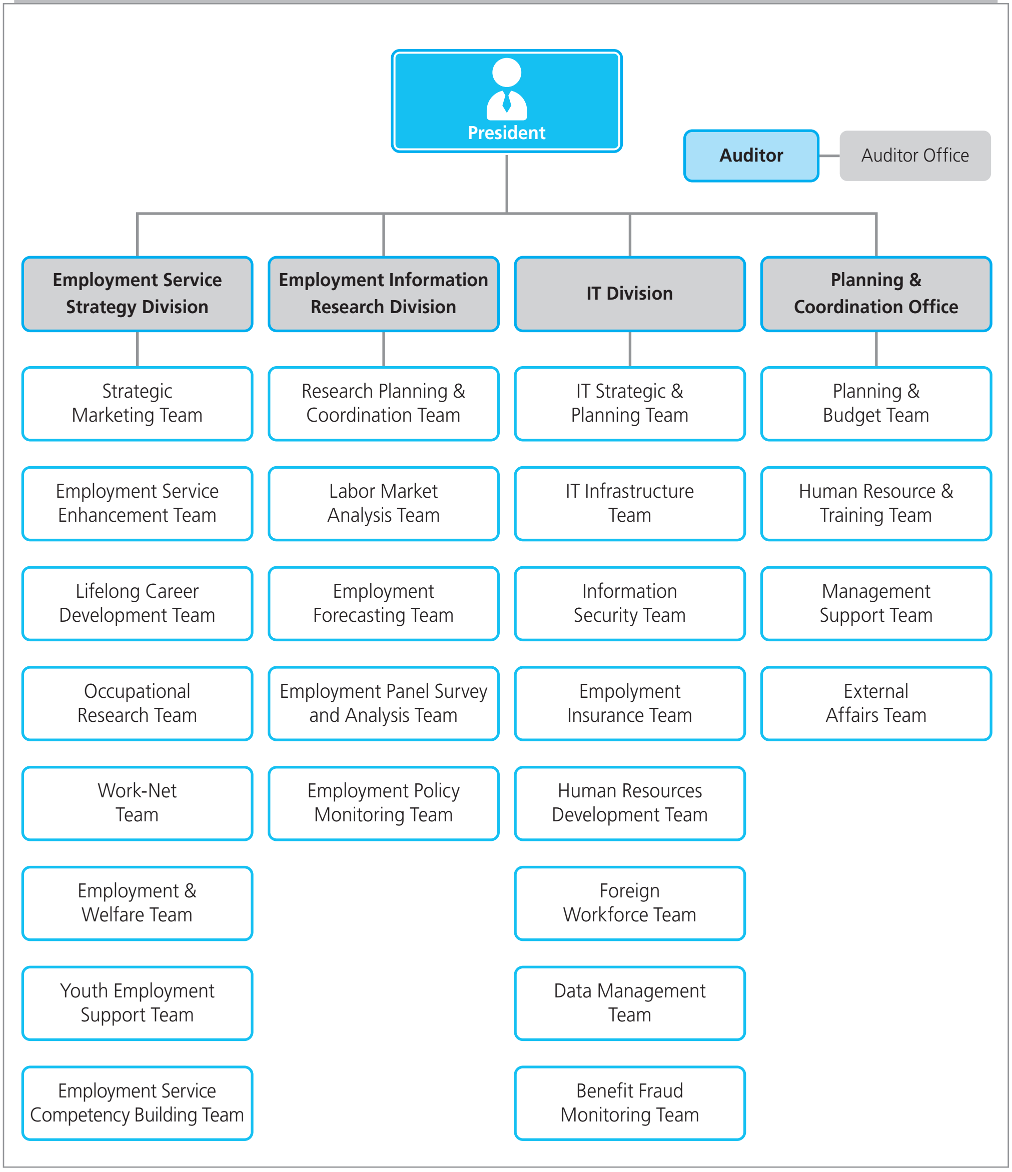
What is more worrying is that the supply-demand gap will worsen if subdivided by a sub-major even if the aggregate supply and demand seem fairly balanced. This level of doctorate supply is likely to experience a serious shortage, particularly in areas where R&D demand is growing. Fortunately, the supply of technical support staff seems nonproblematic when looking at the number of graduates with a master's, professional specialization, licenciate and a bachelor's, at least quantitatively.

4.3. Policy Recommendations with Further Suggestions in a Broader Context

The first step is to collect and integrate data on STEM enrollments and graduates from public and private universities and operate a small research group to analyze supply-and-demand forecasting from the most basic stages.

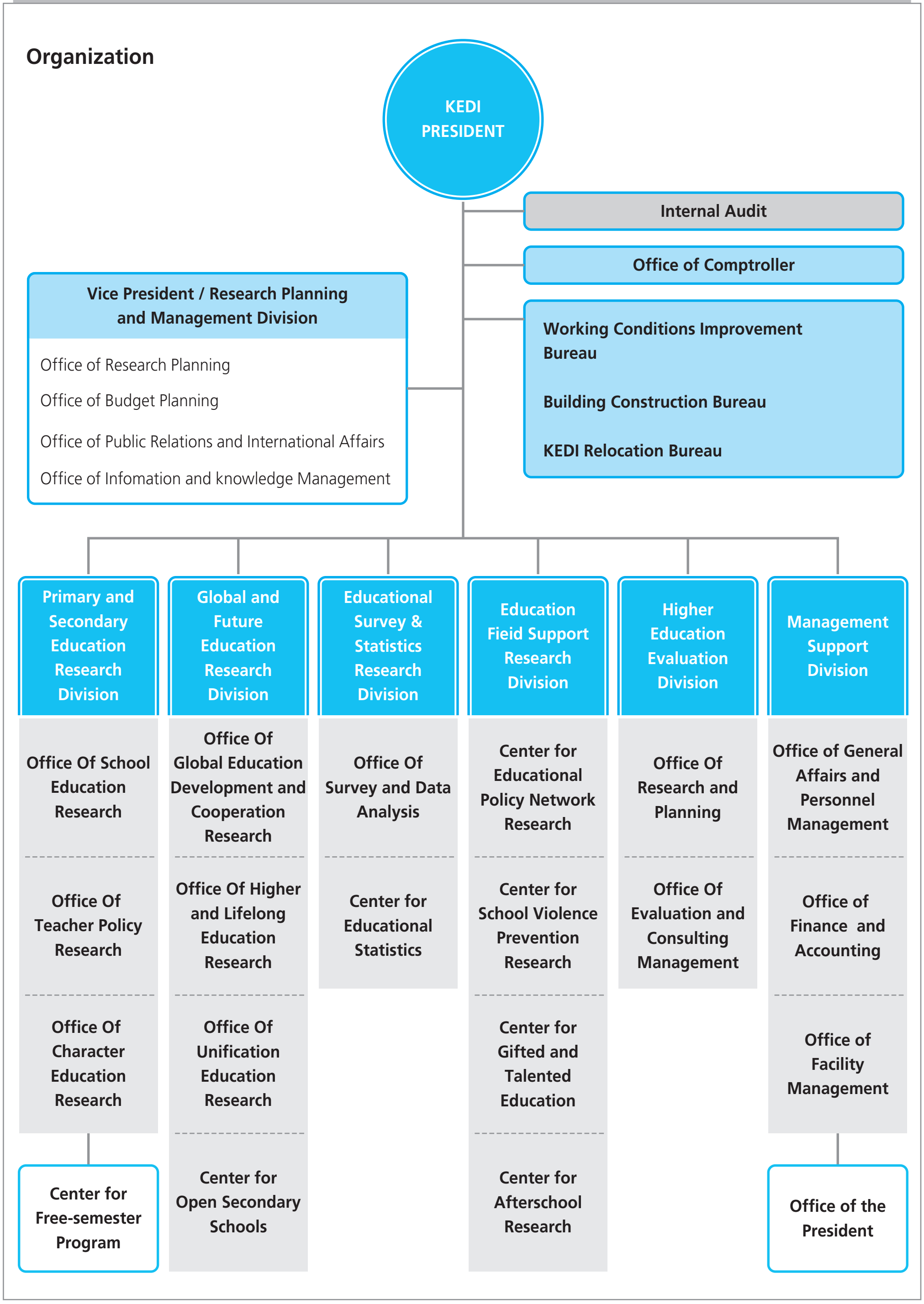
In the case of Korea Employment Information Service (KEIS), its Employment Information Research Division performs labor market analysis, employment forecasting, panel surveillance and policy monitoring. The Korean Education Development Institute (KEDI), a leader in education policy development and implementation since 1972, has been providing the Korea Education Statistics Service. The KEDI subsidiary Education Survey and Statistics Research Division includes the Office of Survey and Data Analysis and the Center for Educational Statistics, which conduct organic investigation and analysis.

[Figure 2-30] Organizational Structure of Korea Employment Information Service (KEIS)



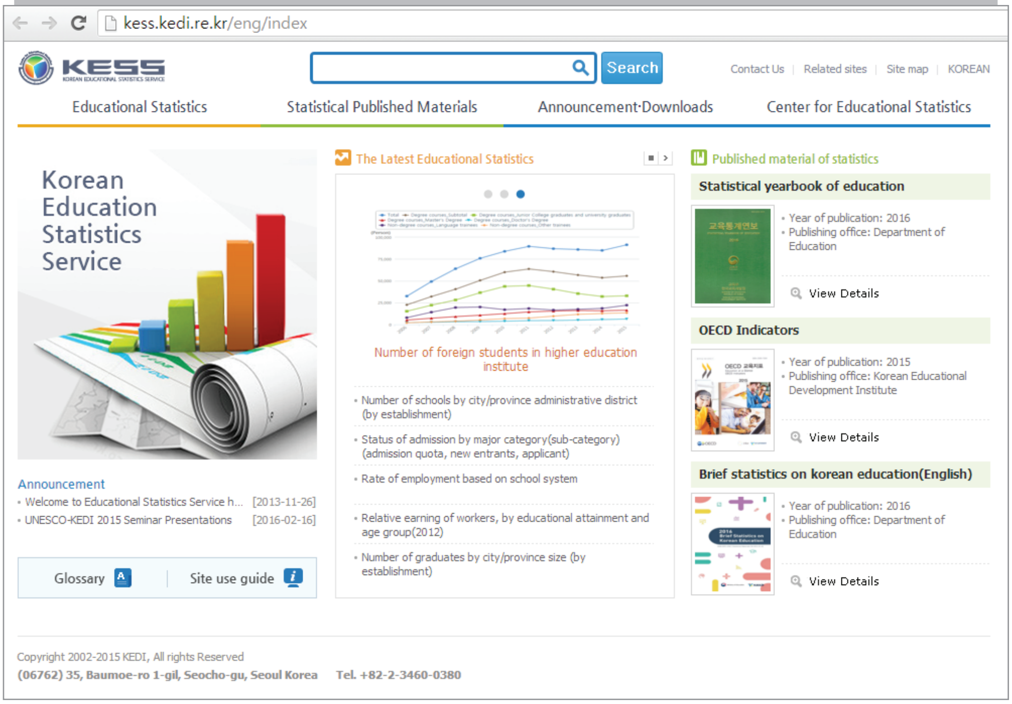
Source: KEIS webpage (http://eng.keis.or.kr/eng/subIndex/2246.do), February 21 2017, 12:00PM.

[Figure 2-31] Organizational Structure of Korean Education Development Institute (KEDI)



Source: KEDI webpage (http://eng.kedi.re.kr/khome/eng/about/chart.do), February 21 2017, 12:00P .

[Figure 2-32] Example of Education Information Service: Korean Education Statistics Service (KESS)



Source: KESS webpage (http://kess.kedi.re.kr/eng/index), February 21 2017, 12:00PM.

Korea Research Institute for Vocational Education and Training (KRIVET) also deserves recognition. This think tank effectively performs tasks for skills development, thereby contributing to the development of vocational education and training and enhancement of the public's vocational competencies. This center for global skills development policy spearheads network building between education and training with employment as its main long-term vision. KRIVET was founded in 1997 to promote vocational education and training and boost the vocational skills of the Korean public. The institute's activities include research and projects on skills development, including those on vocational education and training policies, qualification systems, and development and dissemination of vocational education and training. KRIVET is a national policy think tank under the Office of the Prime Minister whose vision is becoming "a think tank for global skills development policy that spearheads the creation of a link between education and training with employment."

The Center for Educational Statistics is part of KEDI, another state-run research organization under the Office of the Prime Minister, and supervises the provision of services for national education statistics like the Korea Educational Statistics Service (KESS). These services were started in 1962 and form the core work of more than 400 of the nation's official social statistics. Education statistics are a core component in educational planning, implementation, assessment and research as well as overall scientific and comprehensive diagnosis and policymaking in national education. Its importance is even more magnified in being an essential factor for assessing national competitiveness.

To build supply-and-demand models for STEM graduates, a mid- to long-term roadmap is needed with emphasis on four key tasks.

The first task is to identify the statistical requirements for supply and demand forecasts, design specific surveys to collect such data and develop questionnaires.

The second task is to identify the functions needed to complete the forecasts and select the institutions to participate. The functions should be allocated and assigned to the participating organizations to set sequences and processes and designate the person in charge. Above all, this stage requires the formation of a supervisory body or supervisor to coordinate this process.

The third task is to secure a budget, identify it as a government task and assign it to a specific ministry. In the Republic of Korea, each ministry independently undertook supply and demand forecasting but even if not successful, the Office of the Prime Minister sought to coordinate those functions.

The fourth task is to create a research network with experts. In the Republic of Korea, the education minister, who was concurrently deputy prime minister at the time and responsible for policy toward human resource development, supported the creation of a network of researchers responsible for supply and demand forecasts through research affiliates such as KRIVET.

To develop a supply-and-demand forecasting model for STEM graduates, surveys and analytical techniques, finding and fostering experts are crucial. In the Republic of Korea, labor economists and econometricians were mostly involved in model development and statisticians participated in surveys. In addition, the contribution of macro- and industrial economists was needed to forecast GDP growth and growth rates by sector, which are fundamental data for supply and demand forecasts for STEM fields. Above all, the most effective way to develop a supply-and-demand forecasting model is to start with a relatively simple model and build experience. In this regard, completion is important of the supply and demand forecast for research personnel as conducted through this KSP project.

This study also came up with additional suggestions in a broader context. First, significant advantages can be obtained by organizing committees as the heads of relevant ministries and agencies, as well as forming task forces with those responsible for their work. Supply-and-demand forecasts are based on the ability to cooperate with a number of organizations and create governance, though they will be carried out at the single project level. Second, a structured and multi-level national qualification system, professional engineers (PE) at its highest level, was the most effective way the Republic of Korea promptly produced country's fast-growing industries. The functioning of higher education systems, particularly universities, might be limited in the pursuit of fostering a large number of qualified technicians and engineers. Since such a qualification system is run by the government and the award criteria can be objectively tested, candidates other than national university graduates should be allowed. Another consideration is a system that exempts select examinations for graduates of universities that have only been previously accredited. In this case, it is also advantageous to slightly differentiate graduates of national universities boasting a relatively high quality of education and quality control certification and those of private universities whose education quality is relatively poor. Over the short term, such a system will be operated by CONARE (Consejo Nacional de Rectores) but it is also considered the method of preferential application exclusively for the electric-electronics and medical engineering sectors, which have high demand for FDI companies. Third, a top decision-making body should be set up chaired by the President to coordinate policies on science, technology and innovation among ministries and allocate budget. The Republic of Korea has a long history of running the National Science and Technology Council (NSTC) as the chief decision-making body with the President as its chair. At the same time, the Presidential Advisory Council for Science and Technology (PACST) advised the President on S&T policy. In 2004, the head of the Ministry of Science and Technology of the Republic of Korea was made deputy prime minister, giving the ministry more power other than that to review and allocate the R&D budgets of all ministries. Finally, an active solution is needed on how to overcome underinvestment in R&D and university STEM fields.

The Republic of Korea has seen spectacular growth in information and communications technology (ICT) thanks to bold R&D investment made possible by government policy that allowed a portion of sales to be spent on R&D. In 2005, the Ministry of Science and Technology of the Republic of Korea issued S&T bonds to promote bolder R&D projects. So the nation's ICT technology and industry started from one successful R&D project: an electronic telephone switch. This created a chain reaction leading to advances in consumer electronics, semiconductors and communications. The companies that participated in this electronic telephone exchange at the time grew into conglomerates, one of them being Samsung Electronics.

This study does have limitations, however. Supply and demand were analyzed from a general point of view, mainly on the basis of R&D personnel because of limited relevant information. Given Costa Rica's needs, however, especially those of FDI companies, a stable supply of technicians and engineers with bachelor's degrees and quality management and improvement of graduates from private universities are considered the most urgent issues. This is expected to be emphasized in future research and applications by researchers in Costa Rica.

Along with these limitations, a careful approach is needed to apply the results of supply and demand models to policy. The outlook for supply and demand in the Republic of Korea is different from industrial demand. First, the supply-and-demand outlook is based on macroeconomic forecasts for economic growth. Considering this, a study is needed to compare the results of supply-and-demand forecasts with the results of the labor market over a two-year period after the release of one long-term outlook for supply and demand. By comparing the assumptions about economic or industrial growth rates used in the forecasts and real growth rates or employment coefficients, the benefits of this research can be maximized.

References

Costa Rican Investment Promotion Agency. (2016). Costa Rica's Workforce. Retrieved from http://www.cinde.org/en/resources

Costa Rican Investment Promotion Agency. (2016b). Costa Rican Human Capital. Retrieved from http://www.cinde.org/en/resources

Costa Rican Investment Promotion Agency. (2016c). Education Overview in Costa Rica. Retrieved from http://www.cinde.org/en/resources

Herrera, R.& Gutierrez, J.M. (Eds.). (2011). Conocimiento, innovación y desarrollo [Knowledge, Innovation and Development]. Universidad de Costa Rica: San José, Costa Rica.

Hipatia. (2016). Estado de las Capacidades en Ciencia, Tecnología e Innovación [State of the Capacities on Science, Technology and Innovation]. Programa Estado de la Nación: San José, Costa Rica.

Human Resources Development Service of Korea. (2014), A Study on the Improvement Model of Industrial Personnel Demand and Supply Forecast: Focusing on the model of German Industry.

Jeju National University Dept. of Tourism Institute of Management & Economics. (2012), A Study on Mid/Long-term Industrial Workforce on Jeju-do Demand and Supply Forecasts.

Jeonbuk Research Institute. (2006), Industrial Workforce on Jeollabuk-do Demand and Supply Forecasts.

Korea Creative Content Agency. (2010), A Demand/Supply Forecast on Human Resources and Advanced Case Study in Contents industry.

Korea Employment Information Service. (2013), Forecasts on Demand of S&T Personnel.

Korea Employment Information Service. (2015), A Revision Study on Mid/Long-term Forecast on Industrial Workforce: 2014-2024.

Korea Health Industry Development Institute. (2015), Mid/Long-term Forecasts on Health Industry Workforce Demand and Supply: 2013-2023.

Korea Institute of Science & Technology Evaluation and Planning. (2013), A Study on the Demand and Supply Forecast of Nano-Technology(NT) Personnel.

Korea Internet & Security Agency. (2014), A Study on the Status and Demand/Supply Forecast of Information Security Personnel in 2014.

Korea Labor Institute. (2005), Mid/Long-term Forecast on Industrial Workforce: 2005-2020.

Korea Science and Engineering Foundation. (2000), Long-term Forecasts on Demand and Supply of R&D Personnel: 2000-2010.

Ministry of Agriculture, Food and Rural Affairs. (2014), A Forecast on Food Industry and Education Demand.

Ministry of Education and Human Resources Development. (2007), A Study on Improvement of Mid/Long-term Manpower Demand and Supply Forecasts.

Ministry of Education and Science Technology. (2008), Mid/Long-term Science & Technology Manpower Demand and Supply Forecasts.

Ministry of Employment and Labor. (2012), Mid/Long-term Forecast on Industrial Workforce: 2011-2020.

Ministry of Employment and Labor. (2014), Mid/Long-term Forecast on Industrial Workforce: 2013-2023.

Ministry of Public Education. (2016). Curso Lectivo 2016. Información General [2016 School Year. General Information]. Retrieved from http://www.mep.go.cr/sites/default/files/page/adjuntos/mep-curso-lectivo-2016-datos.pdf

Ministry of Science and Technology. (2001), Long-Term Forecast on Demand and Supply of the S&T Human Resources: 2001-2010.

Ministry of Science, Technology and Telecommunications. (2016). Indicadores Nacionales de Ciencia, Tecnología e Innovación [National Indicators for Science, Technology and Innovation]. MICITT: San José, Costa Rica.

National Statistics and Census Institute. (2015). Encuesta Nacional de Hogares 2015 [2015 National Household Survey]. INEC: San José, Costa Rica.

National Statistics and Census Institute. (2016). Encuesta Nacional de Hogares 2016 [2016 National Household Survey]. INEC: San José, Costa Rica.

OECD (1994), Frascati Manual 1993 - Proposed Standard Practice for Surveys of Research and Experimental Development, OECD, Paris

OECD (1995), The Measurement of Scientific and Technological Activities, Manual On the Measurement of Human Resources Devoted to S&T - Canberra Manual, OECD, Paris

Science and Technology Indicators Network. (2016). Indicators: Costa Rica. Retrived from http://db.ricyt.org/query/CR/1990,2014/calculados

Science and Technology Policy Institute. (1990), Prospects for Long-term Demand for Science and Technology Personnel for the 21st century

Science and Technology Policy Institute. (1999), Prospects and Responses of S&T Human Resources Demand and Supply in Restructuring Period.

Science and Technology Policy Institute. (2003), Realization of 21st Century S&T Human Resource Power: Key Challenges and Policies.

Science and Technology Policy Institute. (2004), A Study on Status and Improvement of Science & Technology Workforce.

State of Science, Technology and Innovation. (2014). Informe Estado de la Ciencia, la Tecnología y la Innovación [State of Science, Technology and Innovation Report]. Programa Estado de la Nación: San José, Costa Rica.

State of the Education. (2015). Quinto Informe Estado de la Educación 2015 [Fifth State of the Education Report 2015]. Programa Estado de la Nación: San José, Costa Rica.

State of the Nation. (2016). Décimo Segundo Informe Estado de la Nación en Desarrollo Humano Sostenible [Twenty Second State of the Nation Report on Sustainable Human Development]. Programa Estado de la Nación: San José, Costa Rica.

UNESCO (1984), Manual for Statistics on Scientific and Technological Activities.

United Nations Development Program. (2015). Human Development Report. United Nations: New York.

Universidad de Costa Rica. (2015). Presupuesto Universitario ¿Para Qué? [University Budget, What For?]. Retrieved from http://www.ucr.ac.cr/presupuesto-universitario.html

World Economic Forum. (2016). The Global Competitiveness Report 2015-2016. Insight Report. World Economic Forum: Geneva.

Chapter 3

STEAM Education for S&T HRD and Policy Suggestions for Costa Rica

STEAM Education for S&T HRD and Policy Suggestions for Costa Rica

Joonmo Ahn (Sogang University)
Natalia Flores Sanchez (Independent Consultant)

Summary

This report suggests short-, mid- and long-term policy recommendations based on Korean experience in STEM and STEAM education. As indicated in the OECD PISA results, Costa Rica has one of the world's smallest gaps between the top and bottom 10 percent in Science and Math test scores. This implies that Costa Rica has good universal education and successfully achieved its Political Constitutional value. Yet, Costa Rica must raise the quality of its STEAM education given that its science and math scores are lower than not just the OECD average but also those of other Latin American countries.

The results of semi-structured interviews and document analyses suggest that STEAM education in Costa Rica faces a number of obstacles and challenges. First, many interviewees pointed out teacher quality problems. Multiple reasons, such as the quality gap between public and private universities, ineffective teacher recruiting system, and teacher training, cause this vicious cycle. Second, science, technology, engineering and math are not correlated into one group in the Costa Rican educational system, which makes it difficult to introduce STEAM education in the country. Third, no special track exists for gifted and talented students. Although Costa Rica has the Scientific High School system which effectively selects top students and provides intensive and high quality education, but has failed to keep such students in S&T field. Fourth, the STEAM capability of female students needs a major boost to alleviate the serious gender imbalance in STEM performance and

prevent gender issues in STEM-related jobs. Fifth, Costa Rica's industrial structure and teaching-oriented universities result in low demand for high-level S&T personnel from academia and industry.

The Republic of Korea's STEAM policy has five key agendas: (1) incubation of leading groups; (2) empowerment of teachers; (3) dissemination of content; (4) hands-on inquires for students; and (5) systematization of infrastructure. In addition, for an excellence track, the Korea Advanced Institute of Science and Technology (KAIST) was set up as an S&T-focused university under a special law, and the system of science high schools followed. To build a talented pipeline for human resources, students at science high schools are encouraged to attend KAIST through incentives such as early graduation and free tuition.

This report suggests that Costa Rica adopt STEAM as an ultimate goal and enhance its STEAM capability and establish a foundation for implementing multidisciplinary integration. The policy recommendations are comprised of six domains – track for gifted and talented students, leader groups, teachers, content, hands-on experience and infrastructure - and a timeline should also be considered to distinguish short policies from those covering the mid to long term. The following are policy recommendations.

A. Hands-on experience: The university community work (UCW) program should be changed into one called "STEAM with university students" to initiate STEAM outreach with the help of CONARE's national lab and public universities.
B. Content: In addition to a regular curriculum, a diversity of STEAM supplementary content should be developed and distributed.
C. Teacher training: Online training content of KOFAC can be implemented by IDP or UNED and advanced offline training should be introduced to enhance training quality.
D. Fostering leader groups: A society for STEAM teacher research is needed to promote the bottom-up capability and development of teachers, as well as designate STEAM leader schools that will play a regional hub role in STEAM education.
E. Track for gifted and talented students: Strong incentives are recommended such as a preferential university admission system (e.g., exemption of entrance exams for top students) or scholarships. Over the mid to long term, TEC (and/or UTN) needs to be transformed into a science-oriented university under a special law (like the KAIST model). Once this is accomplished, an excellence track, from STEAM leader school, Scientific High School to TEC, will be completed.

F. Infrastructure: The setup of a STEAM institution (Costa Rican Foundation of Advancement for Science and Creativity or COFAC) and a national science museum is highly recommended, as is alleviation of the gender imbalance in STEM education.

1. Introduction

1.1. Project Background

Many countries invest in research and development (R&D) activities to generate and exploit new knowledge (OECD, 2015), indicating that knowledge is an important source of value creation. Though many factors such as financial resources or locational proximity play an important role in promoting innovation, skilled human resources are a fundamental driver of innovation (Fagerberg *et al.,* 2005). This is because innovation is mostly dependent on tacit knowledge (Freel, 2003, Rallet and Torre, 1999). Since such knowledge is personal, subjective and hard to codify (Polanyi, 1958, Polanyi, 1966), the role of talented individuals who can digest and transfer the complicated aspects of tacit knowledge is crucial in innovation as the latter grows more complex (Rallet and Torre, 1999).

Recognizing this, Costa Rica is striving to be an innovation-oriented country by reforming its development system for S&T human resources. To date, foreign direct investment (FDI) has played a crucial role in the Costa Rican economy together with ecotourism. The government has provided tax exemptions to attract international companies, making the country an FDI-friendly destination. According to the Global Competitiveness Report (WEF, 2015), Costa Rica was ranked 13th worldwide in the portion of FDI and the latter's contribution to the economy. Major multinational corporations (MNCs) in pharmaceuticals, financial outsourcing and software development such as Intel, Glaxo Smith Kline and Procter & Gamble have set up manufacturing sites in Costa Rica. In 2006, Intel's microprocessor facility alone was responsible for 20 percent of Costa Rican exports and 4.9 percent of GDP (elEconomista, 2006). Because of the emergence of other developing countries with cheaper wages, MNCs are turning their attention to new emerging countries like China and Brazil. For example, Intel in 2014 announced that it would end manufacturing in Costa Rica and lay off 1,500 staff (Randewich, 2014). To cope with this challenge, it is necessary for Costa Rica to reform its innovation system to remain competitive in the world market. A key driver of innovation is S&T human resources. Well aware of this need, the Costa Rican government along with the Republic of Korea has implemented the Knowledge Sharing Program (KSP), a policy consulting project. The goal is to offer policy advice based on the Republic of Korea's experience in economic development, and both countries have focused on enhancing Costa Rica's innovation capability. In 2015, a preliminary project on S&T human resource development was conducted, and to further develop this topic, the two subtopic of "supply and demand expectations for S&T human resources "and "STEM education" were chosen in 2016 by Ministerio de Ciencia Tecnologíay Telecomunicaciones (MICITT) of Costa Rica. The idea is to cover two pillars of the development of S&T human resources. The goal of the first subtopic is to gain more skilled S&T researchers from tertiary education and that of the second is how to nurture future S&T personnel through primary and secondary education. So through these two subtopics, the 2016 KSP attempts to suggest an overall policy for S&T human resources covering primary to tertiary education. For this purpose, the Republic of Korea is a good reference country rich in R&D and STEAM education experience. The country's ratio of R&D investment to GDP was the world's highest at 4.16 percent (OECD, 2015), and the number of R&D researchers and portion of bachelor's degree holders in S&T was ranked sixth and ninth in 2015, respectively (IMD, 2015). This high level of innovation is the fruit of government policy priority on human resources and education. Since the country lacks natural resources, it has instead developed highly skilled workers, and education has played a vital role in this approach, particularly in science and technology. In addition to regular institutions of tertiary education, a new form of higher education institution specialized in S&T has emerged, namely KAIST. The foundation of science high schools also provides high quality education for talented young students, and this excellence track has played a great role in supplying promising S&T human resources and systematically nurturing them after they finish secondary education. In 2011, the Republic of Korea introduced the concept of STEAM (science, technology, engineering, arts and math) to promote multi-disciplinary education and stimulate student interest.

1.2. Research Design

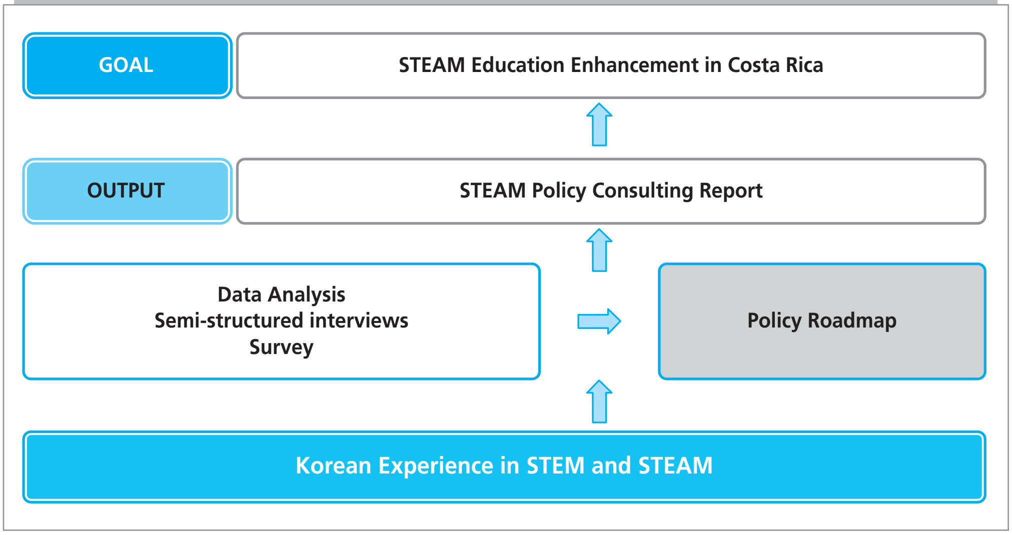
To provide high quality S&T human resources who satisfy both tertiary education and industrial needs, Costa Rica must restructure its STEAM education. In this context, this chapter focuses on the second subtopic of " STEAM education", and as illustrated in [Figure 3-1], the aim is to suggest short-, mid- and long-term policy strategies using the STEAM education experience of the Republic of Korea. This topic was suggested from the 2015/16 KSP with Costa Rica, and the authors held meetings with MICITT in August 2016 to discuss and adjust details.

Considering the complex characteristics of the policy development process and the limited time and resources available, a qualitative research methodology was employed. For data collection, literature review and content analysis were conducted to understand this phenomenon. In this process, important documents such as the

OECD PISA report was analyzed, and with the help of the Korea Foundation for Advancement of Science and Creativity (KOFAC), STEM and STEAM policy documents were collected and analyzed. And thanks to MICITT's assistance, the authors visited a number of leading Costa Rican institutions. They held semi-structured interviews with key personnel, such as the Costa Rican Ministry of Education's curriculum development team and the educational faculty dean of the University of Costa Rica, to grasp the status of Costa Rica's STEAM education. The institution list is as follows:

- MEP: education system, textbooks, teacher recruiting
- FOD (Omar Dengo Foundation): ICT education
- CONICIT: S&T research
- CAMTIC: ICT chamber of commerce
- CONARE: S&T research and national labs
- CINETEC: NGO focusing on science conferences & events
- SINAES: University accreditation
- Scientific high schools
- TEC: Public S&T university
- University Latina: Private university
- UCR education faculty: teacher education system

[Figure 3-1] Research Structure



Source: Author.

In addition to this qualitative approach, a survey was conducted to collect codifiable data. The Spanish-language questionnaire was distributed to regional science advisers who helped the Costa Rican Science Fair PRONAFECYT. Though the response rate (n=7, 25% response rate) was not low, the results were not included because of the conclusion that a small population (N=28) might prove insufficient to draw generalizable interpretations. A few important lessons were elicited from the survey, however, so the questionnaire and its results were included in the Appendix for reference.

1.3. Organization of Research

The remainder of this research consists of four sections. STEM education in Costa Rica will be analyzed in the next section, and the following section will introduce the Republic of Korea's experience, STEAM education and excellence track. 2009 was when STEAM was officially introduced to education policy, but the Republic of Korea has a long history of nurturing talented S&T students using a excellence track utilizing science high schools and KAIST. This report thus does not limit itself to STEAM. Instead, it will illustrate how the government developed policy toward the development of S&T human resources in primary and secondary education. Based on understanding of the experiences of both countries, Section 4 will suggest policy recommendations like short-, mid- and long-term policies. The short-term policies will suggest approaches of using Costa Rica's resources while the mid- to long-term policies will suggest advice on reforming the system, such as forming STEM institutions, a ministry-level collaboration system and revamp of teacher training. The final section includes tentative policy roadmaps.

2. STEM Education in Costa Rica

2.1. Understanding K-12 Education in Costa Rica

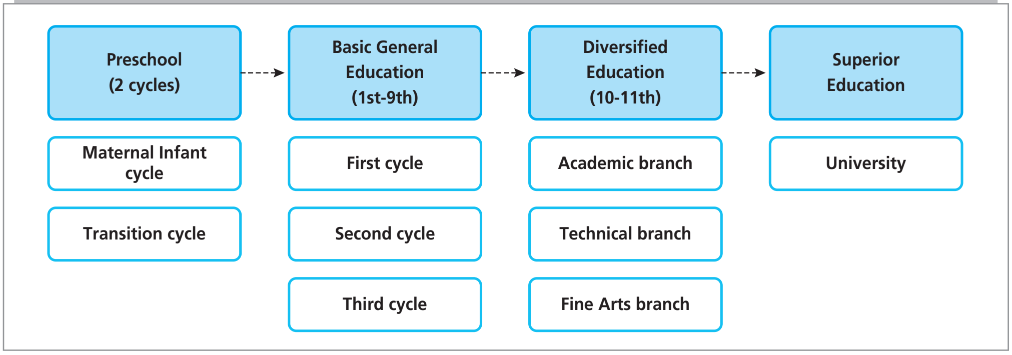
Costa Rica places high value on education. Chapter 1, Article 1 of the Fundamental Law of Education says, "Every citizen of the Republic has the right to an education and the State the obligation to offer it in the most widen and certain form." Moreover, the Costa Rican Political Constitution says in Article XII, a unique chapter on "education and culture", that "preschool education as well as elementary are obligatory. These two and high school education in the public system are free and provided by the nation." This indicates that since 1949, Costa Rica has required education for all citizens ages 6–14. Every Costa Rican has the right to an education. To make this possible, the proper resources are needed throughout the country. Because of this emphasis on education, Costa Rica is well-known for its high education level and low illiteracy rate in Central America. According to the UNDP (2015), public education spending in Costa Rica reached 6.9 percent of GDP and the adult literacy rate was 97.4 percent.

K-12 education in Costa Rica is managed by the Ministry of Education (MEP), which is led by one minister and three vice ministers, the first for academic affairs, the second for administration, and the third for institutional planning and regional coordination. The ministry has 1,846 staff and governs 27 regional offices in seven regions. The country has an estimated 4,523 public schools, 73,616 teachers and 1,084,866 students (MEP, 2016). K-12 education in Costa Rica is divided into four levels: preschool, elementary school, high school and university (as shown in Figure 3- 2).

A. Preschool

The maternal infant cycle admits children from age four years and three months and the transitional preschool cycle starts them from age five years and three months.

[Figure 3-2] K-12 Educational System



Source: MEP.

B. Elementary School

Elementary school in Costa Rica includes the first (from the age of six years and six months) and second cycles (from age 10 years and six months). At the end of this cycle, students receive a diploma certifying completion of elementary school. The curriculum consists of 11 subjects: math, science, foreign language, social studies, music, religion (Catholicism is the national religion), Spanish, physical education, fine arts, daily life and industrial arts. One regular teacher is in charge of teaching the four basic subjects of math, science, social studies and Spanish. Each of the remaining subjects requires its own teacher. Moreover, a type of elementary school called “single-teacher school” (Escuelas Unidocentes) has one teacher for all (or most) subjects and several levels at the same time, all in one class. This school is mostly in rural areas where a low number of students of varying levels can be accommodated in one or two rooms.

C. High School

High school is divided into two parts: the third cycle that goes from the seventh to ninth grades (ages 13-6) and the fourth that is called diversified education, which includes grades 10 and 11 (ages 16-18). At the end of 11th grade, students must take an exam on the six basic subjects to get a diploma.

The third cycle of high school comprises 11 subjects: Spanish, social studies, civic education, math, general science, English, French, music, physical education, family life education and industrial arts. This segment requires one teacher per subject.

Different branches are offered to students so that they can continue their diversified education. Subsequently, when students finish the third cycle, they have three options: academic education, technical education or fine arts. The academic option is divided into five school choices: bilingual (English or Italian), sports, environment, rural and indigenous, and humanistic, technological and scientific. The last three choices include an extra year because of the inclusion of university-style classes. Technical education includes one more year of classes due to the addition of technical modules such as those on industry, agriculture, commerce and services. One teacher teaches each subject most of the time to offer preparation in a variety of mechanical areas. The main goal is to prepare students to work. Finally, the fine arts option includes classes on dance, musical instruments and theater.

Costa Rica has an estimated 4,520 schools and high schools, of which 163 specialize in technology, nine in science, two in humanities and one in art. A combined 53 specializations are offered in technical education per Hipatia 2016.

D. University

The final and continuing step of the education process is the university, both public and private. In Costa Rica, autonomy of university education is guaranteed by law. The budget for state-run (public) universities is assigned to MEP, but budget allocation and distribution among national universities is up to CONARE (Council for Presidents of Public Universities); MEP is not involved in important decisions for public universities. The autonomy of private universities is also guaranteed and the government can get involved in their administration only when indicated by law. The National Accreditation System for Higher Education (SINAES) is responsible for accrediting professional careers in Costa Rica. SINAES is broadening its reach to private universities to enhance their education quality, but accreditation is not mandatory for university education autonomy. Costa Rica has five state-run universities, 63 private universities and other educational institutions. The five state-run universities are:

- Universidad de Costa Rica (UCR)
- Universidad Nacional de Costa Rica (UNA)
- Instituto Tecnológico de Costa Rica (TEC)
- Universidad Estatal a Distancia (UNED)
- Unidad Técnica Nacional (UTN)

University Community Work (UCW)

Universities in Costa Rica have one graduation requirement, university community work (UCW), to be completed to finish the career program. This program can vary from one university to another. For instance, Latin University of Costa Rica (the country's biggest private university) asks for 150 hours, while UCR (one of the five public universities) asks for 300. The idea is that college students should give something back to the community or their country. According to Alejandrina Mata, education faculty dean at UCR, every student from UCR since 2017 must dedicate a percentage of their 300 UCW hours to help high school students with their studies. At most universities (e.g., private ones such as Latin University), however, no official guideline for UCW exists. UCW can be redesigned to exploit well-educated university students as an important resource for STEM education, but the absence of a specific guideline means this resource has not been used effectively.

2.2. Teaching Staff

Since education is implemented by teachers, how they are recruited and trained (and re-trained) plays a vital role in enhancing the quality of education. Because STEM content changes quickly, hiring quality teachers and providing re-training are important.

2.2.1. Teacher Recruitment

Teacher recruitment in Costa Rica is no different from how the rest of professionals in the country are selected in the public sector. It starts with the civil service announcement of the opening of the recruitment season. A candidate hands in a file with the diplomas and extra courses taken. There is no formal interview. Then each candidate's file is uploaded to assign him or her a score in the system. The more titles one has, the more points are earned. After a score is set, the system assigns the person a property or interim place. If not, he or she is put on waiting list until a spot appears.

2.2.2. Teacher Quality Control

The lone official entity in charge of teacher quality control is the Institute of Professional Development (IDP). This organization can authorize other organizations to provide teacher training such as universities (e.g., UCR and UNA) and non-profit organizations. Any teacher training has to be validated by MEP so as to have punctuation in the Civil Service. These points could lead to a salary increase.

Institution of Professional Development (IDP)

The IDP was established in 2008 due to teacher demands for proper training in preschool, elementary and high school. Teachers insisted that they were ill-prepared to deal with many situations in the classroom. Mario Avendaño, head of the Department of Plans and Programs, says the IDP is still growing due to high demand from the biggest organization in Central America, MEP. The institute not only focuses on teachers but also the administrative staff of all 27 regions of the country (79,380 workers overall). The IDP enables educators from a number of areas such as academia, technology, science, humanities and art. This also leads to difficulty in getting to all teachers every year. Avendaño also says that according to the Constitution, initial teacher training is the responsibility of universities. This is the main reason MEP does not interfere as much as it should in the early preparation of educators. This condition could affect teacher performance because of lack of direct bonding between most universities and MEP in the teaching profession. Certain private institutions graduate students who have no teaching or class experience. For instance, certain students merely recognize simulations among equals (those from the same university class) but know nothing about other modalities such as night school or the one-teacher room.

A confusing situation has recently arisen because public universities are not the only ones preparing teachers. Other universities focusing on education are leaving behind MEP statements and no watchdog is supervising what these institutions are doing to prepare educators. MEP has no defined profile to provide guidance to these institutions. Moreover, once teachers register for the jobs, no filter can assess or dictate whether they are properly prepared.

The Costa Rican government is working together with the IDP to emphasize this department. The so-called national formation plan, which is called “Actualizandonos” (Updating Ourselves) in Spanish, runs from 2016 to 2018. This allows intervention areas in elementary and high school and administrative tasks with the five axes proposed by authorities. Recognizing the challenge posed by these training programs, the IDP uses the “trickle-down effect” by working with facilitators and representatives from the country’s 27 regions that receive the message for delivering it to teachers.

The majority of topics proposed by teachers for this type of training are qualified by the IDP as "empty spaces" left by universities. This means the institute is filling those gaps instead of pushing forward real professional development.

Over the last two years, the IDP has been working through bimodality, or face-to-face encounters and a virtual platform specially made by the institute. Yet this technique has not worked that well. The two main reasons are the concern of teachers toward the technological era and the lack of self-discipline by certain Costa Ricans to take online courses. The latter s perpetuated by the absence of technological resources in certain areas of the country, lack of time by teachers to follow related procedures and the stress or anxiety demand for this technological tool can cause to teachers.

According to Avendaño, the majority of teachers from the public sector assist in training, workshops or conferences because they are summoned. Yet there are teachers who want to assist these activities to improve their capacity. This is why the IDP has established 27 formation centers to show videoconferences.

2.3. Curricular Development

The educational curriculum in Costa Rica requires no textbooks for both students and teachers. A program devised by the National Council of Costa Rica (which leads national education policy) includes all topics to be developed throughout the year. This is for all educational processes from preschool up to high school. According to Anabelle Venegas, director of the I and II Cycle Department, these "programs are the official guidelines that lead the mediation process of each subject matter in the curriculum." The program is done every five years and based on previous programs, being mostly a renewal of previous content. The council diagnoses the program's content and consult with teachers, students, parents, education authorities and experts to determine the need to change the program, if any. Once a need for change is demonstrated, guidelines dictate the process of modification. For instance, the communicative approach and theoretical basis in English education are considered.

In general terms, programs are organized into three main components: the theoretical basis or scientific guidelines that lead the mediation process, practical aspects (organization of strategies into levels and units including activities, mediation strategies and evaluations) and appendixes (glossary and sites to consult). This program includes the following aspects per subject: abilities, objectives, content, strategies for the mediation process and evaluations a teacher uses to mediate the process. The instructor must organize lessons into units, weeks and months.

Once teachers have the program, they can use any resource they want. For example, they can use technological support to search for class materials. MEP has a department dedicated to creating educational material in digital form, so teachers, students and parents can use such material to review the topics studied in class The web page "educatico" also allows teachers to access material to enrich their lessons.

2.3.1. Math Program

In math, Costa Rica has introduced a new education system for grades K-12 to continue the linking process. According to math supervisor Hermes Mena, this is a linear work among the five main subjects of math: geometry, numbers, algebra and relations, statistics and probability, and measurements. Students study these five areas from the first year of elementary school until they graduate from high school in vertical form. The new program's approach is problem solving related to a student's daily needs and situations. This new program says a correlation among basic subjects is possible and needs to include contextualized problems associated with math history. The five main axes of each class are math history to change misconceptions of the subject; use of smart technology; correct contextualization of math problems; and problem solving. These axes next to mathematical processes look for the development of math competence in students, and stress student ability rather than content to develop critical thinking in a process expected to induce inductive thinking. The program has three levels of difficulty: connection problems (when a problem is related to another subject and/or the environment), reflexive problems (which require a higher level of reasoning and analysis from a student) and reproductive problems (which reinforces a student's acquired knowledge). The math lesson is divided in two stages: knowledge learning and application of acquired knowledge. The first stage is divided into four key steps: problem proposal, independent student work, interactive and communicative discussion, and pedagogic wrap up. The second stage is done for students to work on the three types of problems mentioned above.

2.3.2. Science Program

National Education Adviser Cristina Parra says Costa Rica's new science program wants to include a vision of children as active citizens of the community under the slogan "Educate for New Citizenship." The three main axes are sustainable development (how people relate to the environment); digital citizenship with social equity (possessing technology, learning to use it and how to get it to rural areas), and "Glocal" (combination of the words "local" and "global"). The program is based on competencies and abilities. The competencies are developed by thinking of the context, knowledge, abilities, values and attitudes. This program features 13 main abilities including critical and systematic thinking, learning how to learn, problem solving, how to live with the world, life project, communication and technological tools (how to use and understand them). The topics in this program are no longer isolated and thus correlate with each other. This gives Costa Rica a unique profile, meaning there will be one type of citizen. This science program also has one main axis that goes from first grade (elementary) up to 11th (high school). So knowledge has coherence among the different levels and its main focus is compounded by a holistic theory: social constructivism, critical pedagogue and life abilities with a research focus.

2.3.3. Technological Program

According to Katherine Williams, "2017 will see a technological program that is going to cover elementary and high school education that is called the National Technological Mobile Program." The main objective is to provide a school or high school with high-tech equipment according to level, as well as teachers training in the use of such technology. And the scheduled creation of an educational platform will help the exchange of information and materials among teachers, students and parents.

The government seeks to stress that even rural schools can get access to high-tech resources. The Technological Resources Direction is tasked with extending technology's reach throughout the country. It has three departments: libraries (CRA, small information center at every school), management and production. The latter is in charge of developing digital material for teachers and students.

The last project of this tech department is "Tecnoaprender" (Technolearning), which provides technological equipment to schools and offers teacher training as well. This mobile equipment can be moved from one classroom to another. This is not a static laboratory but rather a dynamic of constant change as it evolves. Three main columns enable connection, equipping and learning. The first is the connectivity needed to proceed. The second is the equipment necessary to make the project active, and the third includes methodologies and manner of development.

This program has seven points of access: Tecnocole (high school), Tecnobliocra (school library), Tecnoadultos (adult education), Tecnoambientes (preschool), Tecnoeducar (elementary school), Tecnorural (rural education), and Tecnoacceso (education for disabled students). Each program can deliver technological material and equipment to teachers and students and add resources for teachers to enrich their classes. The main purpose of this project is to cover all subjects, taking into account study programs or curricula so the same educational objective can be achieved. In five years, this program is expected to reach every part of Costa Rican territory.

2.4. Beyond Standard K-12 System

On top of standard STEM education from grades K-12, Costa Rica has taken additional actions to raise STEM education such as the setup of science high schools, the National Science Fair and non-government organization (NGO)-based STEM activities.

2.4.1. Scientific Schools

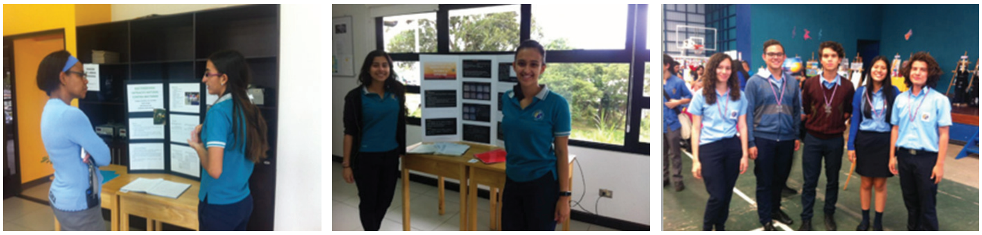
Scientific high school emphasize three of the four STEM subjects: science, technology and math. These schools are directly under MICITT (Ministry of Science and Technology) and MEP (Ministry of Public Education). The schools' curricula offer a variety of subjects within science and help the use of technology and mathematical calculations. As indicated by Law No. 7169, Chapter III, Article 57:

> *"The objective of the Scientific Schools, is the integral formation of their students, taking into consideration the highest Costa Rican values inside the educational process, emphasizing acquisition of solid knowledge and abilities according to the foundation of Mathematics, Physics, Chemistry, Biology and Computer Technology. These high schools are going to be display as an efficient option to the improvement of Science teaching, without eliminating other alternatives that may be found."*

A scientific high school requires one more year than a regular high school because selected subjects are taught by university teachers. These subjects allow the students to gain an advantage once they start more advanced studies. Costa Rica has nine scientific high schools and their students are renowned for their participation in the Academic Olympiad. Based on a suggestion from former Costa Rican Vice President Francisco Pacheco, the first scientific high school was opened in 1986; the first two were established in Cartago and San Pedro. Four followed in Liberia, San Ramon, San Carlos and Perez Zeledon in 1993, and three more in Alajuela, Puntarenas and Limon (Robles, 2016).

A major advantage of the scientific high school is its access to the academic resources of state-run universities. For example, the scientific high school in Cartago (see Figure 3-3) is located within the state-run university TEC (Tecnologicode Costa Rica). TEC teaches STEM subjects to the scientific high school's students, who can also access TEC's science labs. The nine scientific high schools operate their own curriculums, and as in the case of Cartago Scientific High School, all of them are connected to state-run universities such as UCR or UNA. Each scientific high school recruits students using its own entrance examination; just 30 talented students gain admission into a scientific high school each year (i.e., 10th and 11th grades).

[Figure 3-3] Scientific High School in Cartago



Source: Robles, 2016.

2.4.2. PRONAFECYT

PRONAFECYT stands for the "National Program of the Science and Technology Fair" operated by MICITT and MEP. PRONAFECYT aims to stimulate creativity and promote an S&T culture, and grants participation at different levels and in a number of research categories in the science fair process to students in preschool, primary (grades 1–6) and high school (grades 7–11 or 12) (Chacón, 2016). PRONAFECYT was initiated by Law No. 7169, Law for the Promotion of Scientific and Technological Development, and National Executive Decree No. 39853 MEP- MICIT (2015); many stakeholders participate in this project (see Figure 3-4). MICITT provides the necessary budget for 27 regional science fairs, and this fund is supervised by CONICIT. MEP provides human resources and encourages schools, and state-run universities to help with implementation support. Research organizations play the role of judge and the private sector sponsors the project by providing awards. More than 6,000 schools in 180 districts of the 27 regions participate in PRONAFECYT, and its schedule is shown in <Table 3-1>.

[Figure 3-4] PRONAFECYT Organizers

Source: MICITT.

〈Table 3-1〉 Typical PRONAFECYT Schedule

Month	Science Fair Process
February - December	Teacher orientations and training
June - July	Institutional Science and Technology Fairs
August	District Science and Technology Fair
September	Regional Science and Technology Fair
November	National Science Fair

Source: MICITT.

2.4.3. Omar Dengo Foundation (FOD)

The non-profit Omar Dengo Foundation (FOD) develops and implements innovative education proposals focused on learners and their appropriation of digital technologies to stimulate cognitive capacity, collaboration and innovation (see Figure 3-5). FOD was established in 1987 under the idea of "Bring computers to schools" and has a public-private partnership with MEP. Through 29 years of operation, the foundation saw coverage of ICT skill education for grades K-9 reach 80 percent (FOD, 2016).

In 1988, Costa Rica made its first attempt to provide ICT education in schools, and 57 elementary schools participated in two ICT lessons per week. Over the first 10 years, FOD focused on setting up ICT education fundamentals through training support provision to teachers and securing stable financial resources. Over the next decade, secondary schools (grades 7–9) were incorporated and the content was diversified from basic ICT skills to extracurricular activities, robotics and entrepreneurship. Over the last six years, FOD has tried to provide a more enriched and deeper program through actions like the Educational Informatics Lab, through which FOD aims to develop high student capacity in areas such as problem solving, physical computing and computational concepts.

[Figure 3-5] FOD's Mission

PRONIE MEP-FOD

Objectives: Use computers as tools to develop student's high-level thinking skills and train teachers in the methodology to be used rather than on the computer hardware and software.

Digital citizenship	Thinking and problem solving skills	Entrepreneurship and innovation	Digital technology ownership
Use technology to particpate in local and global communities, using web collaboration tools effectively	Use technology to think, research and solve problems drawing on different formal thinking frameworks	Use technology to create new ideas and ventures, and to lead them to success	Use technology to create useful products and to know how to use tools effectively with an understanding of digital systems

- Communication
- Collaboration
- Creativity
- Information literacy
- Self-direction
- Ethics and security

Source: FOD, 2016.

[Figure 3-6] The Key FOD Statistics

Multigrade rural elementary schools

- 33.983 students benefited
- 928 schools
- 1 to 1 and 1 to 2 technological solution

Rem@

- 6,534 students benefited
- 82 Rural High Schools
- 461 teachers benefited
- 21 electrical improvements projects
- Rural Entrepreneurship Project available 29 Rural High Schools

Mobilab-equipped elementary schools

- 25.999 studnts benefited
- 188 schools
- 730 boys and girls trained as technoscientific leaders

Multigrade rural elementary schools

- 43,542 students benefited
- 98 high schools

Source: FOD, 2016.

Thanks to its collaboration with MEP, the Educational Informatics Lab was incorporated into the regular curriculum, with two weekly lessons (each 90 minutes) given at 1,184 schools. As illustrated in [Figure 3-6], FOD-run programs have provided many opportunities to students by enhancing their ICT capabilities.

In addition to the aforementioned ICT education program, FOD has operated an online platform for teacher training (www.upe.ac.cr) and expanded its scope to entrepreneur education, adult training (e.g., senior citizens and teenage mothers) and science programs. The foundation runs three science programs: GLOBE, Ciencia Aventura and Environmental Supporters. GLOBE projects are offered at 14 public high schools and coordinated under collaboration with external partners such as NASA, National Science Foundation of the US and Intel. Ciencia Aventura is a school-based science project, and the Intel-sponsored Environmental Supporters is a program encouraging environmental protection. To date, the three programs have trained 85 teachers and 1,081 students (FOD, 2016).

2.5. International Comparison: OECD PISA

The Organization for Economic Cooperation and Development (OECD) conducts an international student performance test, Program for International Student Assessment (PISA), on OECD member and partner countries. The most recent results were announced in December 2016. The results of PISA 2012 and 2015 are illustrated in <Table 3-2> and [Figure 3-7].

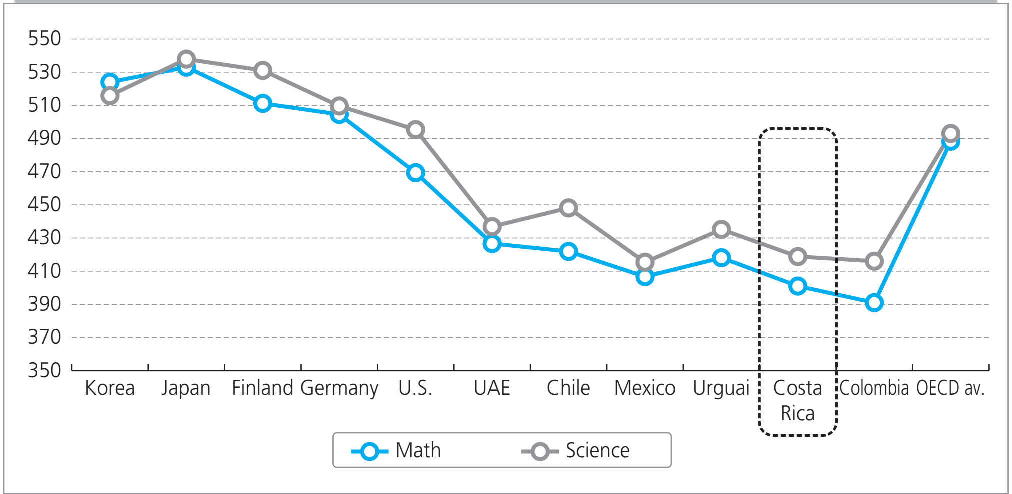
〈Table 3-2〉 OECD PISA Results

(Unit: Number)

Country	Math score		Science score	
	2012	2015	2012	2015
Republic of Korea	554	524	538	516
Japan	536	532	547	538
Switzerland	531	521	515	506
Finland	519	511	545	531
Canada	518	516	525	528
Germany	514	506	524	509
US	481	470	497	496
Turkey	448	420	463	425
UAE	434	427	448	437
Thailand	427	415	444	421
Chile	423	423	445	447
Mexico	413	408	415	416
Uruguay	409	418	416	435
Costa Rica	407	400	429	420
Colombia	376	390	399	416
OECD average	494	490	501	493

Source: OECD.

[Figure 3-7] Graphic Comparison of PISA Results



Source: OECD.

Costa Rican students scored lower than the OECD average (see Figure 3-7), and their scores were not significantly different from those of Latin American countries (OECD, 2016).

In math, Costa Rican students scored an average of 400 points, lower than the OCED average of 490. Boys performed better than girls with a statistically significant difference of 16 points, wider than the OECD average of eight. The percentage of top performers in math was one of the lowest among PISA-participating countries (0.3 percent, rank of 65/69), and the score difference between the top 10 percent of the highest scoring students and the lowest 10 percent of the lowest scoring students was one of the smallest among PISA-participating countries (174 PISA Score, rank 69/69) (OECD, 2016).

In science literacy, Costa Rican students scored 420 points, lower than the OECD average of 493. Boys performed better than girls with a statistically significant difference of 18 points (the OECD average is 3.5 points more for boys). The percentage of top performers in science (Level 5 or 6) was one of the lowest among PISA-participating countries (0.1 percent, rank 62/69), and the score difference in science between the top 10 percent of the highest scoring students and the lowest 10 percent of the lowest scoring students was one of the smallest among PISA-participating countries and economies. (182 PISA score, rank 66/69) (OECD, 2016).

Despite these disappointing results, Costa Rica's scores for classroom environment and education resources were not low. The average time per week spent learning regular lessons was one of the longest in the PISA survey (31.5 hours, rank 4/55). The quality of educational resources at schools was one of the highest among PISA-participating countries (1.03 PISA index, rank 2/69). Schools attended by 15-year-olds saw a high share of science teachers with a university degree in science. (96.9 percent, rank 2/68). Reports from school principals, however, indicated that Costa Rica has one of the largest shortages of education staff among Pisa-participating countries (0.91 PISA index, rank 3/69) (OECD, 2016).

2.6. Obstacles and Challenges of STEAM Education in Costa Rica

As indicated in the OECD PISA results, Costa Rica has one of the world's smallest gaps between the top and bottom 10 percent, implying that it has good universal education and achieved the goal of its constitution. Yet the country's poor showing in math and science scores compared to the OECD average, and even than other Latin American countries, suggests to the nation's need to raise the quality of STEAM education. Based on analyses of interviews, documents and data, the following obstacles and challenges were identified.

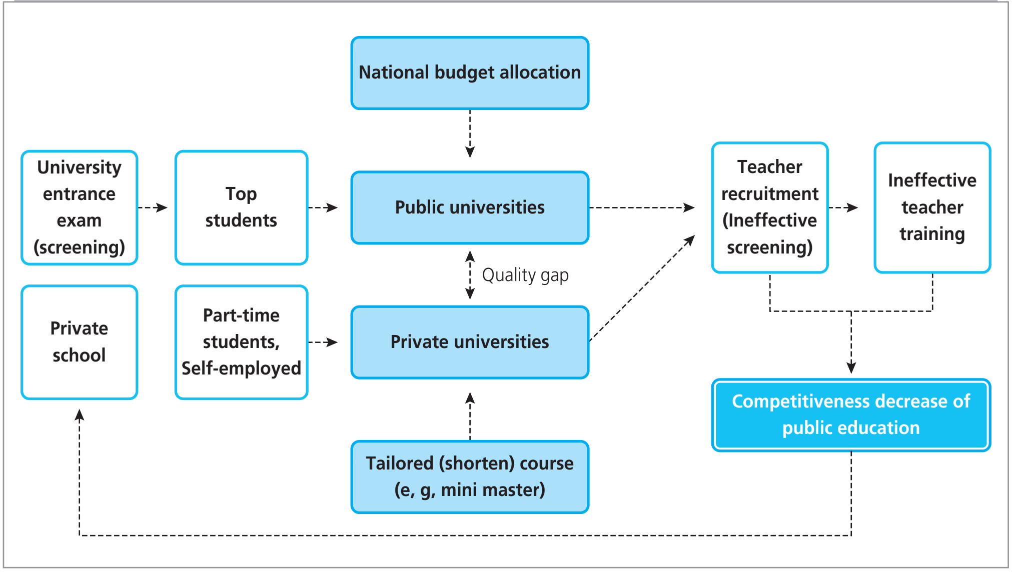
First, many interviewees cited problems with "teacher quality[1]." Most teachers in Costa Rica attended private universities, and a large quality gap exists between public (state-run) and private universities. Because of their academic reputations and cheap tuition, the five state-run universities attract high quality students. Costa Rica invests a high portion of GDP (6.9 percent) in education (UNDP, 2015); the budget for tertiary education goes to the five public universities via CONARE. Sixty-three private universities are autonomous from MEP in funding and policy, so they operate market-oriented courses. As their main customers are part-time students with jobs or self-employed businesspeople, private universities operate night classes and provide shorter courses such as a one-year mini-master's degree or three-year bachelor's program. To earn profit, private universities have not strongly controlled course content, so the quality gap between public and private universities has grown substantial.[2] The problem is that despite this quality gap, the teacher recruiting system fails to properly screen high quality teaching candidates. No specific process of teacher selection defines their abilities or class management. Whether a teaching candidate has an academic degree is simply quantified as a score and no formal interview is conducted to evaluate qualitative skills. Furthermore, other factors such as resistance from teacher unions make it difficult to introduce mandatory teacher training. Updated teacher training and follow-up tests should be applied to keep teachers motivated to pursue self-development and professional growth. The existing incentive system is based not on evaluation but attendance, so

1) In our survey, many regional advisers also indicated that teacher training is one of the most important keys to advancing STEAM education.

2) SINAES has encouraged private universities to join the accreditation system but remains in the initial stage.

reform of the teacher training system should be done in a way to improve teaching capability. Problems in teacher recruiting and training can lower the quality of public education. According to Alejandrina Mata Segreda, former vice education minister and education faculty dean at UCE, more than half of UCE students come from private high schools, which only account for just 8 percent of all high schools in Costa Rica. The problems of teacher quality are illustrated in [Figure 3-8].

[Figure 3-8] Problem of Teacher Quality



Source: Author.

Second, science, technology, engineering and math are not considered as part of one group within the Costa Rican education system. They are generally taught as individual subjects and sometimes two of them are combined. Recent changes have brought programs for math, science and technology relatively closer to STEAM education. MEP is creating programs to immerse technology into regular matters. This could be the beginning of fusing technology with subjects such as math, Spanish, physical education or science and promoting a STEM or STEAM philosophy.

Third, a pressing task is to raise the STEM capability of female students. As indicated in the PISA results, top-performing girls in science and math in Costa Rica had one of the lowest rankings of 60 and 65, respectively, among 69 PISA-participating countries. The serious gender imbalance in Costa Rica's STEM performance can cause problems in STEM-related jobs. So high school counselors need more knowledge of and should promote more STEM careers to girls. Female students are highly likely not to be well informed of their multiple options in these areas.

Fourth, a track for gifted and talented students is needed in Costa Rica. Scientific high schools effectively screen for top students and provide intensive and high quality education to them along with public universities, but few students remain in S&T. Interviews with staff at a scientific high school indicated no incentives for those who choose to major in science and engineering in college.

Fifth, because Costa Rica's main industries are ecotourism, coffee and FDI-driven manufacturing and many universities focus on teaching rather than research, demand for high-level STEAM students from higher education and industry is low. But the Costa Rican government needs to strengthen STEAM education and create research jobs at public universities or national science labs to meet industry needs. One interviewee from industry had this to say about the need for reform:

> *"Costa Rica has achieved good education in Latin America because of its high investment in education and, in fact, has shown some pioneering examples such as ICT education through the Omar Dengo Foundation (FOD). FOD is good, and now Costa Rica is harvesting from it. The problem, however, is that Costa Rica is not investing in the same initiative at the moment, which will lead to a decrease in growth momentum. To supply high quality S&T HR, a radical and innovative approach has to be taken in due course."*

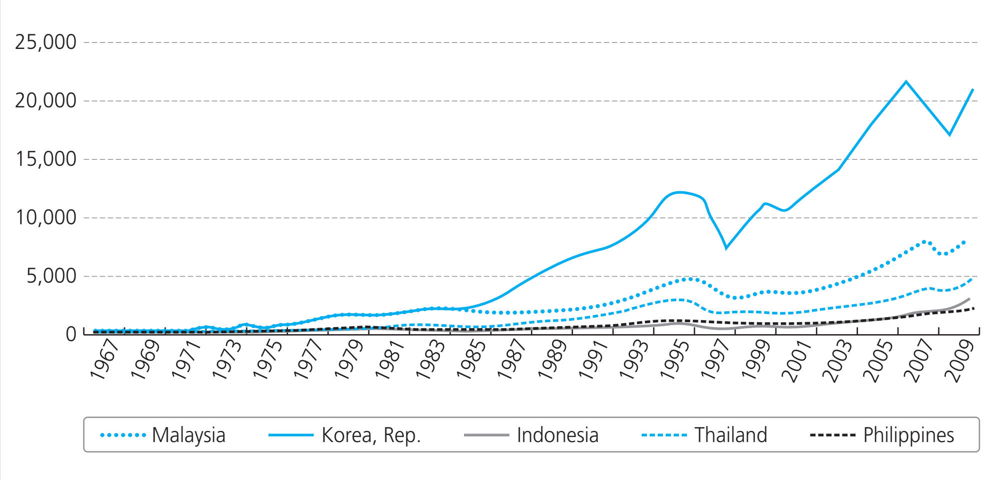
Finally, efficiency in Costa Rican education needs a boost. Though the country invests 6.9 percent of GDP in education (UNDP, 2015), its PISA results were not higher than other Latin American countries. Costa Rican students spend an average of 31.5 hours per week at school, one of the highest rates in the world, and with plenty of educational resources (rank 2/69). Also, a high number of science teachers hold university degrees in science (rank 2/69). Despite these advantages, school principals complain of a shortage of education staff (rank 3/69) and the top performers in science and math were ranked low at 62nd and 66th out of 69 countries, respectively. This mismatch between resources and performance indicates strong inefficiency in STEAM education and that quality rather than quantity is an issue. Including the problem of teacher quality, systematic reform is an urgent task.

3. Republic of Korea's Policy Experience

3.1. Policy Background

The Republic of Korea has set detailed economic and technological development plans every five years since the 1960s. In the late 1950s, the country lacked an industrial structure because of the devastation left by the Korean War and had few natural resources. In this situation, the role of S&T human resources is considered one of the most important drivers of economic development. In its first five-year plan for economic development in the 1960s, the government focused on educating technicians to promote the light industry, and in the second plan, the focus shifted to S&T education in college and university (Marginson *et al.,* 2013). From the 1970s, the economy started to grow rapidly as shown in [Figure 3-9], and this greatly raised industrial demand for skilled human resources. After the 1970s the focus moved to engineering education to promote the heavy and chemical sector. In the 1980s, when annual economic growth averaged a robust 12 percent, demand for highly qualified and specialized S&T researchers intensified. The Korea Advanced Institute of Science and Technology (KAIST) was set up by the government and an R&D zone followed to house many public think tanks such as Electronics and Telecommunications Research Institute (ETRI) and Korea Research Institute of Bioscience and Biotechnology (KRIBB). The introduction of science high schools also sought to enhance S&T education from the secondary education stage.

[Figure 3-9] Growth per capita, 1967-2009



Source: World Bank development indicator.

In the 2000s, the need for advanced human resources increased with the advent of the knowledge-based economy, but the Asian financial crisis of 1997-98 and the dot-com crash in the early 2000s, along with chronic problems such as a mismatch between supply (i.e., university education) and demand (i.e., industry needs), caused students to avoid studying science and engineering (Marginson *et al.,* 2013). To encourage S&T careers and enhance the competitiveness of S&T education, the First Master Plan for Educating and Supporting Human Resources in Science and Technology was formulated and soon followed "by the second (2011-2015)" under the Special Act for Science and Engineering for Improving National Competitiveness" focused on S&T education and workforce preparation.

To support the second master plan, many strategies and programs on implementation were developed. The concept of STEAM (science, technology, engineering, arts and mathematics was initiated to strengthen inter-disciplinary education and encourage self-motivation by students in STEM. Despite showing high performance in OECD PISA results, Korean students showed low self-motivation in math (rank 41/42) in the 2011 Trends in International Mathematics and Science Study (TIMSS) (see Table 3-3). In this regard, a student-centered STEAM education was employed to cope with the challenges (i.e., low self-motivation) and strengthen multidisciplinary education. The Korea Institute for the Advancement of Science and Creativity (KOFAC) was established to promote S&T culture and science communication and introduce and disseminate STEAM education. At the same time, other strategies focusing on elite education, such as the Comprehensive Plan for Discovering and Educating Talented and Gifted Youth in Science, were initiated to identity and teach promising young students in the early stage.

〈Table 3-3〉 TIMSS 2011 Results

Rank	Performance		Interests		Self-motivation	
	Grade 4	Grade 8	Grade 4	Grade 8	Grade 4	Grade 8
Math	2/50	1/42	50/50	41/42	49/50	41/42
Science	1/50	3/26	50/50	26/26	48/50	24/26

Source: KOFAC.

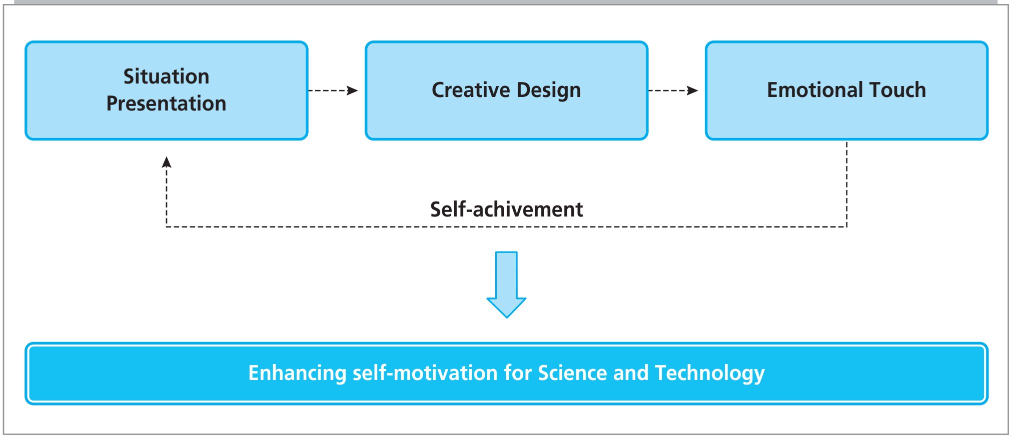
2011, the year in which the second master plan was established, was a good time for the Republic of Korea to implement STEAM education by emphasizing multidisciplinary integration thanks to government restructuring. In 2008, the Ministry of Science and Technology and Ministry of Education of the Republic of Korea were merged to form the Ministry of Education, Science and Technology (MEST) to integrate research with education. STEAM was one of the new ministry's most important policy tasks in that STEAM was an area in which S&T research and education could create synergy. After the establishment of MEST, the Presidential Advisory Council on Science and Technology was expanded and renamed the Presidential Advisory Council on Education, Science and Technology to support new policy agenda, such as STEAM. MEST in 2013 was divided into the Ministry of Education (MOE) and the Ministry of Science, ICT and Future Planning (MSIP), but both ministries remain engaged in STEAM education and have a good collaborative relationship.

3.2. STEAM Education

3.2.1. STEAM Concept

STEAM education was introduced to provide an integrated multidisciplinary approach emphasizing science, technology, engineering, math and art; its aim is to enhance creative thinking and problem-solving capability in a real-life context. As shown in [Figure 3-10], Korean STEAM education highlights three components: (a) presentation of the situation (b) creative design; and (c) emotional touch (KOFAC, 2015).

[Figure 3-10] STEAM Criteria



Source: KOFAC, 2015.

Here, the presentation of the situation indicates that teachers must illustrate a detailed situation of a problem to stimulate student interest. By providing problems in a real-life context, this step enables students to recognize that the given problem is interesting and worth solving. Through this, the burden of instilling the initiative to learn is moved from teacher to student (KOFAC, 2015).

The stage of "creative design" refers to the comprehensive process by which a learner demonstrates creativity, efficiency, and an economic and aesthetic sense to find an optimal solution to a problem. It includes the concept of engineering, which refers to a technological design and creative problem-solving skill for shared human values (Park *et al.*, 2016). In creative design, a key principle is not to discourage student ideas and teachers must encourage students to explore any possible solution themselves. Open-endedness and collaboration are part of the nature of creative design. Creative design also includes a provision for educational opportunities for students to experience their self-directed processes until the final product of learning is applied in practice (Park *et al.*, 2016).

"Emotional touch", on the other hand, refers to experiences that enable a positive cycle of self-directed learning through which students feel interest, confidence, intellectual satisfaction and a sense of achievement while finding motivation, passion, flow and personal meaning in learning (Park *et al.,* 2016, KOFAC, 2015). This aspect also includes the formation of a clear and tangible relationship between learner and subject in which the former perceives the latter as a personal objective. This covers elements often neglected in education (Park *et al.,* 2016).

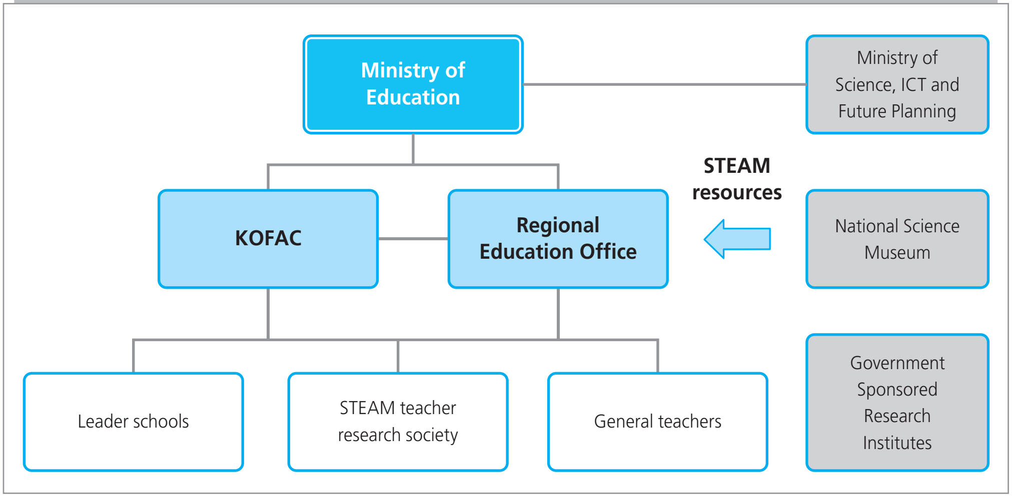
Based on these steps, students feel a sense of accomplishment through the experience of self-STEAM education and this encourages them to solve another problem, which in turn enhances self-motivation in S&T.

3.2.2. STEAM Education Policy

STEAM is based on the Framework Act on Education's Article 22 (S&T Education): "The State and local governments shall establish and implement policies to promote science and technology education" and the Framework Act on Science and Technology's Article[3]and 30 (Promotion of Scientific and Technological Culture and Fostering of Creative Human Resources)." Other STEAM policies have been implemented mainly by KOFAC and regional education offices. The basic STEAM master plan was devised by the Ministry of Education (MOE) of the Republic of Korea with the collaboration of the country's Ministry of Science, ICT and Future Planning (MISP). KOFAC plays an important role in linking the MOE and MSIP; KOFAC is generally managed by MSIP but MOE manages KOFAC's STEAM policy. The structure of the main organizers, implementers and stakeholders is illustrated in [Figure 3-11].

3) Article 30 (Promotion of Scientific and Technological Culture and Fostering of Creative Human Resources)"
(1) The Minister of Education and the Minister of Science, ICT, and Future Planning shall formulate and implement the policies to raise citizens' level of understanding and knowledge regarding science and technology, to develop the scientific and technological culture in which science and technology may be extensively used in the whole society and the citizens may demonstrate their creativeness, and to foster creative human resources
(2) The Minister of Education and the Minister of Science, ICT, and Future Planning shall foster and support the following institutions and organizations in charge of the activities of scientific and technological culture and fostering of creative human resources to efficiently achieve the objectives prescribed in paragraph 1. Science museums registered pursuant to the Act on Establishment, Operation and Promotion of Science Museums; 2. The Korea Foundation for the Advancement of Science and Creativity established pursuant to Article 30-2 (1); 3. Other institutions or organizations relevant to the activities of scientific and technological culture determined by the Minister of Science, ICT, and Future Planning.
(3) The Minister of Education and the Minister of Science, ICT, and Future Planning may fully or partially contribute to or subsidize expenses incurred in relation to projects performed by the institutions or organizations referred to in paragraph (2).

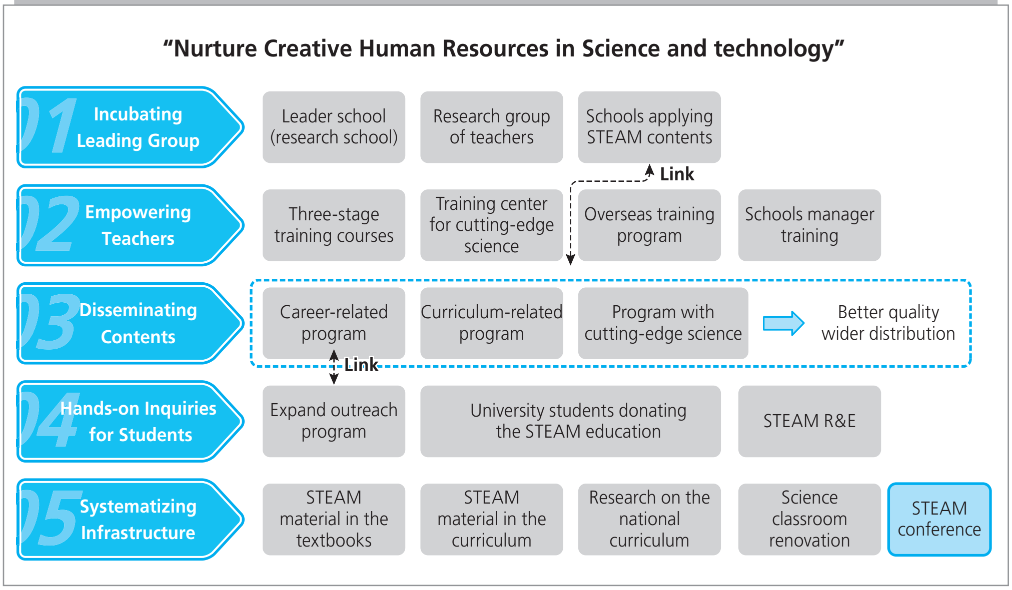
[Figure 3-11] STEAM Organizations and Institutions



Source: Author.

STEAM policy is comprised of five key agendas: (1) incubation of leading groups; (2) empowerment of teachers; (3) dissemination of content; (4) hands-on inquiries for students; and (5) systematization of infrastructure. The sub-program lists are summarized in [Figure 3-12].

[Figure 3-12] Structure of STEAM Education Programs



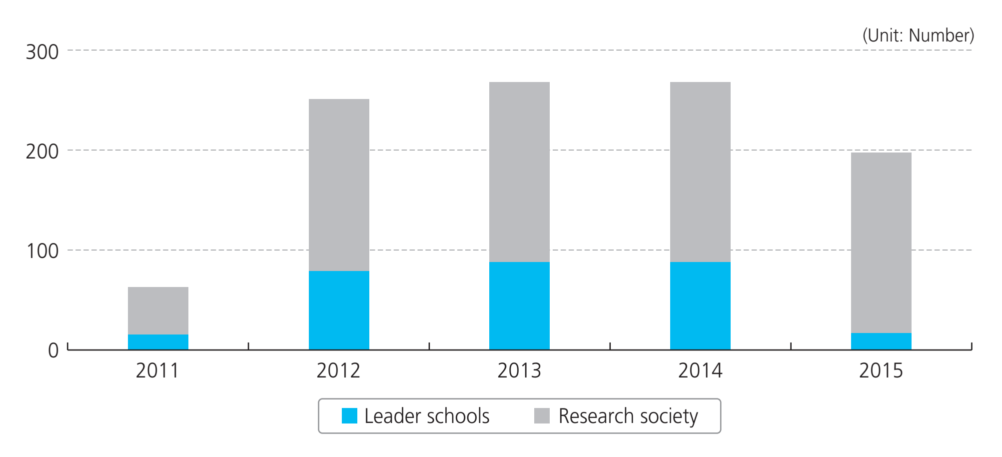
Source: KOFAC, 2016.

3.2.2.1. Incubating Leading Groups

A. Leader schools

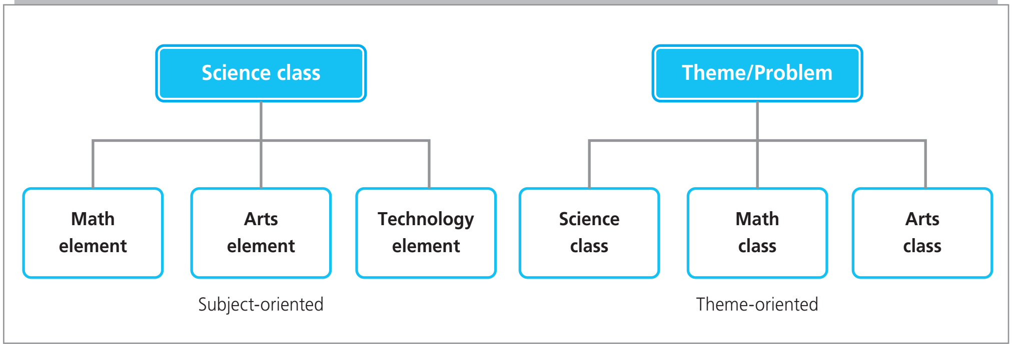
As shown in [Figure 3-13], between 2011 and 2015, 291 STEAM leader schools were designated to establish concrete foundation of STEAM education. STEAM leader schools have to introduce STEAM contents at least 20% of total annual class. Schools can select class types freely among "subject-oriented", "theme-oriented", or "after school." In subject-oriented class a main STEAM subject incorporates some sub-STEAM subject elements, whilst several STEAM subjects are incorporated to form a problem or them in theme-oriented class (see Figure 3-14). Leader schools can design time tables in a various way by employing one of the following approaches, "block time" or "STEAM day/week" (see Figure 3-15).

[Figure 3-13] STEAM Leader Groups



Source: KOFAC.

[Figure 3-14] Class Types for STEAM



Source: KOFAC.

[Figure 3-15] Time Table Design for STEAM

Block-time

	M	T	W	T	F
1					
2	Math				
3	Sci			Math	
4	Arts			Sci	
5				Arts	

STEAM Day

	M	T	W	T	F
1		Math			
2		Sci			
3		Arts			
4		Tech			
5		Sci			

Source: KOFAC.

Recently, the MOE of the Republic of Korea released a new three-year plan (2016-19) for STEAM leader schools under which they are assigned more tasks in addition to the 20-percent STEAM requirement in their annual curriculums. A number of new STEAM content, methodology and programs will be introduced to the leader schools and student performance, interest and self-motivation will be monitored to enhance content quality. After two years (2016-17) of application, new STEAM content will be disseminated to other schools via regional teacher workshops and open classes.

B. STEAM Teacher Research Society

As STEAM education aims to converge different subjects, the integration of various filed knowledge and stimulation of collaboration between teachers are crucial. For this purpose, 180 societies for STEAM teacher research have been supported (see Figure 3-13 and 3-16). This program enables teachers to discuss their needs from the bottom-up, such as the development of class application strategy or teaching collaboration method, and encourages them to develop their own STEAM content. Such societies are selected by regional education offices that contribute approximately US$5,000 annually to each society. To help these societies, KOFAC organizes regional consulting workshops that share and disseminate case studies of STEAM leader schools and best ideas from the societies (see Figure 3-16).

[Figure 3-16] STEAM Schools and Society Workshop

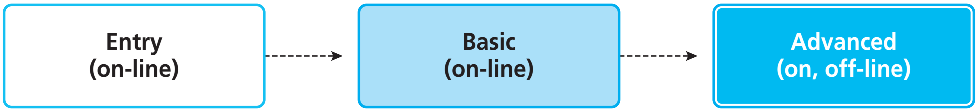
STEAM leader school | Consulting workshop

Source: KOFAC, 2015.

3.2.2.2. STEAM Teacher Training

KOFAC has a three-stage program for in-service teachers consisting of entry-level, basic and advanced stages (see Figure 3-17). The entry stage is a 15-hour online in-service training program to introduce the concepts, policies and leading content of STEAM education. Since 2012, more than 50,000 teachers have completed this course. The basic stage is also a 15-hour online program to present specific action plans such as linking STEAM to afterschool programs or organizing STEAM education suitable for a school's curriculum (Jho *et al.,* 2016, KOFAC, 2015). Teachers at those levels take lessons and are assessed by an online system.

[Figure 3-17] Three-Stage Teacher Training

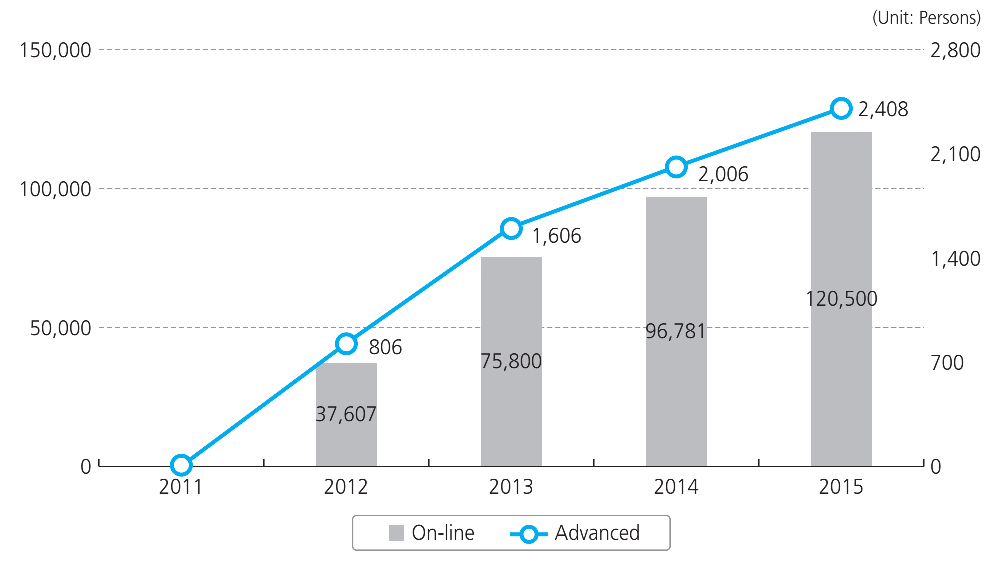


Source: KOFAC, 2015.

The advanced stage is a mixture of online and offline learning, comprising about 10 hours of online training, about 40 hours of collective offline training at one of the two Teacher Training Center for Cutting-edge Science at Ewha Womans University in Seoul and KAIST in Daejeon, five hours of field training and five hours of STEAM fair attendance to share practices (KOFAC, 2015, Jho *et al.,* 2016). About a half of the combined 60 hours are individual oriented (10-hour online training and offline lectures at the training center), while the other half is composed of collective activities, including the development of classroom-applicable STEAM educational material, fieldwork and STEAM fair attendance (Jho *et al.,* 2016). The goal of the advanced stage is to encourage teachers to develop and implement educational material for STEAM education themselves. Thus the advanced stage is designed to be relatively activity oriented compared to the entry-level and basic stages (Jho *et al.,* 2016). Teachers are allowed to take the advanced stage after completing the first two stages. Those completing the final stage can then become instructors for in-service training programs.

In addition, two other training programs are available. The manager course is a specialized program for head teachers, school principals or regional advisers and aims to introduce recent changes in STEAM policy and provide new STEAM methodologies. The overseas training program offers teachers the opportunity to study case studies of STEM application in advanced economies. As shown in [Figure 3-18], 123,507[4)] (28.9 percent) of 427,000 teachers had completed STEAM teacher training as of 2015.

[Figure 3-18] Teacher Training



Source: KOFAC, 2015.

In 2016, the MOE of the Republic of Korea and KOFAC introduced a new pilot training program for STEAM leader teachers. Under this program, 10 or more talented elementary school teachers will undergo six months of training.[5)] Afterwards, they will play an important leadership role by monitoring other teachers, providing consulting on STEAM curriculum development and organizing STEAM teacher conferences.

4) Online: 120,500; Advanced: 2,408; Overseas: 145; Manager 454
5) Regional education offices will allow these teachers to take (paid) study leave.

3.2.2.3. STEAM Content Development

To disseminate STEAM at school, developing new educational content is key. To stimulate student interest and enhance creative thinking, the MOE of the Republic of Korea and KOFAC have developed more than 416 new pieces of STEAM content (see Table 3-4 and Figure 3-19). Because this new content is well linked to existing textbooks, they have replaced textbooks. KOFAC is also developing a STEAM content map to provide an overall reference guide for teachers.

〈Table 3-4〉 Types of New STEAM Content

Type (416)	Topics (example)
Theme convergence (160)	Inclusive technology, robotics, plant factory
High-tech product utilization (104)	ICT, high-tech medical device, new transportation
Science and arts integration (108)	Creative manufacturing, design management
Future career (44)	Big data analyst, green energy consultant

Source: KOFAC, 2015.

[Figure 3-19] Examples of New STEAM Contents

Source: KOFAC, 2015.

3.2.2.4. Hands-on Activities In and Out of School

A. STEAM Outreach

Thanks to its innovation-driven policy, the Republic of Korea has many S&T institutions, and a STEAM outreach program was designed to exploit these resources for stimulating student interest and self-motivation. The program (1) enables students to experience cutting-edge high technology; (2) provides opportunities to get career consulting; and (3) encourages companies and think tanks to develop unique content using their own resources. To date, 21 organizations (nine universities, three companies, and nine state-run think tanks) have participated in this program. The examples of Korea University, Korea Institute of Ocean Science and Technology (KIOST), and the National Science Museum in the southern Seoul suburb of Gwacheon are illustrated in <Box 3-1>.

〈Box 3-1〉 STEAM Outreach Examples

A. Computing-based Outreach Program (Korea University, Seoul)

The education faculty of Korea University offers a three-step computing class on both software and hardware. In Step 1, students assemble a single-board computer and in Step 2, they explore a real-life context problem that is solvable using a computer or small machine device. In the final step, students develop software that can control their devices and check if the latter work properly.

Outreach at Korea University

B. KIO-Dream (KIOST, Gyeonggi-do)

Korea Institute of Ocean Science and Technology (KIOST) runs the program KIO Dream, in which students collect and classify marine litter themselves and make crafts using the collected trash. Through this process, students learn the importance of marine environment protection and better understand the role of marine scientists.

〈Box 3-1〉 Continued

Outreach in KIOS

(1) Craft making using marine litter

(2) Research lab tour

(3) Marine litter collection

(4) Categorizing marine litter

(5) Workbook activities

C. National Science Museum in Gwacheon

Fifty-two percent of exhibitions at the National Science Museum in Gwacheon, Gyeonggi Province, are designed under the concept "Feel on," which allows students to see, hear, touch and experience. The museum has supported many STEAM teacher workshops and has a so-called "Infinite Imagination Room where" students and individual makers can use 53 cutting-edge 3-D printer facilities. Also, the museum has developed many afterschool STEAM activities such as crime scene investigation (CSI). This content was developed through collaboration with ChungAng University, and students learn more than 24 themes related to school curriculum.

Outreach at National Science Museum

Source: KOFAC, 2015.

B. STEAM with University Students

A program for STEAM with university students was designed as a donation for education, but is now one of the most popular offerings featuring STEAM. Since 2013, 400 university teams have participated in this program, and an evaluation report indicates that this program (1) enhances the teaching capability of university students; (2) helps schoolteachers raise their teaching quality and improve their methodology; and (3) provides students with an experience-based opportunity to learn more about STEAM. Three support centers for future STEAM teachers at Hanyang University, Korea National University of Education and Jeju National University provide participating university students with online and offline training and consultations for their projects. After the program, the wrap-up conferences in which both schoolteachers and university teams participated in were organized to share best practices and develop new STEAM content. An example of this program is illustrated in <Box 3-2>.

〈Box 3-2〉 STEAM with University Students

Making my own handkerchief (Year 3)

Learning points

Science: Understanding how solids change when heated
Math: Symmetry of plain figure
Arts: Drawing and designing

Making my own handkerchief

Source: KOFAC, 2015.

C. STEAM R&E

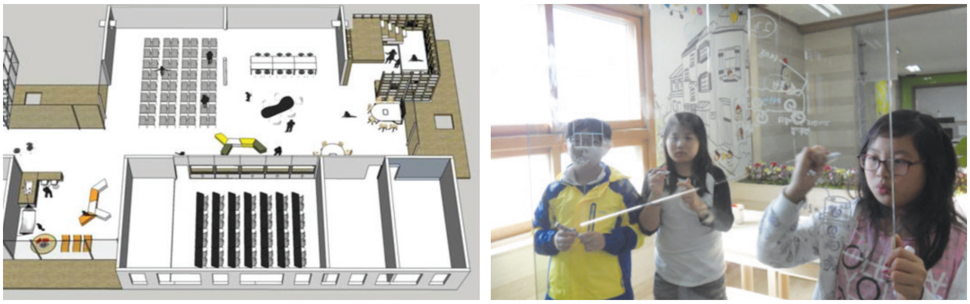
STEAM R&E (research and education) is a program that supports self-motivated and in-depth research activities of students. At a science high school, student teams from STEAM leader schools can apply STEAM R&E and each team is supervised by teachers from science high schools or STEAM leader schools. Each of the estimated 130 teams selected gets US $3,500 for a STEAM research activity. Similar to

PRONAFECYT, the annual STEAM R&E conference offers the best teams opportunities to attend science competitions abroad, such as the Intel International Science and Engineering Fair (Intel ISEF) in the US.

3.2.2.5. Infrastructure for STEAM Education

To strengthen STEAM education, the MOE of the Republic of Korea has supported the creation of 32 STEAM classrooms each specially designed for STEAM education. The aim is to support participation-based learning by providing cutting-edge educational devices (e.g., smart tablets, node chairs and smart TVs) as well as individual toolkits. Also, as shown in [Figure 3-20], the space is designed to emphasize collaboration, so movable walls and small group meeting rooms are recommended.

[Figure 3-20] STEAM Classrooms



Source: KOFAC, 2015.

The MOE of the Republic of Korea and KOFAC are also developing a STEAM content map to help schoolteachers use STEAM content easily, and they have increased the portion of STEAM content in textbooks. To enhance the quality of policy, KOFAC has assessed STEAM policy by supporting meta-studies.

3.2.2.6. Effects of STEAM Education

To analyze the impact of STEAM, KOFAC conducted a survey on 1,373 students at 23 elementary, middle and high schools. Approximately half of the students were from ordinary schools, while the other half were from STEAM leader schools, science high schools and schools with STEAM classrooms. As shown in <Table 3-5> and <Table 3-6>, students with experience in STEAM education showed higher academic interest and performance, and these differences were statistically significant at the 1 percent confidence level (KOFAC, 2013).

〈Table 3-5〉 Statistical Analysis of STEAM (1)

	Mean (St. deviation)		t-value
	Ordinary students	STEAM students	
Interest in science	3.40 (1.14)	3.58 (1.07)	3.39**
Interest in science learning	3.22 (1.19)	3.46 (1.14)	4.68**
Embracing science values	3.85 (1.00)	3.98 (0.95)	3.04**
Confidence in science learning	3.53 (1.06)	3.73 (1.00)	4.16**
Wellness to conduct science assignments	3.06 (1.13)	3.36 (1.08)	6.00**
Wellness to choose science career	2.80 (1.24)	3.08 (1.20)	4.61**

Note: ** p<0.01, * p<0.05
Source: KOFAC, 2013.

〈Table 3-6〉 Statistical Analysis of STEAM (2)

	Mean (St. deviation)		t-value
	Ordinary students	STEAM students	
Self-motivation	3.24 (1.05)	3.36 (1.00)	2.36**
Cognitive strategy	3.18 (1.04)	3.39 (1.01)	4.50**
Motivation to study	2.90 (1.06)	3.14 (1.04)	5.16**
Willingness to solve problems	3.30 (1.01)	3.43 (0.98)	2.88**
Tool application	3.33 (1.05)	3.53 (1.00)	4.26**
Ability to collaborate	3.40 (1.04)	3.56 (1.02)	3.52**

Note: ** p<0.01, * p<0.05
Source: KOFAC, 2013.

In addition to these quantitative results, many qualitative studies have shown that STEAM education (1) helps teachers recognize hidden student potential; (2) enable students to feel a sense of achievement; and (3) raise class quality by stimulating communication.

3.2.3. Excellence Track

High school education in the Republic of Korea was standardized in 1974, but this policy was criticized because of keen demand for highly qualified and specialized S&T researchers. In the 1980s, the economy saw annual growth exceeding 12 percent, so to tackle this pressing societal need, the government set up the Korea Advanced Institute of Science and Technology (KAIST) and science high schools. In the Republic of Korea, universities are established under the Higher Education Act of the MOE, but another law helped to form KAIST: the Act on Korea Advanced Institute of Science and Technology. Thus, except for certain academic regulations, overall management and findings of KAIST are supported by the Ministry of Science, ICT and Future Planning (MSIP) of the Republic of Korea. KAIST aims to conduct high quality research and education, and thanks to its success, more science-oriented universities have sprung up (see Figure 3-21). Gwangju Institute of Science and Technology (GIST) in 1993, Daegu Gyeongbuk Institute of Science and Technology (DGIST) in 2003 and Ulsan National Institute of Science and Technology (UNIST) in 2009 were also each established by a special law. Those admitted to these schools qualify for tuition waivers (including room and board), which plays an important role in attracting talented students.

In 1983, Gyeonggi Science High School was established as the country's first science high school, and Gwangju, Daejeon and Gyeongnam science high schools followed in 1987. Based on Article 90 of the Enforcement Decree of the Act on Elementary and Secondary Education, these schools are designated special-purpose high schools and authorized to select talented students and conduct offer specialized education programs. In 1999, the Presidential Advisory Council on Education, Science and Technology (PACEST) suggested changing these schools into science gifted schools to enhance educational quality and methodology and allow educational flexibility. Via the Act on the Promotion of Specific Education for Brilliant Children, a few of the science high schools made the switch to science gifted schools, which are not governed by the law. In 2003, Busan Science High School became the nation's first science gifted school and renamed Korea Science Academy of KAIST, and was allowed to select talented students, use a specialized curriculum and freely recruit teachers. Science high schools in Seoul, Gyeonggi-do and Daegu in 2008, and those in Daejeon and Gwangju four years later made the transformation. In 2012, to emphasize STEAM education, a new type of gifted school, Incheon and Sejong Science and Arts Gifted High School, was established. High schools emphasizing science education have played a vital role in educating talented students and getting them to pursue STEM majors in college. Science high schools allowed their students to enter KAIST after their junior year. This early graduation and free tuition at KAIST have given strong incentive for students to remain in the STEM track.

Based on the Act on the Promotion of Specific Education for Brilliant Children, education centers and classrooms for the gifted and talented have recently opened to foster young talented students (see Table 3-7).

〈Table 3-7〉 Special STEM Track in Korea

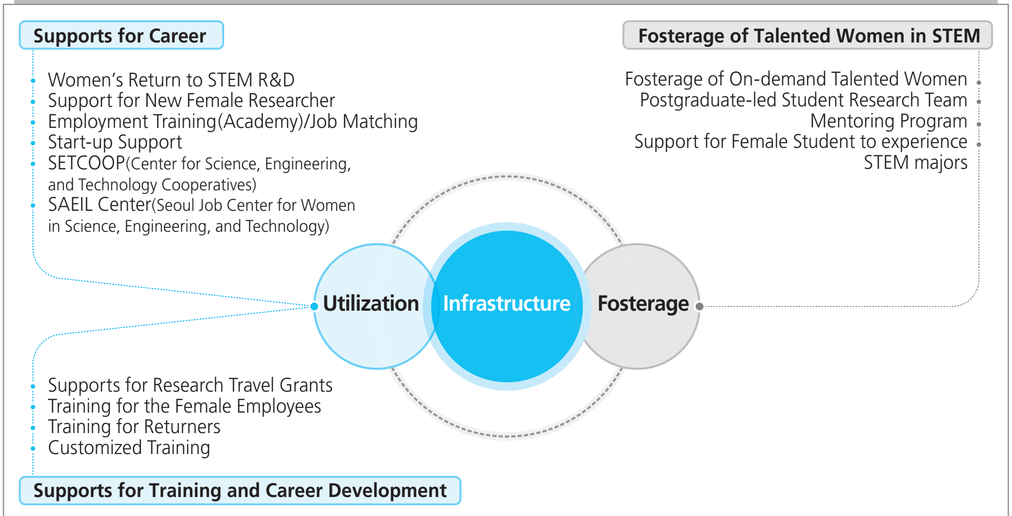
	Science high school (including gifted schools)	Gifted education centers		Gifted education classrooms	Total
		By regional education office	By university		
Institution (#)	27	261	82	2,168	2,538
Proportion (%)	1.1	10.3	3.2	85.4	100

Source: MOE.

3.3. STEM for Women

To alleviate Costa Rica's significant gender disparity in STEM, the Korea Advanced Institute of Supporting Women in Science, Engineering and Technology (WISET) has numerous programs for female scientists and engineers (Marginson *et al.*, 2013). WISET mainly supports the careers of female scientists and engineers by helping with job placement and their return to R&D labs, but also fosters talented women in STEM by funding female postgraduate students or providing mentoring as shown in [Figure 3-21].

[Figure 3-21] WISET Programs



Source: WISET homepage.

In addition, the Women's Academy for Technology Change in the 21st Century (WATCH 21) promotes the study of natural science and engineering to high school students. This organization is both an R&E (research and education) program and a team organized by female high school, university and graduate students, and supervisors and teachers can apply to this program. Sixty teams are selected every year and each gets approximately US$4,500 to support research activities.

4. Conclusions and Policy Recommendations

4.1. Why STEAM?

STEAM should be a priority goal for Costa Rica to simultaneously enhance individual capability in each subject and the capacity for multidisciplinary integration. STEAM demands more complicated issues because of its nature of focusing on integration, so issues in both education and S&T should be resolved for smooth introduction and implementation. In this regard, the structure of the Republic of Korea's STEAM policy (see Figure 3-12) can be benchmarked as it was designed to tackle important issues generally found in education.

4.2. Policy Recommendations

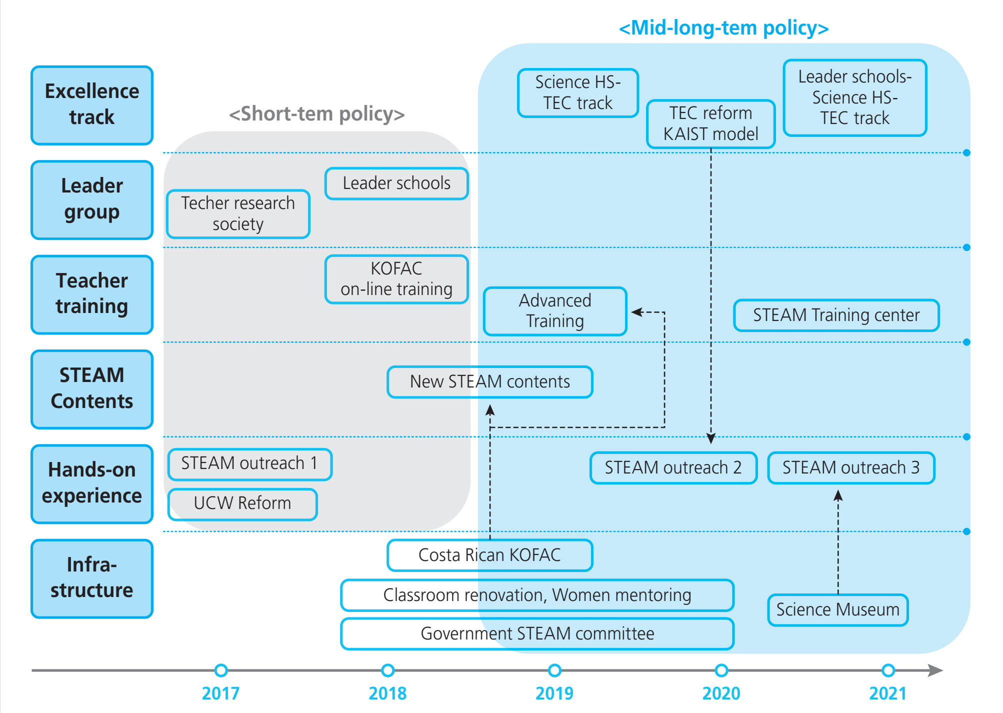
This section suggests policy recommendations comprised of six domains: excellence track, leader groups, teachers, content, hands-on experience and infrastructure - and a timeline is also considered to distinguish short-, mid- and long-term policies. The overall roadmap for time-line policy is illustrated in [Figure 3-22].

4.2.1. Hands-on Experience

4.2.1.1. Reform of UCW

As illustrated in Section 2.1.1.4.-A, UCW (university community work) is an important graduation requirement for university students in Costa Rica, but no official guideline governs this. Each university demands its own working times and certain (private) schools do not confine working areas. Yet university students who major in STEAM subjects or education can be good human resources for STEAM education, and this report suggests changing UCW into a program for "STEAM with university students." In a survey, respondents showed high expectations for the positive effects of undergraduate participation in STEM classes (see Appendix). UCW reform can be easily implemented with relatively low budgets and enhanced by training university students before they participate. Once a STEAM institution is established (see Section 4.2.6), it can manage training and wrap-up conferences to enhance program quality and disseminate best practices.

[Figure 3-22] STEAM Policy Roadmap for Costa Rica



Source: Author.

4.2.1.2. STEAM Outreach

External organizations such as private companies or universities can serve as good resources for STEAM education. This report suggests a three-stage approach for STEAM outreach. The first stage can be initiated using existing resources such as national research labs at CONARE and Costa Rica's five public universities, and government can also encourage private companies to participate in this program. The second stage can be implemented when TEC is converted into a science-oriented university (see Section 4.2.5) and the third can start when a national science museum is established (see Section 4.2.6).

4.2.2. STEAM Content Development

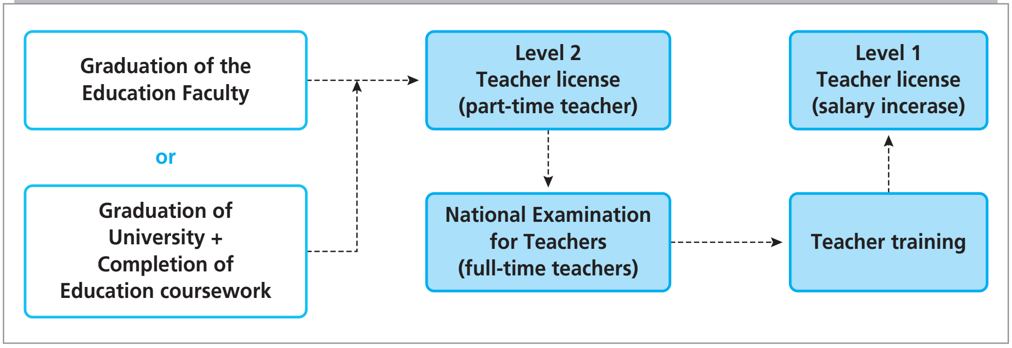
School curriculum is an important part of STEAM education that needs systematic development and regular updates. The curriculum development team of MEP has recently sought to develop new content by emphasizing creative thinking and integration of multiple topics. This action should continue and supplementary STEAM resources must also be developed to support teachers and stimulate student interest. In a survey, respondents emphasized the importance of formal development of a STEAM curriculum (see Appendix). Once a STEAM institution is established (see Section 4.2.6), it can take full charge of the development and dissemination of STEAM content.

4.2.3. Teacher Training and Recruiting

Teachers play a mid-level role in STEAM education, and teacher training should be the most important policy agenda when considering teacher recruiting and training in Costa Rica (see Section 2.2). Despite its importance, however, teacher training is not easy as it requires substantial time and resources. So teacher training can be conducted in two stages. The first is online training content (entry level and basic, see Figure 3-17). Fortunately, KOFAC is experienced in transferring its online training system to Vietnam, and the IDP (or FOD) or UNED in Costa Rica offers online training (or distance learning). Because the existing incentive system is inefficient (see Section 2.2), however, a new incentive system based on individual performance or official qualification (e.g., certificate for leader teacher) is needed. Next, from the mid- to long-term perspective, provision of in-depth offline training at advanced training centers is a must to nurture STEAM leader teachers. The centers can be operated by the STEAM institution (see Section 4.2.6) or designated public universities.

Over the long run, however, the teacher recruiting system should undergo innovation to enhance the overall quality of teaching staff. Costa Rica's teacher recruiting system fails to consider the quality difference between a national and private university. In the Republic of Korea, teachers are recruited via a competitive licensing and examination system. To be an elementary school teacher, candidates must graduate from one of the country's 11 education colleges, Korea National University of Education or the Department of Education at Ewha Womans University. A Level 2 teaching license is then given to a candidate that allows him or her to work part-time as elementary school teachers. To be a full-time teacher, Level 2 license holders have to pass the National Recruiting Examination for Primary School Teachers. Those who pass this exam can work as full-time teachers, but to gain the Level 1 license requires additional teacher training (approximately 20 days). As the Level 1 license is linked to the teacher salary system, most Level 2 license holders complete a training course. The recruitment system for middle and high school teachers is similar to that of those at elementary schools. Candidates must have a bachelor's in education or complete a course in teacher education if their major was not education. The Level 2 license is given when candidates graduate, and if they pass the National Recruiting Examination for Secondary School Teachers, they qualify as full-time teachers. A financial incentive is also linked to the Level 1 license. What the Republic of Korea achieved through this recruitment system is "quality control" in hiring teachers. Recognizing the quality difference between a national and public university, Costa Rica appears to strongly need a systematic approach toward teacher recruitment (see Figure 3-23). The IDP leads teacher training in the country, but to provide higher quality training, national universities need to engage and lead training courses at least in STEAM areas. Over the long run, this training should be linked to the Level 1 license, thus providing financial motivation for teachers.

[Figure 3-23] Teacher Recruitment and Training System



Source: Author.

4.2.4. Fostering Leader Groups

In the beginning stage, a leader group can play a vital role in encouraging and disseminating STEAM education. Thus MICITT must support the formation of a STEAM teacher research society to promote teacher development from the ground up. Another need is to designate STEAM leader schools to allow them to play a regional hub role for STEAM education. Incentives can be considered to encourage schools to apply leader schools. The following are examples of such incentives.

- Priority allocation of UCW students
- Priority allocation of STEAM outreach program
- Priority allocation of advanced teacher training opportunity
- Priority application of new STEAM content
- Priority installation of STEAM classrooms
- Priority support of STEAM teacher research society

4.2.5. Special Excellence Track

To nurture talented students, a "pipeline" for human resource development is needed to keep talented students interested in STEM. The Republic of Korea's special track, namely science high schools to KAIST (and other universities modeled after KAIST) has played a vital role in supplying leading scientists and engineers to academia and industry. Costa Rica should benchmark this strategy.

Though Costa Rica has a good scientific high school system that effectively looks for top students and provide intensive and high quality education along with public universities, little progress has been seen in keeping these talented students in S&T. So strong incentives are needed such as a separate system of university admission (e.g., exemption of entrance exams for top students) or scholarships.

Over the mid- to long term, however, TEC (and/or UTN) must be transformed into a science-oriented university governed by a separate law (i.e., KAIST model). Unlike other domestic universities established by the High Education Act, KAIST has its own law that laid the basis for the school's foundation. This law has secured stable funding for KAIST from the MSIP of the Republic of Korea and autonomy in student selection, education and research planning (see below).

〈Box 3-3〉 Act on Korea Advanced Institute of Science and Technology[6]

Article 1 (Purpose)

The purpose of this Act is to establish the Korea Advanced Institute of Science and Technology to train highly qualified scientific and engineering specialists with profound theoretical background and practical application ability in the fields of science and technology required for developing industries, in order to conduct mid- and long-term research and development implemented in accordance with the national policies and basic and applied research for developing potential of national science and technology, and further to provide other research institutes, industrial sectors, etc. with research support.

Enforcement Decree of the Korea Advanced Institute of Science and Technology Act[7]
Article 8 (Submission of Budget Requests for Contributions)

(1) The KAIST shall submit a budget[8] request for contributions for the following year to the Minister of Science, ICT and Future Planning by no later than May 31 each year along with the following documents:
   1. The business plan for the following year;
   2. The estimated income statement and the estimated balance sheet for the following year;
   3. Other documents necessary for clarifying the details of the budget.

(2) If the details of the request under paragraph (1) are deemed reasonable, the Minister of Science, ICT and Future Planning shall include them in the budget and pay them.

Source: Ministry of Legislation.

6) The full Act can be found at:
http://www.law.go.kr/engLsSc.do?menuId=0&subMenu=5&query=%ED%95%9C%EA%B5%AD%EA%B3%BC%ED%95%99%EA%B8%B0%EC%88%A0%EC%9B%90#liBgcolor0

7) The full Decree can be found at:
http://www.law.go.kr/engLsSc.do?menuId=0&subMenu=5&query=%ED%95%9C%EA%B5%AD%EA%B3%BC%ED%95%99%EA%B8%B0%EC%88%A0%EC%9B%90#liBgcolor2

8) The annual budget of KAIST in 2015 was approximately US$656 million, US$373 million of which came from the MSIP of the Republic of Korea through direct funding and research funding.

TEC is funded by CONARE but given that S&T requires substantial financial investment, Costa Rica strongly needs to change its funding distribution system. CONARE represents the autonomy of the country's tertiary education, but it is unclear whether the budget distribution appropriately reflects increasing budget demands from S&T universities such as TEC or UTN. In 2013, UCR accounted for more than 70 percent of the country's R&D expenditures, while TEC spent less than 10 percent (Romero, 2017). To fix this problem, MICITT needs to pass a law allowing a new form of university management. This step is crucial because the reform of TEC and/or UTN can be a vital stepping stone toward Costa Rica's transformation into an innovation-driven economy. As discussed in Section 2.6, a key challenge for STEM in Costa Rica is raising the insufficient industrial demand for S&T researchers. Because Costa Rica is not manufacturing-oriented country, demand from industry for S&T human resources remains low. Consequently, the few private think tanks and university research labs have not been utilized well. Of course, this can be viewed as the classic question of which came first, the chicken or the egg, but to break this vicious circle, Costa Rica needs a strong S&T university like KAIST to conduct high quality research and lead the development of cutting-edge technology. This will require substantial investment of financial resources and mid- to long-term efforts to nurture talented students and instill in them different values. Once TEC and UTN are converted into KAIST-type universities separately managed by MICITT with their own stable funding, they will create higher demand for high quality scientists and engineers. Since these universities modeled after KAIST are research oriented, they will systematically operate research labs needing talented researchers holding master's degrees and PhDs. Consequently, university labs will play a buffer role in the recruiting of scientists and engineers, and if the quality of university labs at TEC and UTN is of a high level, the knowledge spillover effect will occur from these universities to industry, which will boost private R&D activity. If this virtuous circle is established, industrial demand for scientists and engineers can only go up.

Furthermore, once TEC and UTN are converted into KAIST-type universities, an excellence track (i.e., S&T human resource pipeline) going from STEAM leader school to scientific high school and eventually to TEC, will be completed. Through this pipeline, young talented students will be screened and nurtured systematically to keep them studying S&T.

4.2.6. Establishment of STEAM Infrastructure

4.2.6.1. STEAM Institution

Because STEAM policy covers agenda from teacher training to curriculum content development, a separate STEAM institution for enforcing systematic policy is needed. In the Republic of Korea, KOFAC has played this role by interacting with both the MOE and MSIP. KOFAC[9] was established by the Framework Act on Science and Technology to promote scientific and technological culture and foster creative human resources; its budget comes from the MSIP of the Republic of Korea (see below).

〈Box 3-4〉 Framework Act on Science and Technology[10]

Article 30 (Promotion of Scientific and Technological Culture and Fostering of Creative Human Resources)

(1) The Minister of Education and the Minister of Science, ICT and Future Planning shall formulate and implement policies to raise citizens' level of understanding and knowledge regarding science and technology, to develop the scientific and technological culture in which science and technology may be extensively used in the whole society and the citizens may demonstrate their creativeness, and to foster creative human resources

(2) The Minister of Education and the Minister of Science, ICT and Future Planning shall foster and support the following institutions and organizations in charge of the activities of scientific and technological culture and fostering of creative human resources to effectively achieve the objectives prescribed in paragraph (1):

1. Science museums registered pursuant to the Act on Establishment, Operation and Promotion of Science Museums;
2. The Korea Foundation for the Advancement of Science and Creativity established pursuant to Article 30-2 (1);
3. Other institutions or organizations relevant to the activities of scientific and technological culture determined by the Minister of Science, ICT and Future Planning.

(3) The Minister of Education and the Minister of Science, ICT and Future Planning may provide contributions or subsidies to cover all or part of the expenses incurred in relation to projects performed by the institutions or organizations referred to in paragraph (2).

Article 30-2 (Establishment of Korea Foundation for the Advancement of Science and Creativity)

(1) The Minister of Science, ICT and Future Planning shall establish the Korea Foundation for the Advancement of Science and Creativity (hereinafter referred to as the "Foundation") to support building of systems for promoting science and technology culture and fostering creative human resources.

(2) The Foundation shall be a body corporate.

(3) The Foundation shall be established as at the time when it files for registration for its incorporation at the location of its principal office.

(4) The Foundation shall conduct the following projects

1. Survey, research, and policy development, for promoting the culture of science and technology and supporting the fostering of creative human resources;
2. Project for promotion and dissemination of the citizens' understanding of science and technology;
3. Development of science curricula and programs to foster creative human resources;
4. Support for fostering and training experts for education of creative human resources;

9) KOFAC's annual budget in 2016 was US$79 million, of which US$63 million came from the MSIP of the Republic of Korea.

10) The full Act can be found at: http://www.law.go.kr/engLsSc.do?menuId=0&subMenu=5&query=%EA%B3%BC%ED%95%99%EA%B8%B0%EC%88%A0%EA%B8%B0%EB%B3%B8%EB%B2%95#liBgcolor0

〈Box 3-4〉 Continued

5. Support for developing scientific culture and art convergence programs related to promoting science and technology and fostering creative human resources;
6. Other projects designated or entrusted by the Minister of Education and the Minister of Science, ICT and Future Planning.

(5) The Minister of Science, ICT and Future Planning may make contributions to cover the expenses incurred in establishing and operating the Foundation, within budgetary limits.

(6) Notwithstanding the provisions of the State Property Act, the Government may grant or lease, free of charge, any state property to the Foundation as prescribed by Presidential Decree, where necessary for implementing any project falling under any subparagraph of paragraph (4).

(7) Except as otherwise provided for in this Act and the Act on the Management of Public Institutions, the provisions concerning an incorporated foundation in the Civil Act shall apply mutatis mutandis to the Foundation.

Source: Ministry of Legislation.

One of the important missions of KOFAC is STEAM education, and based on the foundation's functions, the roles of the proposed STEAM organization in Costa Rica, tentatively called COFAC (Costa Rican Foundation for the Advancement of Science and Creativity), are suggested as follows:

- STEAM content development
- STEAM teacher training
- Management of STEAM programs (e.g., UCW or outreach)
- Support for STEAM leader schools and teachers
- Encouragement of female students and promoting S&T culture

Based on the Republic of Korea's experience, both MEP and MICITT are strongly urged to participate in the establishment process of COFAC for smooth collaboration between both ministries. STEAM policy in the Republic of Korea was designed and initiated smoothly because only one ministry, the Ministry of Education, Science and Technology (MEST) of the Republic of Korea, handled S&T. Though MEST was eventually divided into two ministries, KOFAC works with both the MOE and MSIP (see Figure 3-11) of the Republic of Korea. So for smooth initiation and sustainable implementation, both MEP and MICITT need to help devise STEAM policy, and this report suggests that the Costa Rican government pass a law on "STEAM education" based on the Framework Act on Science and Technology of the Republic of Korea.

4.2.6.2. National Science Museum

A national science museum is an important public resource for STEAM across the globe. Because such museums are generally free from a standard school curriculum, organization of a program to stimulate student interest and the exploration process using museum resources is relatively easy. The Republic of Korea has utilized a host of exhibition items for STEAM education, and many world-class science museums run their own STEAM programs. For example, the Smithsonian National Museum of Natural History has "Q?riouos," a STEAM outreach organization (see Figure 3-24), and the London Science Museum also provides various STEAM programs (see Table 3-8). So to promote S&T culture and establish the nation's main STEAM resources, Costa Rica is strongly recommended to build a national science museum.

[Figure 3-24] Q?rious Programs

Examples of programs

- Reefs Unleashed
- Forensic Mysteries
- Dig Deep
- Bird Strike Whodunit

Source: KOFAC, 2015.

〈Table 3-8〉 STEAM Club of London Science Museum

Program	Age 5-7	Age 7-11	Age 11-14	Age 14-16
Spaghetti Challenge	O	O	O	
360 Periscope		O	O	
Soap Challenge		O	O	
Launch Ball		O	O	
Crime Lab Kit			O	
Launch Box			O	
Mars Mission Kit			O	
Mousetrap Drag Racer			O	
Blooming Paper		O	O	O
Bath Fizzers		O	O	O
Robot Bug			O	O
SOS: Save Our Snacks!			O	O
Future Cade			O	O

Source: KOFAC, 2015.

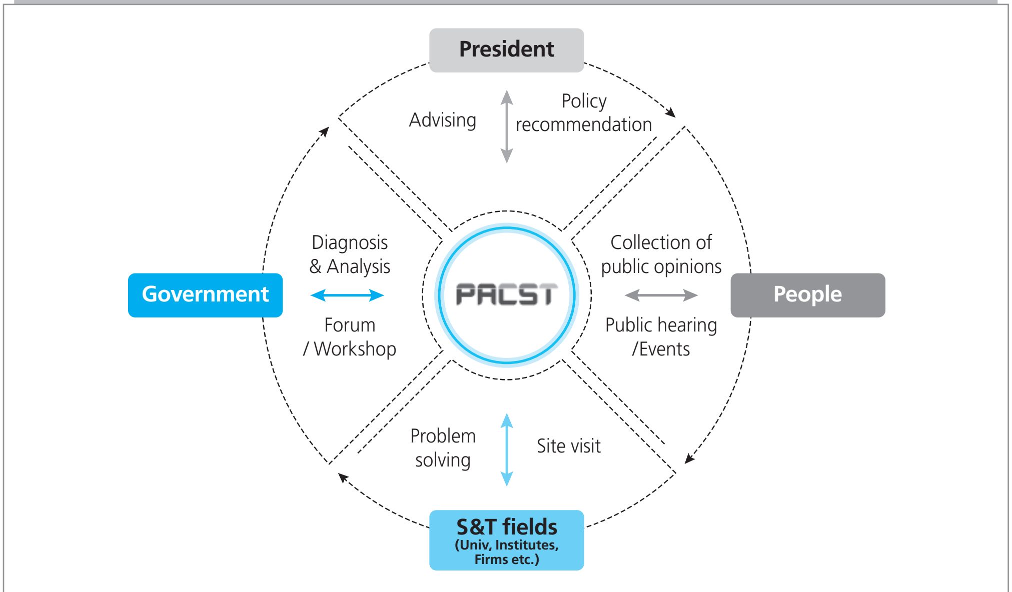
4.2.6.3. Inter-ministry Collaboration

In the Republic of Korea, the 2011 merger of the Ministry of Education (MOE) and the Ministry of Science and Technology (MOST) was a milestone in STEAM policymaking, and with KOFAC being funded by two ministries, the MOE and Ministry of Science, ICT and Future Planning (MSIP) of the Republic of Korea is also important for smooth policy implementation. This means that inter-ministry collaboration is essential for STEAM since the latter covers both education and S&T. Though Costa Rica's MEP and MICITT have produced productive outcomes such as PRONAFECYT, a ministry-level collaboration platform is critical for stable policy implementation. The following is suggested for the collaborative platform.

- Comprehensive long-term agreement
- Enactment of Act on "STEAM Education"
- Formation of "Special Presidential Committee for STEAM Education"

In the Republic of Korea, the Presidential Advisory Council on Education, Science and Technology (PACEST) has played an important role in STEAM by contributing to the passage of the Act on the Promotion of Specific Education for Brilliant Children. In Costa Rica, a special presidential committee could play a vital role of bridge between MICITT and MEP.

[Figure 3-25] Role of PACST[11]



Source: PACST homepage (http://english.pacst.go.kr).

11) Because of government restructuring, PACEST was renamed PACST (Presidential Advisory Council on Science and Technology) but remains in charge of providing policy advice on STEAM education.

4.2.6.4. STEAM for Female Students.

As illustrated in Section 2.6, Costa Rica's serious gender imbalance in STEAM performance can cause problems in STEM-related jobs. So high school counselors need more knowledge of and should promote STEM careers more to female students. Young girls are probably not well informed of career tracks in STEM areas. The Republic of Korea has tried to solve this problem through a funding program for female scientist mentors or STEAM R&E (research and education) projects by female teams of scientists and students. A similar program could be initiated by the proposed STEAM institution of Costa Rica.

References

Chacón, N. V., A successful K-12 National Program of Science Fairs: Integrating ISEF Regulations and meeting local needs. The experience of Costa Rica. San Jose: MICITT, 2016.

elEconomista 2006. Intel supone el 4,9 por ciento del PIB de Costa Rica. elEconomista.

Fagerberg, J., Mowery, D. C. & Nelson, R. R. (eds.), The Oxford Handbook of Innovation, Oxford: Oxford University Press, 2005.

FOD, Introduction of Omar Dengo Foundation, San Jose: Omar Dengo Foundation, 2016.

Freel, M. S., "Sectoral Patterns of Small Firm Innovation, Networking and Proximity," Research Policy, Vol. 32, 2003, pp. 751–770.

IMD, IMD World Competitiveness Yearbook, IMD, 2015.

Jho, H., Hong, O. & Song, J., "An Analysis of STEM/STEAM Teacher Education in Korea with a Case Study of Two Schools from a Community of Practice Perspective," Eurasia Journal of Mathematics, Science & Technology Education, Vol. 12, 2016, pp. 1843–1862.

KOFAC, The Effects of STEAM Education, Seoul: KOFAC, 2013.

KOFAC, Understanding STEAM, Seoul: Korea Foundation for the Advancement of Science & Creativity, 2015.

Marginson, S., Tytler, R., Freeman, B. & Roberts, K., STEM: Country Comparisons, Report for the Australian Council of Learned Academies, Melbourne: Australian Council of Learned Academies, 2013.

MEP, Costa Rica Educational System,. San Jose: MEP, 2016.

OECD, Main Science and Technology Indicator, Paris: OECD, 2015.

OECD, PISA 2015 Results: Excellence and Equaity in Education, Paris: OECD, 2016.

Park, H., Byun, S.-y., Sim, J., Han, H. & Baek, Y. S, "Teachers' Perceptions and Practices of STEAM Education in South Korea," Eurasia Journal of Mathematics, Science & Technology Education, Vol. 12, 2016, pp. 17391753.

Polanyi, M., Personal Knowledge: Toward a Post-Critical Philosophy, Chicago, IL, University of Chicago Press, 1958.

Polanyi, M., The Tacit Dimension, New York: Doubleday, 1966.

Rallet, A. & Torre, A., "Is Geographical Proximity Necessary in the Innovation Networks in the Era of Global Economy? GeoJournal, Vol. 49, pp. 373–380.

Randewich, N., "Intel Closes Costa Rica Operation, Cuts 1,500 Jobs," Reuters, 2014.

Robles, L. Scientific High Schools of Costa Roca. Cartago, UNDP 2015, Human Development Report, UNDP, 2016.

Romero, R. C., Long-term Employment Projections and Manpower Planning for Research Personnel in Science and Technology of Costa Rica, 2017.

WEF, The Global Competitiveness Report 2015-2016, World Economic Forum, 2015.

Appendix

Survey Questions and Response

- Distributed to 28 regional PRONAFECYT advisers
- Survey period: Dec 17, 2016 - Jan 15, 2017
- Response rate: 25% (7 of 28)
- Methods: Online (email invitation) using Qualtrics.com

Key Findings

- Regional advisers recognize STEM teacher training as most important agenda
- Results show need for development of STEM formal curriculum
- University students can be effective resources for STEM education

1. How do you evaluate STEM education in Costa Rica? Please indicate how much you agree with the following statements.

(5 Likert scale: 1 very unlikely – 5 very likely)

	Mean
Very competitive and well-structured compared to Central American countries	3.71
Very competitive and well-structured compared to Latin American countries	3.16
Very competitive and well-structured compared to US	3.00
Very competitive and well-structured compared to OECD countries	2.33

2. To what extent do you agree with the following statements?

	Mean
Science curriculum in public K-12 is very competitive and well structured	2.86
Math curriculum in public K-12 is very competitive and well structured	3.29
Training for science teachers in public K-12 is very competitive and well structured	3.00
Training for math teachers in public K-12 is very competitive and well structured	2.86

3. In your opinion, which of the following choices is most crucial for improving STEM education in Costa Rica?

	Count
Government policy change	2
More teaching material and resources	1
More teacher training material and resources	3
Student willingness and interest	-
Parent willingness and interest	-
Individual teacher willingness and interest	1

3-1. If you chose "More teaching material and resources," what type of teaching material is the most necessary?

	Count
Curriculum guide development (e.g., official guide published by MEP)	-
Formal published textbooks	-
Advanced online interactive materials	1
Classroom experimental tools	4
Others (please name)	-

3-2. If you chose "More training material and resources," what type of training material is the most necessary?

	Count
Online interactive courses	2
Offline lectures and workshops	-
Knowledge and experience sharing through STEM teacher community	-
Others (please name)	2

Others: (1) Impartir cursos con material didáctico experimental q puede dispobes en el aula para q el estudiante junto on docente spliquen la metidologia de la indagacion y formemos estudiantes autodidacticos no dolo receptires o repiten la informacion aprendida que sean criticos y analiticis.

(2) Change in training and continuing training profiles

3-3. If you chose "individual teacher willingness and interest," what is the most attractive incentive to raise teacher motivation?

	Count
Financial incentives (e.g., salary increase)	1
Formal qualification issued by government	1
Sabbatical leave for STEM training	-
Others (please name)	2

Others: (1) Positive feedback and recognition for work done, (2) Salary and efficiency and effectiveness in work performed (Se paga un salario, debe haber eficacia y eficiencia en el trabajo realizado.)

4. What is the most urgent issue for improving STEM education in Costa Rica?

	Count
Setup of STEM education agency	-
More budget for STEM education	-
Reform of STEM education curriculum	2
Enhancement of STEM teacher training	5

5. If the Costa Rican government forms an agency specifically for STEM education, what roles should it have? (multiple choices)

	Count
STEM formal curriculum development	5
STEM informal curriculum development	1
STEM teacher training	5
National events and competitions	2
International collaboration	2
Others (please name)	0

6. What is the most challenging hurdle for STEM teaching in practice?

	Count
Updating teaching material for new scientific knowledge	1
Integration of topics	3
Preparing classroom experiments	1
Inviting special guest speaker to share STEM knowledge with students	0
Asking help from relevant organizations	1
Others (please name)	1

Others: Vocation and disposition of teaching staff. An evaluation system that not only measures results but also process (Vocación y disposición del profesorado, sumado a un sistema de evaluación que no solo se mida resultados sino que también proceso).

7. What is the most effective program for STEM education improvement?

	Count
Visiting science labs at universities	1
Visiting factories	-
Additional afterschool class	-
Mid- to long-term STEM project involving science experiments	4
Project competition	-
Others (please name)	2

8. If you could hire a university student (majoring in a STEM subject) as an assistant teacher for free, would you?

(5 Likert scale: 1 very unlikely – 5 very likely)

(Answer) Mean value 4.25

Chapter 4

Enhancing Capacities of Healthcare Industry in Costa Rica for Strengthening Globalization and Fostering Regional Economy

Enhancing Capacities of Healthcare Industry in Costa Rica for Strengthening Globalization and Fostering Regional Economy

Jongyearn Lee (KDI School of Public Policy and Management)
Massimo Manzi (Council for the International Promotion of Costa Rica Medicine)

Summary

The healthcare industry plays a significant role in Costa Rica's economy. Due to its location, language and competitive labor supply, the country holds many multinational companies in technology and health (medtech). Costa Rica's location and renowned tourism destinations have also given rise to its famous medical and wellness tourism (MWT) sector. Given the recent stagnation in these sectors, however, the Costa Rican government needs policy actions to strengthen the country's global competitiveness and foster regional development in areas outside of the capital.

This chapter assesses Costa Rican healthcare to identify key issues. In medtech, the challenges are relatively weak small and medium enterprises (SMEs) compared to multinationals, a mismatch between skilled labor supply and production structure demand, and a gap between the capital and provincial areas. In MWT, the main problems are lack of collaborative public policy and international marketing plan. In sum, the chapter attempts to answer the following questions: how to link the segmented domains and how to narrow the gaps to achieve balanced development.

The rest of the chapter is divided into two sectoral parts, medtech and MWT. Each part introduces the Republic of Korea's experience and lessons that could benefit Costa Rica.

In medtech, this study takes a look at the Republic of Korea's masterplan being implemented for linking specialized and regionally allocated clusters to provide a long-term outlook. As the main content, the case study of a medical device cluster, Wonju Medical Industry Techno Valley (WMIT), is analyzed in depth. WMIT is an exemplary model of government support effectively helping a spontaneous effort by the private sector. WMIT's success is due to seven factors: (1) collaboration between a research institute (local university) and local government; (2) consistent support independent of change in leadership (local government); (3) full-blown support from the central government; (4) timely supply of facilities to new and potential tenant companies; (5) overcoming of resident opposition; (6) steady expansion of production base; and (7) easy access to a well-skilled and qualified labor force.

Additionally, this study will look at a privately led model of startup incubation administered by the Korean Small and Medium Business Administration (SMBA), namely the Tech Incubator Program for Startup (TIPS). The program is, intended to foster high-tech startups and create jobs.

The final suggestion is to build a cluster specialized in medical devices for domestic SMEs based on lessons learned from the Republic of Korea's experience. In so doing, the Costa Rican government needs to bear in mind a few key points. First, a strategic location is required. For the sake of balanced regional development, authorities must consider the labor supply (high schools and universities), proximity to highways, ports and airports, and access to multinationals (e.g., those manufacturing in the COYOL Free Trade Zone), to name a few. Second, the division of labor among industry, academia, research and government has to be clearly defined. For example, regional S&T universities such as Costa Rica Institute of Technology (TEC) and think tanks like the National Center for Biotechnology Innovations (CENIBiot) can play a significant role from the inception stage. Third, the private sector's creativity and efficiency must be maximized. Thus the government needs to get stakeholders actively engaged rather than adhering to the top-down approach solely driven by the government itself. Fourth, the government needs to devise bold policy at times and exercise patience. Since the tech-oriented system evolves due to many uncertain circumstances, performance can prove volatile over time.

The Republic of Korea has a relatively short history in MWT. Since the medical service industry under law is supposed to be non-profit per se, advertising and promotion to attract patients are generally not allowed. To promote MWT to foreign visitors, however, the Republic of Korea's government and National Assembly amended the Medical Service Act in January 2009 to allow medical institutions to attract foreign patients. In May 2009, the Ministry of Justice of the Republic of Korea started to issue medical tourism visas and the Ministry of Health and Welfare of the Republic of Korea started to require registration by medical institutions and coordinators for quality control purposes.

To formally institutionalize MWT, the Act on Support for Overseas Expansion of Healthcare System and Attraction of International Patients was enacted in June 2016. Under this law, medical institutions and coordinators were designated and evaluated annually, monitored for their medical expenses and fees, and required to be insured against medical accidents.

Moreover, the government later introduced several measures to further back the sector: (1) support for fostering leading medical institutions in the provinces through region-specific technological R&D, promotion and infrastructure; (2) projects for MWT development such as international marketing, infrastructure and online platform; (3) designation of MWT zones for infrastructure, marketing, health food and networking; (4) refunds of value-added tax for cosmetic services; and (5) collaboration for more effective support like forming a public-private MWT association co-chaired by director generals of the Ministry of Health and Welfare and the Ministry of Culture, Sports and Tourism of the Republic of Korea.

Public agencies also support MWT activities. First, Korea Healthcare Industry Development Institute (KHIDI) administers the registration of medical institutions and coordinators, collects and manages data for attracting international patients, and publishes reports on domestic and international trends. Second, Korea Tourism Organization (KTO) hosts the Korea International Medical Tourism Convention (KIMTC), promotes the country's MWT through influential international media and celebrities, develops MWT products and operates medical tourism information centers.

The policy suggestions for MWT over the short term are (1) forming an inter-governmental collaborative organization accommodating agencies and industry; (2) collecting and managing related data; (3) constructing an online platform for promotion; and (4) supporting medical institutions for hospital management consultations including promotion, specialization, service upgrading and cost-effectiveness improvement. Mid-term measures include (5) institutionalizing MWT by amending and/or enacting laws and (6) introducing incentives to stimulate the market in accordance with laws. These are suggested as mid-term tasks not because they are not needed immediately but because they require time to achieve. Finally, over the mid to long term, the Costa Rican government should consider (7) public-private partnerships (PPPs) that integrate medical institutions and recreational facilities such as hotels, resorts and eco-parks.

1. Introduction

As with other industries over the past 50 years, healthcare has experienced continuous internationalization and breakdown of geographic, trade and professional boundaries. For countries like Costa Rica, the globalization of healthcare offers a number of business and investment opportunities, from medical tourism to the global movement of students looking for medical education abroad. Costa Rica can link its well-developed sector for medical devices to growing demand for medical services. Also, it can diversify its service sector by introducing "healthcare business process outsourcing (BPO)" and attracting foreign companies in fields like medical transcription, imagining and billing and insurance reimbursement.

Based on talks with policymakers and stakeholders, this chapter will focus on two of these areas: medtech and MWT. More specifically, this study chose medical devices in medtech and medical tourism in MWT as the main fields because of Costa Rica's potential to grow further as well as the Republic of Korea's accumulated knowhow and experience in these sectors.

In medtech, the global market for medical devices is valued at more than US$300 billion and forecast to reach US$436 billion by 2020 (ITA, 2016). The industry is steadily adapting to dynamic changes in the medical landscape. A push for more personalized treatment, higher availability of healthcare and the aging of populations are among the factors driving new markets.

In Latin America, the medical devices industry is valued at US$24 billion (including production and imports). Brazil (US$4 billion) and Mexico (US$3 billion) are the region's two largest markets (webpage of Global Healthcare Intelligence, http://www.new.globalhealthintelligence.com/news/medical-device-market-in-latin-america-scope-challenges/, accessed Feb. 12, 2017). In addition to Mexico and Brazil, Argentina and Colombia account for over 80 percent of the region's import and sales of capital equipment (webpage of Latinvex, https://www. bancoadopem.com.do/app/article.aspx?id=2555, accessed Feb. 12, 2017).

The medical devices industry is undergoing major changes of all sorts: newly available technologies, changes in healthcare systems, demographic shifts, redefinition of the sector's structure and new target markets.

In MWT, medical tourism is defined as the phenomenon of people traveling from one country to another for medical intervention based on perceived personal value (Enea and Mungiu-Pupăzan, 2013). The reasons people travel for care depends on the countries they live in as well as their personal situations. Nevertheless, the four main drivers of medical tourism are affordability, accessibility, availability and quality.

Grasping the scale of the medical tourism market is challenging, as estimates and forecasts vary widely among the world's top research companies due to inconsistencies in defining medical tourism and unreliable and non-verifiable data at the country level (webpage of Patients Beyond Borders, http://www.patientsbeyond borders.com/medical-tourism-statistics-facts, accessed Feb. 10, 2017). According to the editors of Patients Beyond Borders, the market size is US$45.5 billion to 72 billion, based on approximately 14 million cross-border patients spending an average of US$3,800–6,000 per visit, including medical costs, in-patient stay, cross-border and country-wide transportation, and accommodations. An estimated 1.4 million Americans were estimated to have traveled outside of their country for medical care in 2016 (Woodman, 2015).

Patients Beyond Borders estimates growth of the global medical tourism market at 15–25 percent, with inbound patient flows highest in Mexico and Southeast and South Asia (Woodman, 2015). Such growth is thanks to a number of reasons, it says:

> *"The world population is aging and becoming more affluent at rates that surpass the availability of quality healthcare resources. In addition, out-of-pocket medical costs of critical and elective procedures continue to rise, while nations offering universal care are faced with ever-increasing resource burdens. These drivers are forcing patients to pursue cross-border healthcare options either to save money or to avoid long waits for treatment." (webpage of Patients Beyond Borders, http://www.patients beyondborders.com/medical-tourism-statistics-facts, accessed Feb. 10, 2017).*

The policy roadmap of the Costa Rican government seeking to stimulate exports in healthcare services is laid out in three steps as shown in [Figure 4-1]. Noticeably, required policy measures include education, production and incentives to promote the innovation and participation of SMEs, as well as public-private partnerships to attract investment in regions outside of the capital metropolitan area.

This chapter will focus on the global competitiveness and regional economy in medtech and MWT. From the perspective of regional economy, the gap between the San Jose metropolitan (capital) area and provinces is a major issue. For each sector, similar gaps exist between multinationals and domestic SMEs, and between medical and tourism sides in medtech and MWT. Accordingly, the two questions this chapter attempts to answer are (1) how to link the segmented domains and (2) how to narrow the gaps to achieve balanced development.

The rest of this chapter consists of the followings. First, it will assess the medtech and MWT markets in Costa Rica to identify the challenges to overcome.

Second, an overview of the same markets in the Republic of Korea will be given. In medtech, two case studies will be introduced at as exemplary practices: a cluster specifically for medical devices and a government support program for high-tech startups. In MWT, the Republic of Korea's recent experience in medical tourism is featured including legal and institutional matters, government support programs and collaboration efforts.

Third, the chapter concludes with policy suggestions for Costa Rica based on the lessons learned from the Republic of Korea's experience in policy implementations.

[Figure 4-1] Policy Roadmap to Stimulate Costa Rica's Healthcare Exports

Stage 1 (2016-17)

- Form cross-sectoral committee with private sector
- Evaluate strengths and weaknesses and growth potential of healthcare exports based on available data and hold subcommittee meetings and workshops to provide guidelines for improving data collection
- Analyze international best practices in public policy to build domestic capacity
- Devise short- to mid-term policy plan to back cross-sectoral committee and hold workshops for planning and promoting public-private partnerships

▽

Presidential Council on Competitiveness, Innovation and Human Talent controls and supports each institution in implementing measures

▼

Stage 2

- Assign Presidential Council on Competitiveness, Innovation and Human Talent to support implementation of short-term measures and projects for promoting public-private partnerships
- Secure guidelines for improving statistical performance and collect data on interest from domestic and multinational companies
- Build needed capacity for implementing short-term measures for resolving mismatch in labor supply and demand

▼

Stage 3

- Evaluate performance of measures in Stage 2
- Spread and assess short- to mid-term challenges and solutions by engaging core stakeholders
- Support domestic SMEs to participate in value chain, implement mid-term measures to stimulate investment in regions outside San Jose metropolitan area, and support domestic public-private partnerships

Source: Abstracted from KSP proposal by COMEX.

2. Healthcare Industry in Costa Rica: Needs and Challenges

This section has brief analyses of Costa Rica's medtech and MWT markets to identify the needs and challenges of both sectors.

2.1. Technology and Health

Even if Costa Rica's manufacturing of medical devices faces specific challenges in the rapidly changing and competitive global environment, the institutional framework and alignment of the country's public and private sectors remain quite satisfactory.

The leadership of the Costa Rican Investment Promotion Agency (CINDE) and the alignment pushed by the Minister of Foreign Trade (COMEX) by officially endorsing and financially supporting the agency's role has produced a successful model that other countries have tried to emulate.

Nevertheless, Costa Rica possesses untapped potential to link the development of medical devices to ICT and medical services. The majority of companies operating within free trade areas are not fully connected to the domestic medical industry, if at all.

A number of areas exist in which Costa Rica can employ a more comprehensive strategy and maximize the potential of both the medical industry and medical services community, with ICT serving as a bridge between the two. Three promising areas are:

- Medical devices and health innovations
- Telemedicine and digital health
- Medical research

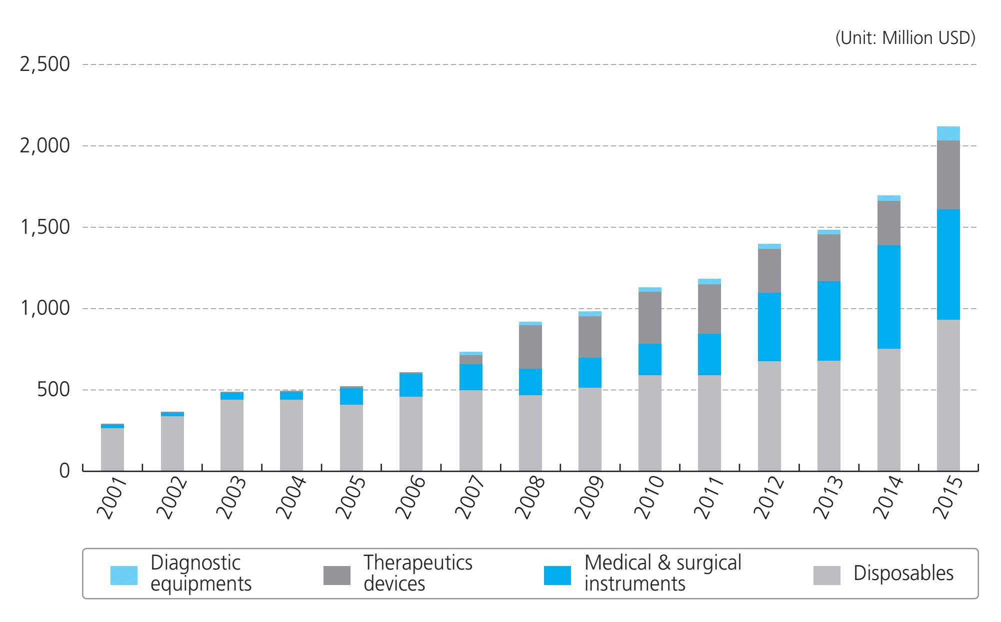
2.1.1. Market Overview

The medical device sector in Costa Rica started in 1987 with the arrival of a major industry player, Baxter Healthcare. The sector has since evolved and grown in size and complexity. From commodities to high-tech, highly regulated devices such as biological heart valves, aesthetic implants and surgical systems, factories have outperformed in fostering a positive reputation that has facilitated and motivated the transfer of more production lines to the country.

Today, the sector plays a crucial role in the Costa Rican economy. The country is the No. 2 exporter of medical devices in Latin America and seventh-biggest supplier to the US. It hosts five global cardiovascular leaders. Medical devices in 2015 were Costa Rica's top export item and represented 23 percent of the country´s overall goods exports (Procomer, 2016).

Costa Rica's export-oriented and FDI-driven strategy has resulted in an influx of investment, steady export growth with outbound shipments reaching US$2.2 billion in value in 2015 (as depicted in Figure 4-2 more in detail) and creation of 19,000 jobs by 2014. The life science sector accounts for 4 percent of GDP.

[Figure 4-2] Medical Device Exports by Sophistication Level

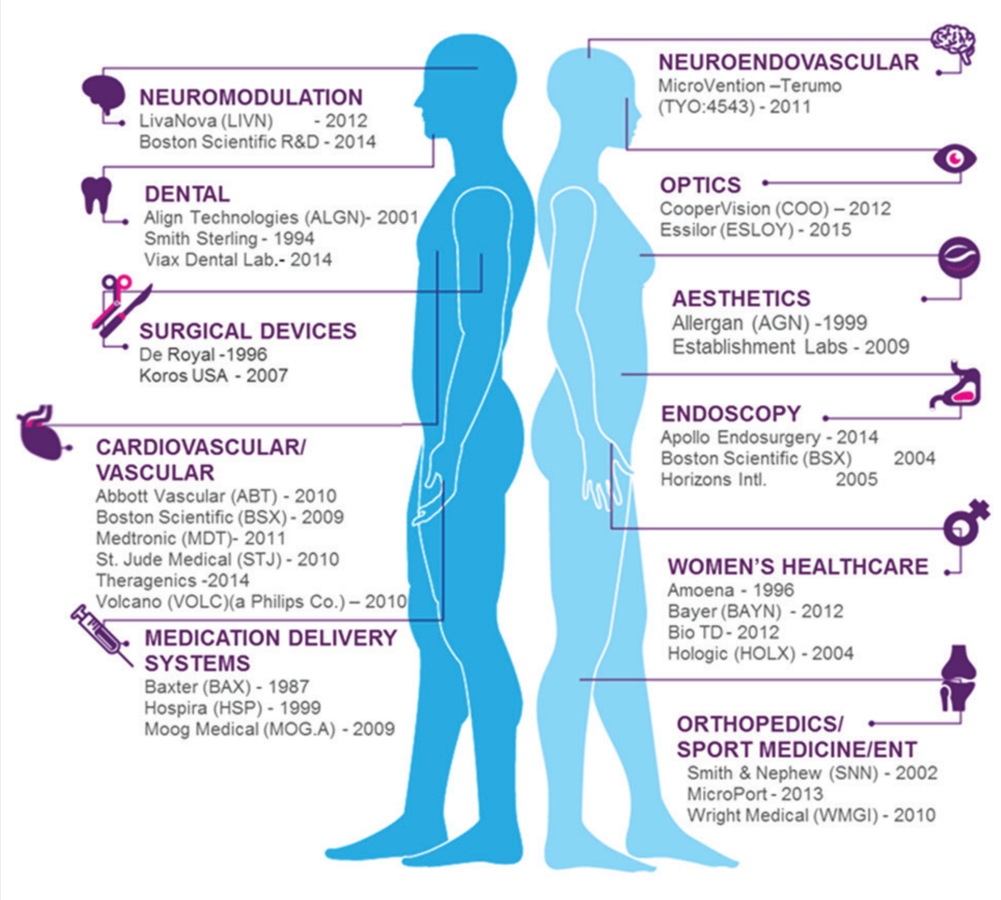


Source: CINDE based on data from BCCR, IMF, and TradeMap, 2014.

Home to over 280 multinationals and 65 medical device corporations, Costa Rica is a major hub for medtech investment, attracting 47 projects over a five-year period.

The country has stepped up in the sector, going from producing Class I to Class III medical devices including those for esthetics, cardiovascular, dental, endoscopy, medication delivery systems, neuro-endovascular, neuro-modulation, optics, orthopedics, sports medicine and ENT, and surgical and diagnostics components. Its export markets are North America, Europe, Asia and Oceania. Examples of areas and multinationals are illustrated in [Figure 4-3].

[Figure 4-3] Medtech Areas and Multinationals in Costa Rica



Source: CINDE.

Factors behind Costa Rica's medtech success are:

- Skilled workforce making Costa Rica No. 1 in production process sophistication in Latin America as base of corporations producing and exporting Class I to Class III devices
- Competitive tax incentives with income tax as low as zero for true ROI
- Leading education system in Latin America, strong command of English, Western cultural affinity and people's thirst for new challenges; ranked region's best for innovation
- Life science companies running R&D processes in Costa Rica
- Strategic location at heart of Americas with access to western and eastern seaboards from Pacific and Caribbean.
- Business friendly with over 14 FTAs that offer preferential access to markets with 2.5 billion people

- All of these concentrated in Latin America's safest country and second most stable democracy; ideal climate for success

2.1.2. Challenges in Medtech

Considering the need for three sectors - medical devices, ICT and medical services – to interact, the main challenge is to effectively link them under COMEX leadership and gain support from institutions such as the Trade Promotion Agency of Costa Rica (PROCOMER), CINDE and the Council for International Promotion of Costa Rica Medicine (PROMED). One of the first steps seems to be approaching medical device companies established in the country and encourage them to open conversations with authorities and support institutions about "upgrading" their presence in Costa Rica, particularly, by focusing on convergent products that combine IT, medical devices and patient needs.

A transversal challenge for export and FDI-oriented industries is Costa Rica's need to maintain and raise competitiveness, as other low-cost global hubs for life science products get more politically stable and raise their competency.

Upgrading processes and products in the medical device sector has grown more sophisticated but multinationals are still outsourcing lower value-added activities to Costa Rica (e.g., components manufacturing) rather than other activities with potentially higher margins like R&D.

After five years of inactivity, Costa Rica as a destination for clinical trials needs to reestablish trust with key stakeholders such as pharmaceutical companies and CROs. The abrupt decision of the Costa Rican Supreme Court to stop all clinical studies on humans in 2010 created uncertainty over the country's framework. This requires multiplying promotional efforts to reattract sponsor interest in Costa Rica. Recommended activities toward this objective include attending trade shows, inviting key influential figures and including this topic in presidential, diplomatic and foreign trade agenda.

Costa Rica faces a growing mismatch between the supply and demand of skilled labor. In general, it produces relatively good quality of graduates but the labor supply by specialization and the skills required by industry are misaligned (OECD, 2012). Another task is to offer incentives to universities and students to pursue R&D-related careers such as statistics, biometry, microbiology, genetics and nanotechnology.

To attract and anchor knowledge-intensive FDI to the domestic economy, specifically in life sciences, strengthening domestic research is critical. Domestic research capabilities enhance Costa Rica's attractiveness to FDI while adding spillover effects to the Latin American economy (OECD, 2012). The country could develop new partnership mechanisms with multinationals to set up small-scale research laboratories.

Market diversification for a small country like Costa Rica is another important challenge in medtech. With its experience in manufacturing medical devices and Spanish-language skills, Costa Rica could adapt high-tech products for emerging markets in Latin America (Bamber and Gereffi, 2013, p.48). Asian countries such China and the Republic of Korea could certainly be major partners in these efforts.

Finally, most issues in the legal framework are in bureaucracy and red tape, like the problems facing laboratories to import specific biological materials or set up a business. This general challenge affects the majority of the country's productive sectors, but certainly affects more companies involved in R&D, small ones suffering from the lack of knowledge in commercialization in particular. A specific challenge requiring legal modification is the provision included in Article 84 of Law No. 9234 that regulates biomedical research; this has created obstacles to the identification of potential participants in clinical trials. This is a critical aspect since the ease of identifying and recruiting participants is a fundamental element to attract clinical trial sponsors to the country.

Summing up the collected facts, the results of a SWOT analysis of Costa Rican medtech can by summarized as in <Table 4-1>.

〈Table 4-1〉 SWOT Analysis Results for Costa Rican Medtech

Strength	Weakness
• Strategic location at center of Americas with direct flights to all major international airports in US and Canada • Economic and political stability • Internationally accredited healthcare facilities (29 hospitals and outpatient surgery facilities) • Internationally educated and trained healthcare professionals • Well established healthcare cluster under PROMED • Diversified epidemiological profile	• Lack of public policy to facilitate development of sector • Shortage of medical researchers • High labor and operating costs • Weak links between healthcare and ICT sector • Reduced investment in R&D • Lack of official endorsement of specifically dedicated national agency • Inactivity of clinical research sector for 5 years • High labor and operating costs • Mismatch between skilled-labor supply and production

〈Table 4-1〉 Continued

Opportunity	Threat
• Aging population • Availability of technologies allowing remote attention to patients • High cost of medical research in US and Europe • Growing trend for pharmaceutical and medical device companies to outsource clinical trials to countries other than US or those in Europe • Rising demand for Phase II and III clinical trials • Growing importance of IT in healthcare industry • High number of new drugs under development	• Regional and international competition • Possible protectionist sentiment in US • Significant support to medical services industry from governments of competing countries

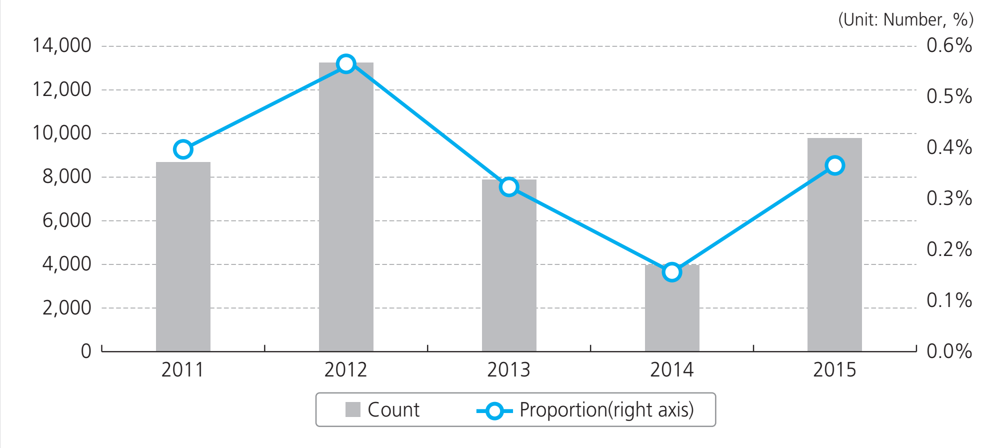
Source: Author's analyses.

2.2. Medical and Wellness Tourism

2.2.1. Market Overview

Costa Rica's Tourism Authority (ICT) mentions "health and medical attention" as a reason to travel in its survey to passengers entering the country through Norman Y. Mineta San Jose International Airport. According to the authority's surveys, the number of medical tourists that visited the country in 2015 was 9,774 or 0.4 percent of the total as shown in [Figure 4-4]. Also, the percentage of tourists who did a wellness activity during their stay (or secondary international visits according to the definition of the Global Wellness Institute) was 34.8 percent.

[Figure 4-4] Number of Medical Tourists in Costa Rica



Note: Estimation using distribution of main motive of aerial visit and information on international arrivals provided by Director General for Migration and Aliens.

Source: ICT, Survey of non-residents at international airports.

The surveys also showed that 34.8 percent of tourists in Costa Rica engaged in wellness tourism from 2014–15 as depicted in <Table 4-2>. The most popular activities in the sector were hot spring visits, wellness treatments like massage and spa, and yoga.

Yet even the tourism authority ICT echoes most opinions that the numbers do not reflect the real size of the sector. This is because of the small number of interviews as medical tourism remains a relatively small niche among tourists (though not small in revenue generated) and the reluctance of patients to say they visited the country for medical reasons,.

〈Table 4-2〉 Percent of Tourists by Activity, 2014-15

(Unit: %)

Group	Total	Personal Reasons	Professional Reasons
Sun and beach	71.0	80.2	26.6
Ecotourism	66.6	75.0	21.1
Adventure	52.9	60.5	14.2
Wellness	34.8	39.6	11.9
Sports	22.8	26.1	6.9
Cultural	18.2	20.8	6.8

Source: ICT, Survey of non-residents at international airports.

On the other hand, the most complete collection of medical tourism data comes from two surveys performed by PROMED. One is a quantitative analysis of healthcare providers and the second is a qualitative analysis of foreign patients that received medical or dental attention in the country. Yet both surveys, even if performed using the best statistical practices, still lack full scientific support due to the limited number of answers.

According to PROMED data, Costa Rica had an estimated 48,000 medical tourists in 2011 who injected about US$338 million into Costa Rica's economy: 83 percent of the visitors were from the US and 11 percent were from Canada.

The most popular procedures were:

- 42% Dental (cosmetic and reconstructive)
- 10% Plastic and esthetic
- 22% Surgery (orthopedic, bariatric, general, gynecological, oncological, ophthalmological)
- 10% Other procedures (dermatology, physio-theraphy, audiology, rehabilitation)
- 16% Preventive medicine (imaging, physical check-ups)

The results of PROMED's quantitative survey showed that more than 1,300 private medical and dental organizations received at least one international patient per year.

From a qualitative perspective, PROMED surveys have collected useful information about medical tourist behavior and habits in Costa Rica, including average spending and length of stay. The most interesting findings include:

- Average spending of more than US$10,000 per medical tourist per trip
- Average length of stay of 15 days for medical or dental tourism
- Vast majority of patients traveled with at least one companion (68 percent)
- 61 percent of patients participated in tourism activity during medical trip, showing MWT's impact on overall tourism

Other efforts to measure the export of medical services are being developed by the Central Bank of Costa Rica and PROCOMER but the results are not yet available as of November 2016.

[Figure 4-5] Regional Potential to Stimulate MWT in Costa Rica

Source: Author's analyses.

The variety of Costa Rica's offerings in medical and wellness services opens up intriguing business and export opportunities for a number of areas within the country. As illustrated in [Figure 4-5], Guanacaste, the Northern Zone, San Jose Province and the Central Pacific Coast have the highest potential to become MWT destinations or strengthen their positioning as such. Also, the provinces of Cartago (mainly the Orosi area) and Heredia (mainly the areas closest to Central Valley) show a few competitive advantages to play a role in health tourism.

First, Guanacaste is a globally renowned tourist destination with large hospitality features and diversified wellness offerings such as spas and hot springs. This province boasts an international airport, excellent medical services (CIMA Hospital and San Rafael Arcangel Hospital) and retirement communities (Pacific Plaza and Sun Ranch). Partnerships with real estate professionals could fuel further development.

Second, La Fortuna in the San Carlos area is another renowned wellness destination with large hospitality offerings and market demand for combined medical and wellness services. Private medical providers with average preparedness are in Ciudad Quesada and Arenal and a well-structured business environment is around the Special Economic Zone of the Northern Area (ZEE).

Third, Quepos and Manuel Antonio in the Central Pacific region round out the triumvirate of Costa Rica's renowned tourism destinations with large hospitality offerings, dental tourism clinics and large expat communities (mainly from North America). They offer the closest seaside resorts to the metropolitan area and are easily reachable from the international airport, and even closer to the future International Airport of Orotina.

Fourth, Orosi in Cartago has an excellent climate for wellness and recovery with its good location close to the metropolitan area, good medical services and hot springs. A recognized place for retirement and with the conditions to become a hotspot for related communities; this is an ideal hub for health tours and excursions including those featuring organic agriculture and volcanoes.

Fifth, Heredia has good accessibility and stellar medical and dental services, which make it ideal for recovery and retirement projects. This place has the potential for combining medical and wellness treatments through facilities like wellness boutique hotels.

2.2.2. Institution and Legal Framework

Costa Rica has few institutions devoted to healthcare for foreign patients. Even if individual institutions are included in the sector, the country suffers from a clear lack of public policy or national strategy.

After the Ministry of Competitiveness finished its mandate in 2010, the Council for International Promotion of Costa Rica Medicine (PROMED) assumed the role of de facto institutional coordinator by involving a number of public organizations according to their specific constitutional mandates.

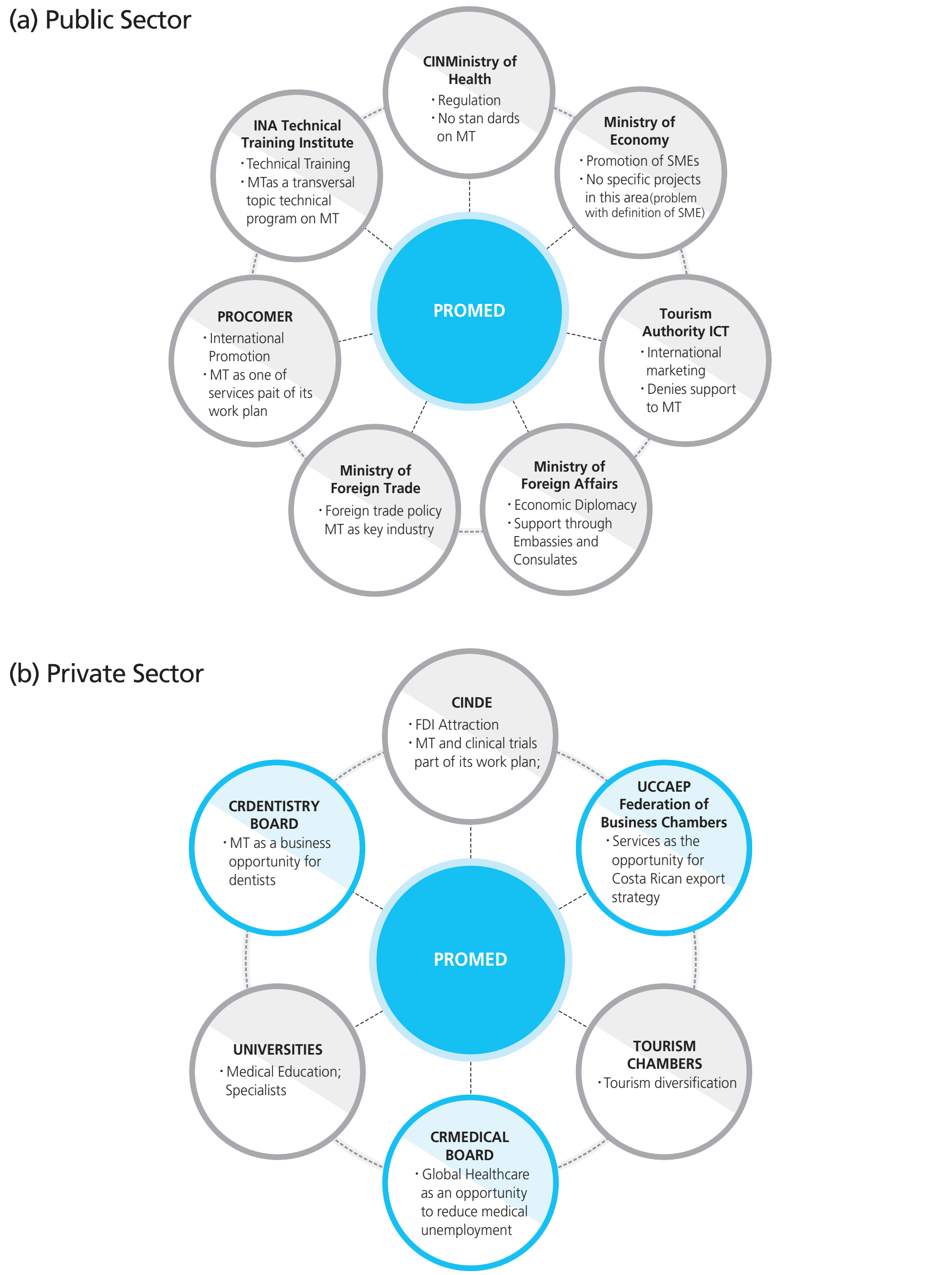
For example, PROCOMER organizes and supports promotional and market research initiatives but cannot be considered an inter-institutional coordinator. On the other hand, an institution that plays a fundamental role as marketing promoter like the Tourism Authority has historically denied support for medical tourism in Costa Rica.

Finally, the majority of Asian countries put the health ministry in charge of strategy for medical tourism, but Costa Rica's Ministry of Health lacks the resources to play this role.

Nevertheless, a globally recognized strength of Costa Rica is its well-organized public-private partnerships under the leadership of PROMED and its efforts for bringing to the table government and non-government organizations as shown in [Figure 4-6].

The country's legal framework is also quite weak. Given the characteristics of the sector, proper development does not necessarily require specific legislation.

[Figure 4-6] Key MWT Stakeholders in Costa Rica



Source: Author's analyses.

The only official specific regulation is the Decree of National and Public Interest in Health and Wellness Tourism approved in 2012, which replaced a decree approved in 2009. The two main points of the 2012 decree are authorization of all public entities to support with available means MWT's development. The decision whether to support the sector is up to each institution, and this has led to situations like the one with the Tourism Authority. On the other hand, however, the decree provides sufficient legal justification for a public institution to implement specific measures to support the industry. For example, the Immigration Authority decided to approve fast-track visas for citizens of select countries wishing to visit Costa Rica for medical reasons.

2.2.3. Challenges in MWT

The first big challenge for the sector is its lack of institutional alignment to effectively position medical tourism as a national priority as pointed out above.

A number of competitiveness challenges also loom for Costa Rica, including:

- **Oversupply of Healthcare Professionals:** Almost all healthcare areas are suffering from human resource saturation. According to Peraza-Valverde and Vega-Espinoza (2014), Costa Rica has an oversupply of 3,493 dentists. On the medical side, the official number of unemployed doctors per the Costa Rican Medical Board is 900. So more than 4,000 general doctors are estimated to be either jobless or underemployed.
- **Medical Fees:** A worrying trend of rising medical costs has hit the country. Higher competition and programs like HMOs or medical networks are needed to create better economies of scale and lower medical (professional) fees.
- **Incentives:** While many competitors offer attractive fiscal incentives to healthcare projects, Costa Rica has yet to produce legislation to allow the establishment of hospitals or other medical projects within free trade areas.
- **Medical Specialists:** A paradoxical situation is facing Cost Rica in healthcare human resources: a glut of general practitioners and a shortage of medical specialists. This is a consequence of a monopoly assigned to the University of Costa Rica over postgraduates program. Thus private universities should be allowed to participate and flexibility is needed to allow collaboration with highly recognized foreign specialists.

The experience of Costa Rica shows the success of a clear strategy executed by a specialized agency. The government needs to accelerate an industry despite a lack of necessary skills and experience. One solution that makes sense is to bolster organization of the sector and its capacity to execute strategy by empowering and funding PROMED under a similar model developed with CINDE as far as investment attraction and reinvestment strategy are concerned.

A key pillar of the strategy has to be quality and specifically implementing clear rules of the game for companies (health or tourism) willing to participate. Compliance with international standards of quality and patient safety is the most viable and convenient way to define access to official promotional activities and endorsement.

Finally, brand recognition and marketing are fundamental to boost exports. Too little has been done to promote a sector with 42 years of experience in exporting medical services. ICT, PROCOMER and PROMED should come up with a national marketing plan to position Costa Rica as the medical and healing hub of the Americas.

Similar to one done on medtech, a SWOT analysis of MWT in Costa Rica came up with results summarized in <Table 4-3>.

〈Table 4-3〉 SWOT Analysis Results for Costa Rica's MWT

Strength	Weakness
• Global recognition as leading medical tourism destination • Strategic location in Americas with direct flights to all major international airports in US and Canada • Economic and political stability • Quality of life • Savings of 50–70% compared to US • Internationally accredited healthcare facilities (29 hospitals and outpatient surgery facilities) • National seal of quality identifying qualified medical tourism providers • Internationally educated and trained healthcare professionals • Renowned tourism destination • Well-established healthcare cluster under PROMED • Highly experienced value chain including specialized hotels and recovery centers, dedicated transportation companies, VIP attention system at Juan Santamaria International airport	• Lack of public policy to facilitate development of sector • Shortage of medical specialists to ensure competitive, sustainable development • Lack of systemic, periodic and reliable statistics • High labor and operating costs • Lack of international marketing plan • Reduced support for promotional activities such as expos, conferences, family trips and trade missions • Weak links between healthcare and tourism • Medical tourism lacks tourism declaration from tourism authority • Healthcare projects banned under free trade regime • Lack of specific regulation identifying healthcare, tourism, and recovery companies officially endorsed as medical tourism providers • Lack of official endorsement of specifically dedicated national agency • Shortage of medical specialists driving competition in medical human resources between public and private sectors

〈Table 4-3〉 Continued

Opportunity	Threat
• Aging population • Increasing attention to self-image • High costs of care in developed countries • Longer waiting lists in countries with public healthcare systems like Canada • Growing wellbeing and anti-aging trends • Availability of technologies allowing remote attention to patients • Growing interest of insurers and self-funded employers in offering global medical tourism options • Lack of quality healthcare in Central American and Caribbean countries • High costs of medical insurance in US and increase in high deductibles and copays plans • Terrorist threat in Europe and security threats in Mexico, Central America and Colombia	• Regional and international competition • Possible protectionist wave in US • High medical costs • Significant support to medical tourism from governments of competing countries

Source: Author's analyses.

3. Republic of Korea's Experience and Implications

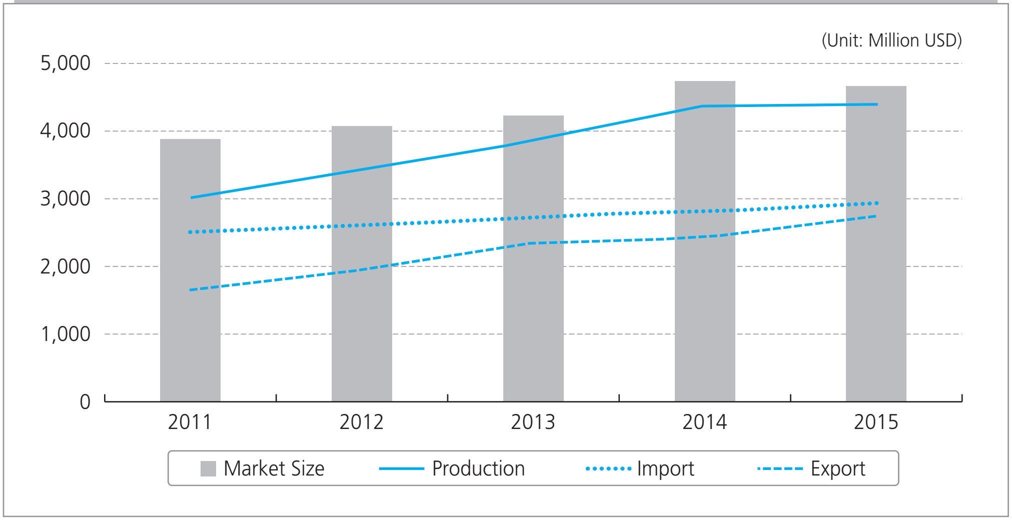
In this section, the Republic of Korea's markets for medtech and MWT are reviewed and the central government's efforts to stimulate both markets are introduced.

3.1. Medtech: Medical Devices

3.1.1. Market Overview and Clustering Policy

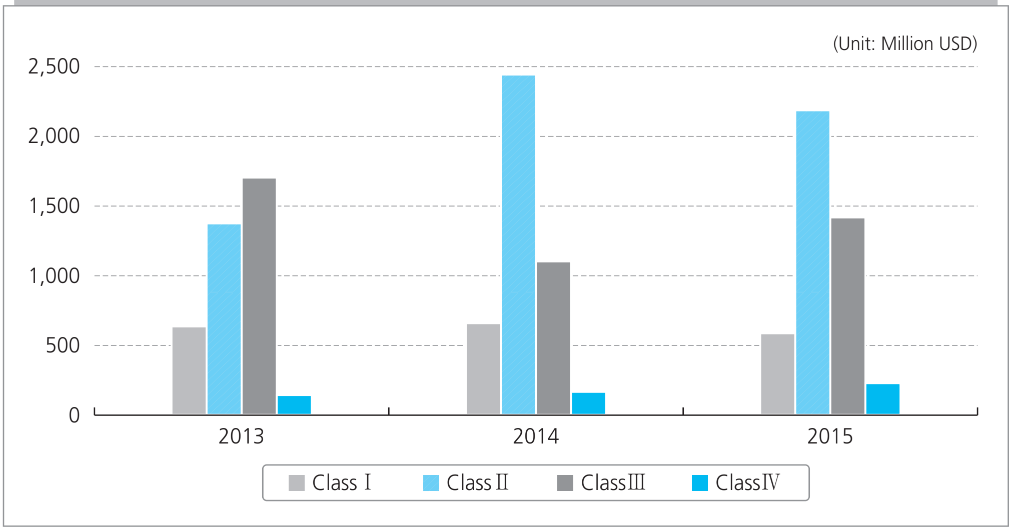
According to Espicom (2015), the Republic of Korea's market for medical devices was ranked ninth in size (US$5.5 billion) as of 2015, coming in between Canada's (US$6.2 billion) and Brazil's (US$4.6 billion). The domestic market has steadily grown in all aspects like size, output, export and import. From the trade perspective, the market has a deficit that has since been narrowed as shown in [Figure 4-7].

[Figure 4-7] Status of Medical Device Market



Source: KHIDI webpage (https://www.khidi.or.kr/board?menuId=MENU01252&siteId=null), accessed February 13, 2017.
Original Source: MFDS, Medical Devices Productions, Exports and Imports Report, annual.

[Figure 4-8] Output in Medical Device Market by Class



Note: Original data in KRW are converted into US dollars using standard annual average FX rate of Bank of Korea.
Source: KHIDI database.

〈Table 4-4〉 Top 10 Medical Device Products, Republic of Korea

(Unit: Thousand USD, %)

Item	2014		2015	
	Production	% of Total	Production	% of Total
Dental implants	567,936	12.99	572,696	12.96
Ultrasonic imaging systems	449,295	10.28	390,374	8.83
Processing device systems, S/W	134,719	3.08	147,067	3.33
Digital X-ray systems	130,925	2.99	141,487	3.20
Soft contact lenses	121,545	2.78	132,301	2.99
Sight corrective ophthalmic lens	112,789	2.58	108,487	2.45
Alloy, noble metals	102,173	2.34	102,658	2.32
Graft/prosthesis, biomaterials	98,978	2.26	96,544	2.18
Medical probes	91,661	2.10	95,424	2.16
CT systems	85,124	1.95	92,596	2.09

Source: KHIDI webpage (https://www.khidi.or.kr/board?menuId=MENU01252&siteId=null), accessed February 13, 2017.
Original Source: MFDS, Medical Devices Productions, Exports and Imports Report, annual.

As of 2015, the Republic of Korea's production of medical devices was 0.32 and 1.2 percent of GDP and manufacturing, respectively. In product class, the country's medical device market produces mainly Class II to III products as displayed in [Figure 4-8]. By item, equipment and instruments accounted for 62.6 percent, dental materials 20.6 percent, medical supplies 9.9 percent and in vitro diagnostic device (IVD) reagents 6.9 percent in 2015. More specifically, the top ten products are displayed in <Table 4-4> and top export and import items in <Table 4-5>.

〈Table 4-5〉 Top 10 Export and Import Items, 2014

(Unit: Million USD)

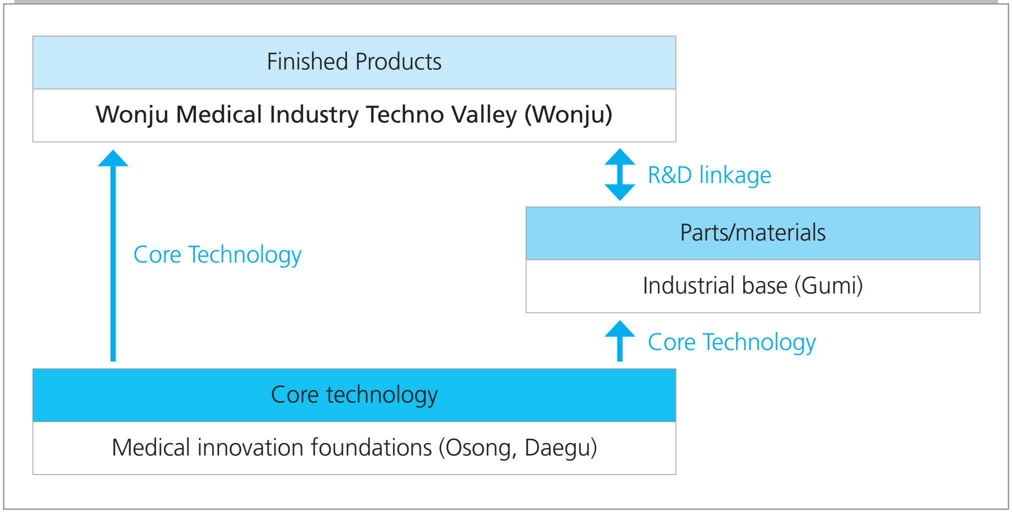
Rank	Export		Import	
	Item	Value	Item	Value
1	Ultrasound imaging systems	539	Stent	120
2	Dental implants	125	Soft contact lenses	106
3	Soft contact lenses	109	Sight corrective ophthalmic lenses	105
4	Heating pad systems under/ overlay, electric, home use	105	Dialyzer	70
5	Digital X-ray systems	99	Knee prosthesis	64
6	Medical probes	90	MRI systems	64
7	Medical image processing device systems, S/W	90	IVD reagents for radioimmunoassay analyzer	61
8	IVD strips for clinical immunochemistry	85	Intravascular catheters	60
9	IVD reagents for infectious disease marker, high risk pathogens, immunological method	84	CT systems	56
10	Surgical lasers	66	IVD reagents for clinical immunochemistry	50

Source: KHIDI webpage (https://www.khidi.or.kr/board?menuId=MENU01255&siteId=null), accessed February 13, 2017.

As seen in the figures and tables above, the medical device market of the Republic of Korea is differentiated from Costa Rica's in two conspicuous aspects. First, the former produces more technology-augmented products, mainly Class II to III products, while Costa Rica primarily produces Class I to II products. Second, major producers in the Republic of Korea's market are domestic SMEs while multinationals are the main players in Costa Rica.

Moreover, the Republic of Korea's government has extensively attempted to stimulate the market on the production side with an array of support measures. R&D gets financial support to perform "intermediate research," meaning research transforming existing source technology suitable for clinical applications and overseas clinical trials, and consulting support for international certification. The biggest form of government support is the setup and backing for industrial clusters specialized in medical devices. As shown in [Figure 4-9], the government plans to link medical device clusters. Considering balanced regional development and proximity to existing production bases, the clusters are strategically located in areas outside of the capital Seoul.

[Figure 4-9] Republic of Korea's Government Plan for Linking Medical Device Clusters



Source: Kim *et al.* (2013), p.3.

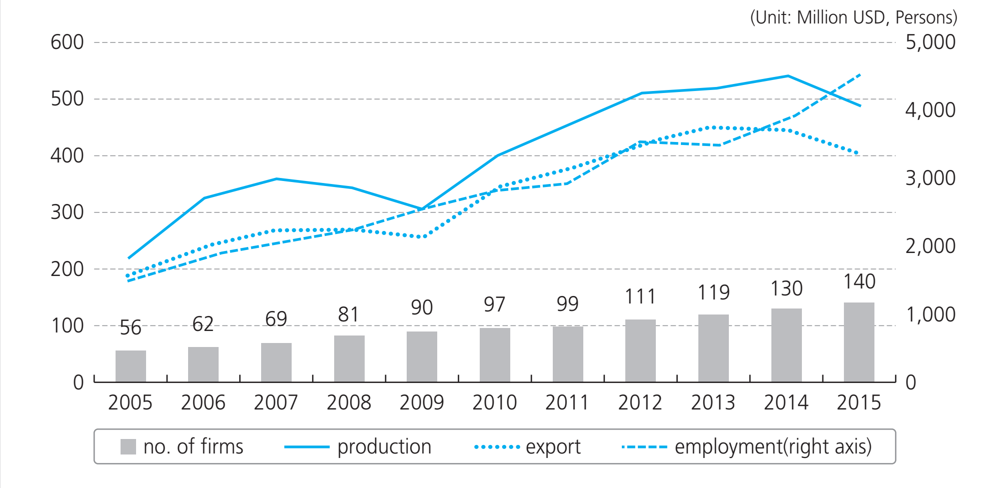
To back a well-functioning cluster for finished products, namely Wonju Medical Industry Techno Valley (WMIT) located in the eastern Gangwon-do, the government attempted to create a hierarchical structure of clusters. To help the industry graduate to producing more advanced high-tech products, one high-tech cluster was built in Osong and Daegu in the central region (Chungcheongbuk-do) and another in the southern part (Gyeongsangbuk-do). Moreover, a state-led industrial base specialized in parts and materials for medical devices was built in Gumi, Gyeongsangbuk-do, a city with an existing national industrial complex and near Daegu. According to the government's plan, once a core technology is developed at medical innovation foundation in both Osong and Daegu, WMIT and the Gumi industrial base are expected to commercialize it. Moreover, WMIT and the Gumi industrial base can collaborate in R&D for more effective production but as newly constructed clusters, they need more time to show substantial achievements.

In this section, two distinctive case studies are introduced: a cluster for medical devices (WMIT) and financial support for tech startups. The former is an exemplary model to accommodate SMEs producing medical devices with a significant government role, while the latter is a successful private investment-led incubating program for high-tech startups and entrepreneurs introduced by the Small and Medium Business Administration (SMBA).

3.1.2. Case 1: Wonju Medical Industry Techno Valley

The formal history of WMIT started with the Wonju business incubator for medical devices established in 1998. Wonju City Hall and a university in the city, however, had collaborated in forming the said cluster for a few years before 1998. For more than two decades, it grew into the hub of the country's medical device industry. As shown in [Figure 4-10], the complex has seen steady growth in production, export, employment and number of tenant companies. As of 2015, 140 tenant companies (4.7 percent of all medical device companies) employed 9.5 percent of workers in the sector. Their production and exports contributed 11 and 15 percent of all domestic production and exports, respectively.

[Figure 4-10] Growth of Wonju Medical Industry Techno Valley



Note: Original data in KRW converted into US dollars using standard annual average FX rate of Bank of Korea.
Source: WMIT database.

The development process of WMIT can be analyzed with the frame of Greiner (1972), the proximity view of Capello (1999), and the evolution structure of Swann (1998) as summarized in <Table 4-6>. In its entrepreneurial stage, WMIT was initiated by Wonju campus of the domestic Yonsei Unversity, Wonju (YUW), to nourish the school's department of biomedical engineering. In the collectivity stage, rules are set for managing the incubating center and agency in a process done jointly by the university and the city government. The formalization stage saw the establishment of the foundation and division of labor set between the city government and university. Now in the elaboration stage, WMIT concentrates on forming a collaborative network with related clusters, domestic and international companies, and central and regional governments.

〈Table 4-6〉 Characteristics of WMIT by Development Stage

Stage	Entrepreneurial	Collectivity	Formalization	Elaboration
Highlights	Led by domestic university	Rule setting for managing incubating center and agency	Setting foundation and dividing labor b/w city government and university	Forming collaborative network
Proximity	Geographical proximity b/w think tank and government	Geographical proximity b/w companies and think tank	Organizational proximity b/w companies, government and think tank	Stable innovative synergy
Structuring	Building research infrastructure	Commercialization and expanding tenant companies	Forming support agencies	Enlarging network and diversification
Mediation	Informal leadership	Intra-organizational hierarchy of authority	Contract and link to committee	Networking to form rules and canon
Collective strategy	Agglomerate, confederate (informal)	Confederate (formal)	Conjugate	Organic

Source: Yu and Han (2008), p.86, Table 3.

WMIT was spontaneously initiated and supported by the city government in the early stage, but received a huge boost after getting help from the central government. The Ministry of Science and Technology of the Republic of Korea (now the Ministry of Science, ICT and Future Planning or MSIP), set up the Regional Research Center (RRC) for strengthening R&D capacity and supporting commercialization. The Ministry of Trade, Industry and Energy (MOTIE) of the Republic of Korea established the Technology Innovation Center (TIC) for tenant SMEs to save costs by lending equipment, and operated on-site education programs at the Medical Engineering Education and Training Center (MEETC). Also, the Ministry of Health and Welfare (MOHW) of the Republic of Korea built the Home Health Care Research Center (HHCRC) specializing in R&D for home healthcare devices. The central government's support was not well-planned or fully designed in the early stage; instead the Wonju municipal government and university utilized actively the central government's support in a fragmentary way. Full-scale support from the central government to WMIT started after the complex showed good performance in the entrepreneurial and collectivity stages.

WMIT supports tenant companies in several ways. First, technical support includes instrument design (product consulting, 2-D and 3-D modeling, and reverse engineering), prototyping (making working mock-ups and printed circuitboards and post-processing) and reliability testing (testing environment of global standard, testing and measuring equipment, and open laboratory). As mentioned above, MSIP, MOTIE and MOHW of the Republic of Korea support WMIT with RRC, TIC and HHCRC, respectively.

Second, marketing support for WMIT is systemized into four steps. (1) In the productization stage, it helps the production of clinical papers, manuals, promotional movies and brochures and package design. (2) In the stage of promotion and building resellers, it supports participation in international conferences and exhibitions, promotion through professional magazines and web portals, and branching and international networking. (3) In the initial contract stage, it supports the creation of service centers, service and sales training, supply of demo units and consulting for contracts. (4) In the stage of stimulating sales, it introduces incentives and supports participation in professional conferences. Moreover, WMIT operates a permanent exhibition hall on its campus to promote the products of tenant companies, a first in the Asia-Pacific area. At the exhibition hall, WMIT holds a professional expo twice a year, namely the Gangwon Medical Equipment Show (GMES), to foster international orders.

Third, WMIT supports registration of health insurance reimbursement in collaboration with the Health Insurance Review and Assessment Service (HIRA), which is responsible for rule making, monitoring and managing infrastructure in healthcare. Support for this category consists of two parts: technical and commercialization. The former includes technical consulting for registration and financial support for testing safety and effectiveness to set rates for health insurance reimbursement. The latter helps participation in conferences and exhibitions with registration of health insurance, making brochures, and networking with domestic and international institutions related to health insurance registration.

Fourth, support for education is offered online and offline. Online education content is in common fundamental and specialized technologies by field. Offline education is given by experts from tenant companies in their specializations including R&D, documentation, quality control, testing and licensing.

Fifth, support for international certification assist in developing a common platform of technical documents based on rules and regulations by country and advice from the International Medical Device Regulators Forum (IMDRF). Also, WMIT supplies information on global trends in the certification of medical devices.

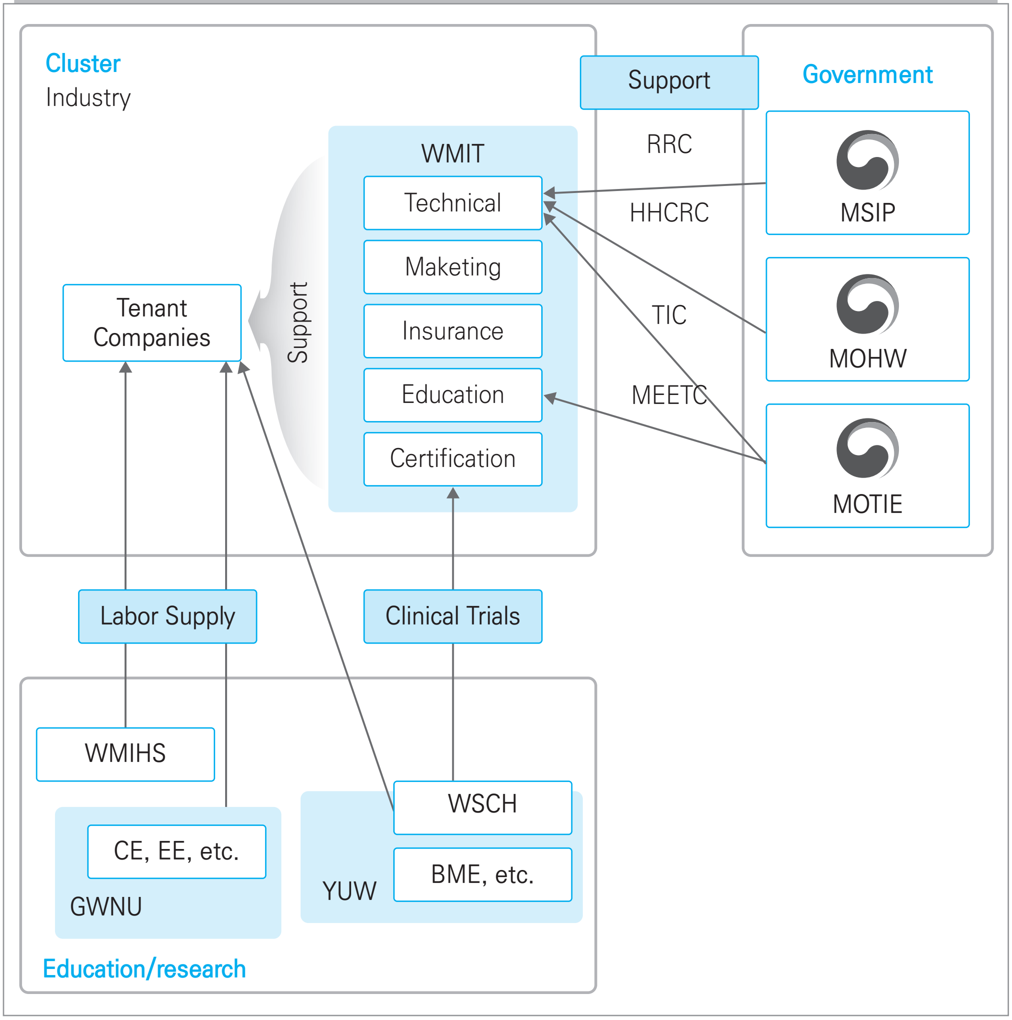
Meanwhile, Wonju Severance Christian Hospital (WSCH), an affiliate of YUW's College of Medicine, operates a center for clinical trials whose main clients are WMIT tenant companies.

From the perspective of labor supply, two four-year universities in Wonju provide labor at the post-secondary level: YUW and Gangneung-Wonju National University (GWNU). YUW opened the country's first biomedical engineering department in 1978 that provides a curriculum specialized in medical device development. GWNU is one of three national universities in the provinces and supplies engineers skilled in computer science and electrical-electronic engineering.

Also in Wonju, a high school specialized in medical device education plays a significant role in supplying labor. Wonju Medical Instruments High School (WMIHS) is a "Meister high school," which aims to operate a customized curriculum directly linked to industrial demand for the development of professional vocational education per the Enforcement Decree of the Act on Elementary and Secondary Education. The country has more than 40 Meister high schools 90 percent of whose graduates have jobs after graduation. WMIHS has two departments related to medical devices: mechanical engineering and electrical and electronic engineering. The former track fosters specialists who can perform maintenance on major equipment by providing knowledge in medical equipment design and processing, radiation devices (X-rays and CT) and dentistry. The latter offers training in biomedical engineering, electronic circuits, programming, medical electronic design and electronic applications, sensor application, and electric circuits and devices. The curriculum for the first grade consists of medical basic practices in measurement, LabVIEW and machine CAD. For the second grade, practices in microprocessors, electronic circuit design using CAD, and analog circuit assembly and measurement are offered. The subjects in the third grade include practices in medical device manufacturing and operations and microprocessor and LabVIEW labs. On top of programs in engineering, both departments deal with the structure and function of human anatomy as well as medical regulation and safety.

WMIT and its support structure discussed above are schematically drawn in [Figure 4-11].

[Figure 4-11] Wonju Medical Industry Techno Valley and Its Support Structure



Source: Author's analysis.

The success factors behind WMIT can be summarized as follows. First, mutual cooperation between YUW's think tank and the city government was a key driver behind the opening of the cluster. Second, the city's consistent support was immune to a change in leadership and thus allowed rapid settlement of the cluster in the early stage of development. Third, full-scale support from the central government helped streamline the cluster. Fourth, timely supply of facilities and incentives to new and potential tenant companies attracted SMEs. Fifth, the city overcame opposition from YUW and residents against building a medical device "techno tower," a building equipped with offices and laboratories. The cost of construction was KRW 70 billion (US$62 million) under a funding ratio of 5:1:1 among the central, regional (province), and local (city) government, respectively. The tower in front of YUW's main gate thus worried both YUW and residents. The university's fear was letting the city use its property free. At the same time, the Wonju City Council opposed the tower over the possibility that YUW would later claim ownership of the tower. The city government won over both parties using media. Sixth, the steady expansion of the production base has supplied sufficient space to accommodate companies willing to move in. And seventh, easy access to qualified workers at the secondary and post-secondary levels has provided a gentle environment for SMEs in securing human resources.

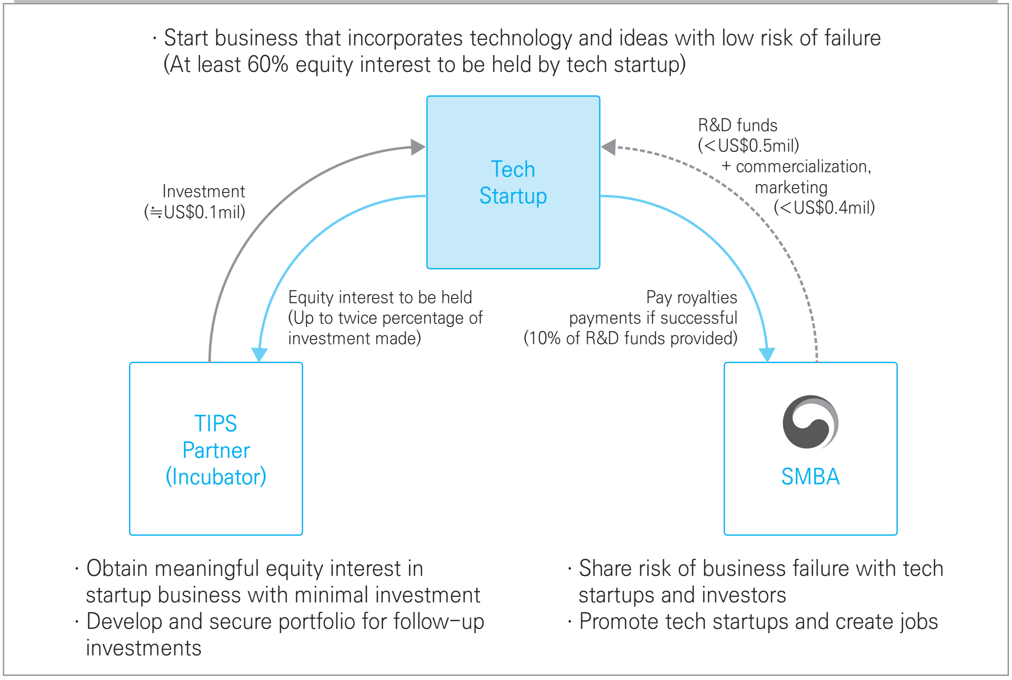
3.1.3. Case 2: Tech Incubator Program for Startups

The Tech Incubator Program for Startups (TIPS) was introduced in 2013 by the SMBA, which says:

> *"TIPS is designed to identify and nurture the most promising startups with innovative ideas and groundbreaking technologies. In order to support them when entering the global marketplace, it appoints and designates successful venture founders–who are now angel investors and leaders of technological enterprises–as their incubators/accelerators. It then offers seamless service encompassing angel investor networking, incubating, mentoring/ professional support and matching R&D funds." (http://www.jointips.or.kr/about_en.php/, accessed Feb. 11, 2017)*

As illustrated in [Figure 4-12], an entrepreneur can start a business that incorporates technology and ideas with low risk of failure via TIPS since at least 60 percent of equity interest must be held by the tech startup. TIPS partners can obtain significant equity interest in the startup with minimal investment. As compensation for the investment, TIPS partners hold equity interest up to twice the percentage of the investment made and can develop and secure a portfolio for follow-up investment. Finally, the government can promote tech startups and create jobs while sharing the risk of business failure with the startups and investors. If successful, the startup pays royalties, equal to 10 percent of the R&D funds provided, to the government.

[Figure 4-12] Framework of Tech Incubator Program for Startups



Source: TIPS webpage (http://www.jointips.or.kr/about_en.php), accessed Feb. 11, 2017.

The angel matching fund program of TIPS is as follows. Angel investors offer KRW 100 million (US$88,000) in initial investment. Then the SMBA of the Republic of Korea provides KRW 500 million (US$441,000) in R&D, and up to KRW 400 million (US$353,000) in additional investments per startup for up to three years: KRW 100 million in startup funding, KRW 200 million (US$176,000) in angel matching funds and KRW 100 million in overseas marketing assistance. Details of TIPS financial support are summarized in <Table 4-7>.

〈Table 4-7〉 Financial Support from TIPS

Initial funding	Technical development funding (R&D)			Add'l financial assistance
Angel investment (accelerator)	Gov't funds	Private spending (out-of-pocket)		
		Cash	In kind	
KRW 100M (Minimum 20% gov't funding)	Up to KRW 500M	Over half of private spending	Required amount	KRW 100M in startup funding, KRW 200M in matching angel funds, KRW 100M overseas marketing assistance
	Under 80% of R&D funds	Over 20% of R&D funds		

Source: TIPS webpage (http://www.jointips.or.kr/support_en.php), accessed Feb. 11, 2017.

In addition, non-financial support is provided: (1) business incubation spaces through consortiums with universities and think tanks and (2) mentoring and business incubation by successful angel investors (TIPS partners).

TIPS is considered a successful model for several reasons. First, it utilizes the private sector's creativity and efficiency as much as possible. It is designed as a private investment-driven incubating program for high-tech startups and entrepreneurs, thus accelerators conduct investment appraisals. Second, risk-sharing and incentive systems are clearly stipulated so that an entrepreneur can start a business that incorporates technology and ideas with low risk of failure. Third, TIPS is specifically designed to foster high-tech startups that require more initial investment and longer time to reach commercialization than general startups. So such support features more generous conditions compared to other assistance for general startups, like "the so-called K-startup" programs administered by Korea Institute of Startup and Entrepreneurship Development (KISED).

TIPS does have its critics, however. The biggest complaint is that accelerators can obtain excessive equity interest because lack of clear standard in sharing equity interest between tech startups and accelerators to ensure maximum autonomy. Screening for tech startups also needs careful consideration since a startup's identity is often ambiguous.

3.2. MWT Area: Medical Tourism

3.2.1. Institutionalization and Market Overview

The "official" history of medical tourism in the Republic of Korea is relatively short. Since medical treatment in the country is considered non-profit by law, medical institutions and practitioners were generally banned from introducing, arranging or offering incentives to attract patients such as medical discounts, money and transportation. In 2009, however, the Medical Service Act was amended to bolster the domestic medical sector's competitiveness to attract foreign patients. Several months after the amendment, the Ministry of Health and Welfare (MOHW) of the Republic of Korea initiated the registration system for MWT to maintain the quality of medical services and preserve the sector's external image. By setting certain requirements for medical institutions and coordinators to attract international patients, disorder in the domestic medical service market can be prevented and protected from indiscriminate attraction of foreign patients. Also, the Ministry of Justice (MOJ) of the Republic of Korea amended the Enforcement Rule of the Immigration Act to introduce two visas for medical tourists, C-3-M and G-1-M, by adding the medical code "M" to the existing short-term (C-3 valid for 90 days) and general (G-1 valid for a year) tourist visas. The former is for simple and elective procedures such as plastic surgery whose period of treatment and travel is up to 90 days, while the latter is for patients who need long-term treatment and rehabilitation.

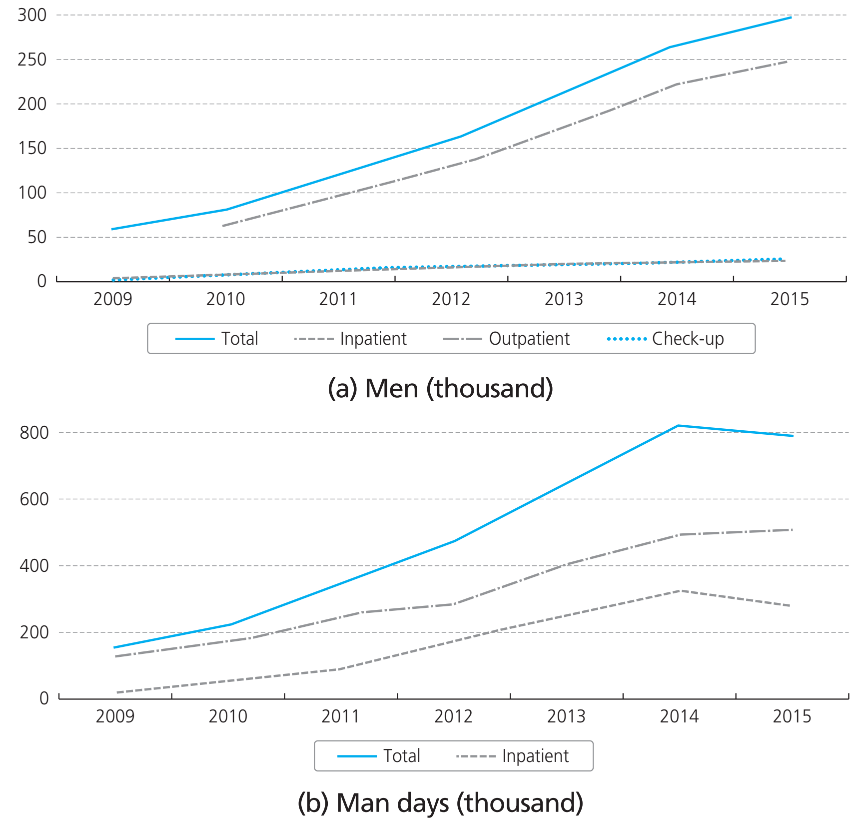
In June 2016, the Act on Support for Overseas Expansion of Healthcare System and Attraction of International Patients was enacted. To secure market integrity and better protect the rights and safety of foreign patients, the law contains regulations specifically on medical tourism including designation and evaluation of medical institutions, cracking down on illegal brokers, offering a reward system for reporting, monitoring medical expenses and fees, and requiring insurance against medical accidents for medical institutions.

Nevertheless, allowing domestic and foreign insurers to conduct services to attract foreign patients and provide follow-up services through telemedicine remains under consideration. To promote medical tourism, the initial bill intended to allow insurers to sell insurance products to foreign patients that guarantee the medical care at domestic medical institutions, but was tripped up by opposition from those in the medical profession such as the Korean Medical Association.

Statistics show the fast growth of the MWT market in the Republic of Korea since 2009. As shown in [Figure 4-13], the number of foreign patients has consistently seen overall growth. One thing to note is that statistics within the country are collected conservatively in two ways. First, the real number of patients is counted regardless of the number of outpatient visits and hospitalizations. In most major markets for MWT like Singapore and Thailand, the number of foreign patients is counted as many days, or the number of days of care plus length of hospital stay if a patient has multiple outpatient visits and hospitalizations. Second, the Republic of Korea strictly defines the scope of international patients mainly as those treated at medical institutions, while other countries consider foreign residents and wellness visitors (to places such as spas and massages) as international patients. This is because the Republic of Korea’s perspective has focused on medical tourism rather than MWT.

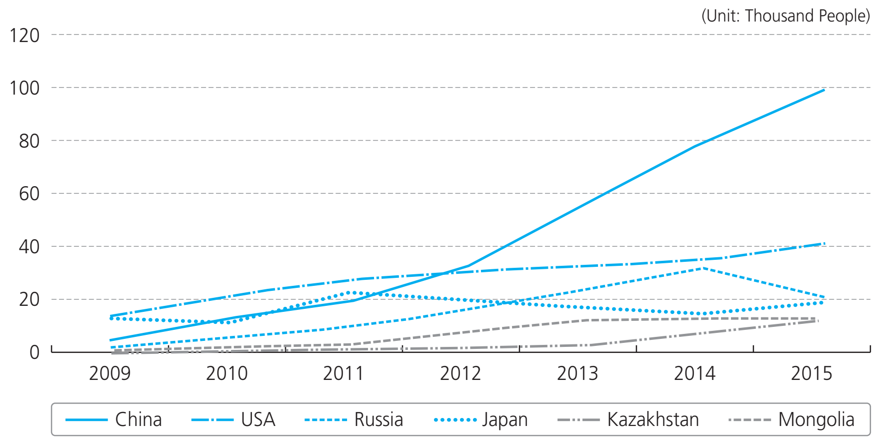
[Figure 4-14] shows the top six countries that send medical tourists abroad as of 2015. Because of geographic proximity, its large population and the popularity of Korean pop culture (or hallyu), China has sent the most medical tourists to the Republic of Korea in recent years. No. 2 is the US, and the majority of American medical tourists are ethnic Koreans.

[Figure 4-13] Number of Foreign Patients in Republic of Korea



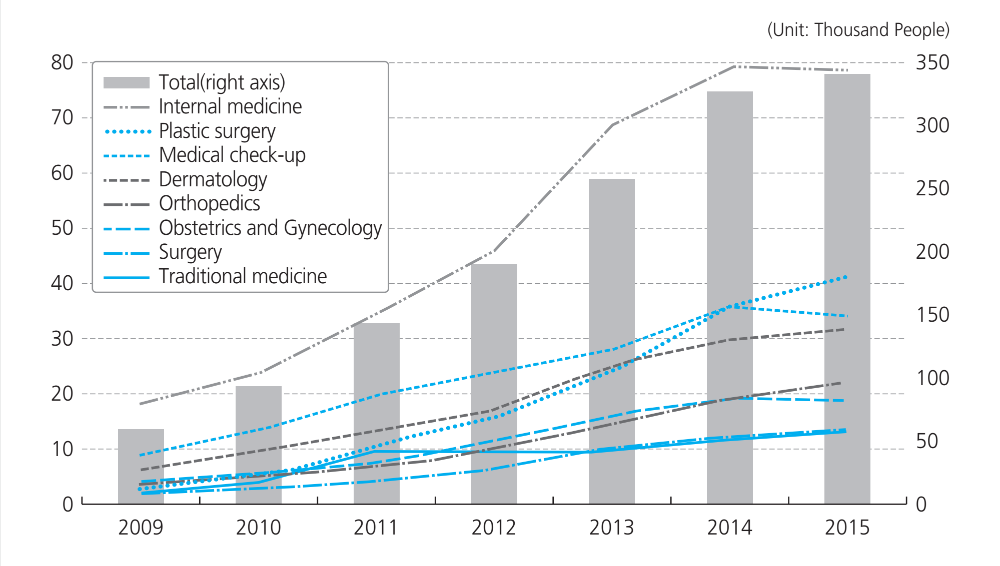
Note: No. of outpatient and check-ups not separately reported in 2009.
Source: KHIDI (2016).

[Figure 4-14] Foreign Medical Tourists by Nationality



Source: KHIDI (2016).

[Figure 4-15] Foreign Patients by Medical Dept.



Source: KHIDI (2016).

By medical department, most foreign patients came for internal medicine as shown in [Figure 4-15]. Cosmetic treatments such as plastic surgery and dermatology also draw high demand in MWT. Medical checkups have steadily grown into a strong area of medical tourism. Noticeably, traditional Oriental medicine (or hanyak) controls a significant portion of MWT. The Republic of Korea's reputation in traditional Oriental medicine has drawn comparisons to Western medicine. Though this medical field has limitations, it has diversified and expanded into offering cosmetic and anti-obesity treatments.

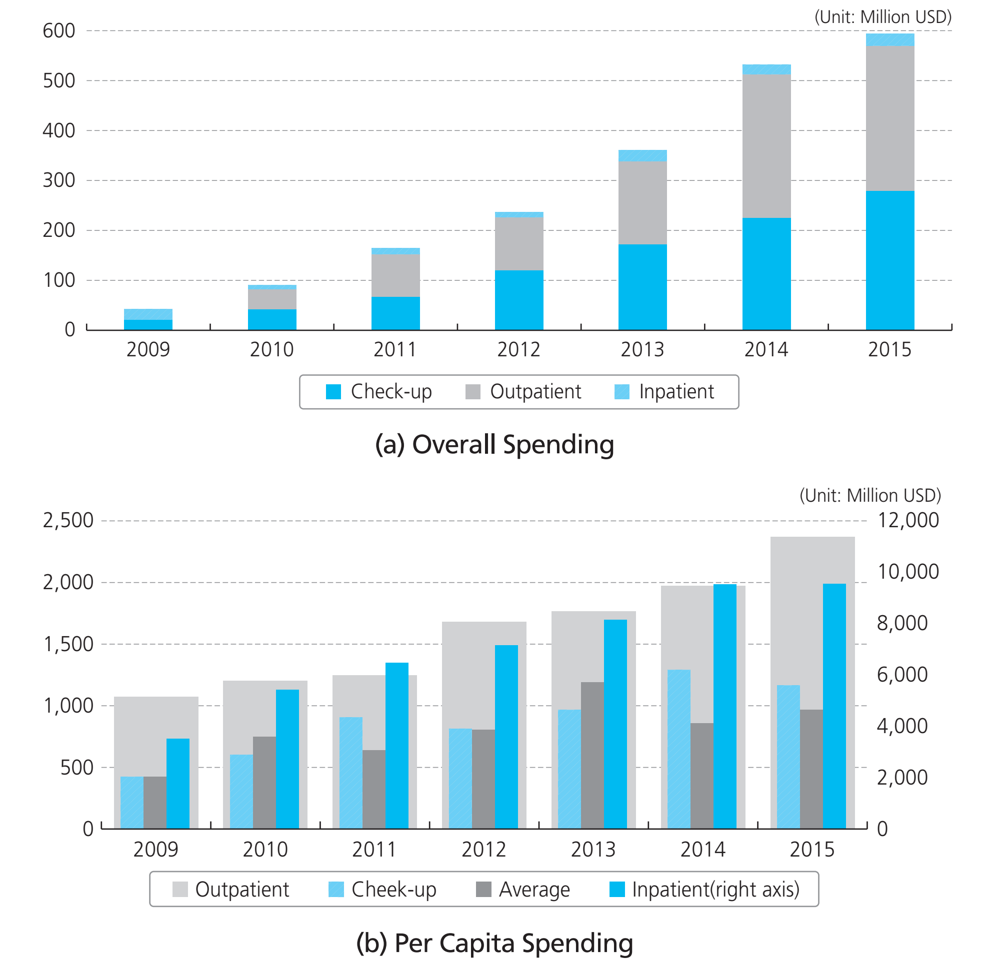
[Figure 4-16] (a) shows overall growth in spending by foreign patients in MWT. Annual growth hit 51.8 percent from 2009-15. As of 2015, annual spending by medical tourists reached US$592 billion, with inpatient care accounting for 47 percent of the sum and outpatient care 48.9 percent.

Per capita spending by medical tourists has shown a growth tendency as seen in [Figure 4-16] (b). Annual growth in this category was 15.7 percent over the same period as above. Per capita spending for outpatient care and medical checkups fluctuate more or less over time. In 2015, a medical tourist spent US$1,989 on average. For inpatient and outpatient care and medical checkups, spending came to US$11,366, 1,167 and 963, respectively.

By nationality, Chinese patients spent a combined US$191.9 million in the Republic of Korea in 2015, accounting for 32.4 percent of medical revenue from foreign patients; their per capita spending was US$194. Russian patients came in a distant second with US$70 million, or 11.8 percent of the total but ranked third in the number of patients and second in the amount of medical revenues generated. The highest per capita spending on average was by nationals of the United Arab Emirates (UAE) at US$13,283, or 6.7 times higher than the overall average (US$1,989) in 2015.

The most popular procedure for medical tourists was plastic surgery (US$164 million), followed by internal medicine (US$93.24 million) and general surgery (US$43.95 million). The average spending per capita in 2015 was US$3,977 for plastic surgery, 2.5 times the overall average, followed by general surgery (US$3,199) and neurosurgery (US$2,236).

[Figure 4-16] Medical Tourism Spending in Republic of Korea Per Capita



Note: Outpatient and check-up data were not separately reported in 2009. Original data in KRW converted into US dollars using standard annual average FX rate of Bank of Korea.
Source: KHIDI (2016).

According to Korea Tourism Organization (KTO), the competitiveness of the country's medical services stems from its advanced medical technology, relatively lower cost and fast service. For example, the survival rate of gastric cancer patients after five years was 67 percent in the Republic of Korea and 26.9 percent in the US. The Republic of Korea has state-of-the-art technology in proton therapy and runs proton therapy centers. The cost of proton therapy is around US$50,000, or about a quarter of that in the US. For liver transplant surgery, which requires high precision and technology, the country conducted 1,066 transplants per year as of 2010 with the world's top success rate of 96 percent, significantly higher than the average of advanced economies of 85 percent. In the case of heart disease and joint replacement, treatment costs a third of that of the US and two-thirds of Japan's. The country's technology and service competitiveness in 2013 was among the highest in the OECD. Medical facilities and equipment ranked second among 34 countries, medical service competitiveness fourth and technology level ninth (KTO, 2013).

Lee (2012) explains the strengths of domestic medical care through questionnaires with the aim of developing a high-quality model of medical service for stimulation of medical tourism as follows. The Republic of Korea has state-of-the-art equipment to conduct medical checkups, and the ensuing analysis results are also highly reliable. In addition to Western medical services, interest is rising in alternative medicine using natural products like hanyak, and demand for traditional Oriental medicine is expected to increase further.

In recent years, interest in cosmetic surgery offered in the Republic of Korea has greatly increased due to the popularity of Korean pop culture, namely hallyu or the "Korean Wave." As the development of the domestic cosmetic surgery industry has gained popularity among people in Japan, China and Southeast Asia, the central and regional governments are making efforts toward fostering medical tourism specializing in cosmetic services. Medical tourists are mostly interested in skin care, mostly laser surgery, and medical skin care, which is relatively quick at 30 minutes to an hour and requires neither hospitalization nor follow-up care in general. Famous hospitals in Korea treat patients with intractable diseases or medical tourists seeking premium treatment. Foreign patients stricken with serious diseases mainly opt for high-risk procedures including cardiac, spinal joint or cancer surgery.

Despite its relatively short history of systematic government intervention, medical tourism in the Republic of Korea has faced a few challenges. First, the full extent of medical services is not offered due to public opposition to the alleged "privatization of healthcare." As mentioned earlier, medical treatment in the country is non-profit per se by law, so public opinion tends to reject a seemingly market-oriented approach such as telemedicine. Consequently, medical tourism products are limited in scope and variety like medical insurance for medical tourists as discussed above.

Second, the country lacks a system to respond to and resolve disputes in medical tourism. This problem is closely related to the challenge mentioned above, mainly due to limitations in providing comprehensive services. Moreover, collaboration between responsible ministries has not been active despite recent attempts as will be discussed below. Since even a few medical disputes can have a huge negative impact on medical tourism, an effective mediation system is a must for promoting the market.

Third, services and products in medical tourism are excessively concentrated in downtown Seoul. Municipal and provincial governments have attempted to promote their own markets for medial tourism, with minimal success. This is mainly because not only are the best medical institutions located in downtown Seoul, medical infrastructure outside the Seoul metropolitan area remains relatively poor.

Cho (2006) and Kim and Kim (2008) conducted SWOT analyses on the Republic of Korea's medical tourism and their results are summarized in <Table 4-8>. The strategies of the government and its agencies in response to the weaknesses and threats listed in <Table 4-8> are introduced below.

〈Table 4-8〉 SWOT Analyses Results for Medical Tourism

Strength	Weakness
• Advanced technology • High population of ethnic Koreans overseas • Value for money • Location • National brand awareness	• Language barrier • Shortage of planning and managing experts • Shortage of medical tourism programs • Shortage of understanding multiethnic and multicultural dynamics
Opportunity	**Threat**
• Gov't attention and willingness to support • Developing medical techniques • Diffusion of Korean pop culture (aka. Korean Wave)	• Rising competition from other countries • Erosion of cost advantage (e.g., labor, accommodations) • Insufficient infrastructure • Excessive regulations

Source: Selected and arranged from Cho (2006), p. 199, Table 7 and Kim and Kim (2008), p.273-274, Table 7-Table 10.

3.2.2. Promoting Measures

In addition to efforts for setting an institutional foundation for medical tourism, the government introduced policy measures to promote the sector. This section will look at support programs run by the central government and administered by its agencies in healthcare as well as the tourism sector. Finally, recent attempts by ministries governing healthcare and tourism to collaborate in medical tourism will be featured to suggest policy lessons for Costa Rica.

3.2.2.1. Government Support

In 2010, the MOHW of the Republic of Korea initiated support for helping leading medical institutions outside of the capital given that the sector was heavily concentrated in Seoul and vicinity, which got 87.8 percent of all foreign patients. Moreover, the ministry faced criticism that many projects promoting medical tourism and building infrastructures were centered solely on the central government, namely the ministry. The latter's new initiative had two objectives: spread medical tourism to all sections of the country and upgrading the level of national healthcare. Achieving this goal will entail diversification of channels to attract foreign patients to prevent the Seoul metropolitan area from getting the lion's share of medical tourists. Health authorities will seek to bolster the competitiveness of medical care outside of the capital by finding and cultivating outstanding medical personnel and technology in the region.

So the project targets development by businesses based in a given region outside of Seoul and promotion of specialized medical technology. Through cooperation with local governments, the MOHW of the Republic of Korea supports marketing activities for developing and promoting specialized technologies in the provinces and building infrastructure to attract foreign patients under an "open call" method to be submitted via the city and/or province. Regional and/or local governments (provinces, cities and/or municipal districts) and medical institutions (inclusion of host companies is recommended) are directed to form consortiums and submit business and public offering plans to the MOHW. The evaluation criteria for the plans are medical technology, infrastructure, marketing, and capacity for project implementation and follow-up management as shown in <Table 4-9> in more detail.

〈Table 4-9〉 Evaluation Table for Selecting Projects to Support Fostering of Leading Medical Institutions in Provinces

	Criteria		Item		Score	
Written	1	Medical technology	a	Competitiveness	10	35
			b	Specialization and upgrading plan	10	
			c	Intensive R&D of core technology	15	
	2	Infrastructure (convergence services)	a	Establishment for attracting (treating) foreign patients	5	20
			b	Plans for establishment for attracting (treating) foreign patients	15	
	3	Marketing	a	Track record in marketing (promotion)	5	20
			b	Plans for marketing (promotion)	10	
			c	Capacity for international marketing	5	
	4	Capacity for project implementation and follow-up management	a	Financial allocation and dedicated organization/ personnel management	10	25
			b	Past year's record and next year's goal	10	
			c	Assessment and implementation plan after gov't support ends	5	
Subtotal					100	100
Interview	5	Understanding of business	a	Understanding of business purposes	10	20
			b	Business plan fidelity and continuity	10	
	6	Local gov't interest and biz promotion prospects	a	Local gov't's interest and willingness to pursue	15	30
			b	Connectivity and synergy between participating agencies	15	
Subtotal					50	50
Total					150	150

Source: MOHW (2016), p.6.

The budget for this project was US$13 million from 2010-15. Although it varies over time, the proportion of ministry support is 50–70 percent of the total project cost (TPC); the rest is covered by local governments and private institutions. Examples of supported projects are summarized in <Table 4-10>.

〈Table 4-10〉 Selected Projects Supported for Upgrading Leading Medical Institutions in Provinces in 2010

Project	Core technology	Project cost (Million KRW)		No. of medical tourists in region		
		National cost	TPC	2009	2010	Change
Seomyeon Medical Street	Plastic surgery and skin care	1,500	3,500	4,676	5,921	27%
Daegu Hair Transplant Center	Hair transplantation	1,500	3,500	69	145	110%
Globalization of Advanced Joint Treatment Technology	Joint	700	1,200	6	48	700%
Advanced Robotic Surgery City	Robotics (urology)	400	1,000	989	1,515	53%

Source: MOHW (2011), p.4, Appendix 2.

Medical tourism in the Republic of Korea has been mainly led by the MOHW, but the Ministry of Culture, Sports and Tourism (MCST) of the Republic of Korea has run its own projects for boosting medical tourism. The MCST operates the Tourism Promotion Development Fund and uses part of the latter to fund publicity marketing of the nation’s medical tourism to raise the quality of overall tourism. The medical tourism budget in recent years is shown in <Table 4-11>.

〈Table 4-11〉 MCST's Medical Tourism Budget by Function and Category

(Unit: Thousand USD)

Item Allocated		2013		2014[1]		2015 (Budget bill)
		Allocated	Executed	Allocated	Executed	
By Function	International marketing	3,196	2,955	5,649	4,339	2,430
	Traditional Oriental medicine	91	91	-	-	-
	Conditions and competitiveness	694	694	722	560	742
	Integrated online platform	-	-	855	722	442
By Category	Clustering	-	-	760	437	707
	Subsidy to private sector	3,982	3,741	7,225	5,621	3,615
	Subsidy to local government	-	-	760	437	707
Total		3,982	3,741	7,985	6,058	4,322

Note: 1) Figures from December 2014.
Source: MCST (2015), p.2.

Details of the MCST support programs for each function are depicted in <Table 4-12>. Its efforts are conspicuously concentrated in international marketing and its programs are designed to be held in both the Republic of Korea and overseas. For example, consultations and information sessions are held abroad and the targeted countries are categorized into main and emerging markets. The first category includes China, Japan and Russia and the goal is to consistently keep raising the number of inbound visitors from such countries, while the second category focuses on emerging markets with high potential demand like Southeast Asia and the Middle East. In the Middle East, briefing sessions are held for the government and medical institutions to attract government-sponsored patients according to government-to-government (G2G) cooperation in healthcare. Also, a free invitation program offers free medical treatment and sightseeing in the Republic of Korea to children in underdeveloped or developing countries.

To help provincial markets get more medical tourists, the MCST of the Republic of Korea supports conventions and conferences on medical tourism hosted by provincial authorities. For example, the Busan International Medical Tourism Convention (BIMTC) co-hosted by Busan City Hall and a Busan-based newspaper, receives support from the MCST and MOHW.

〈Table 4-12〉 Details of MCST Support Programs in 2015

(Unit: Thousand USD)

Function	Programs	Count	Budget
	Invitation of media and companies	10	200
	Promoting medical tourism using media overseas	2	100
	Marketing promotion through online and social media	2	100
	Production of medical tourism promotional materials for Republic of Korea	10	200
	Global healthcare & medical tourism conference	1	200
	Competition for excellent products	10	200
	Korean medical centers abroad	2	200
	Targeted product development and promotion marketing for medical tourism	-	850
Conditions and competitiveness	Information center	4	500
	Concierge service (helping visitors at airport)	8	80
	Co-organizing medical tourism conventions and conferences in provinces	-	160
	Research	1	20
	Job fair	1	80
Clustering	Forming cluster for medical tourism	1	800
Integrated online platform	Establishing hub platform (2^{nd} step)	1	500
International Marketing	Consultations and information sessions abroad	6	600
	Sharing medical care for infants in underdeveloped countries	5	100

Source: MCST (2015), p.4–6.

The designation of medical tourism zones is part of efforts to support medical tourism in the country. Two of the zones are worth reviewing. First, the Jung-gu district of Seoul, with an area of 563,867m^2, was designated the country's first special zone for medical tourism in 2014. This area has traditionally been the country's center of commerce with many foreign visitors. Over the last decade, many small private medical clinics, mostly specialized in plastic surgery and skin care, have opened in this area amid high demand for medical tourism. Using US$30 million in subsidies from the central and municipal governments, the promotion of 11 projects in four areas will be implemented by 2017 including building infrastructure for medical tourism, international marketing, developing and distributing medical tourism-oriented food, and forming a medical tourism network. More specifically, a homepage for the zone is offered in English, Japanese, Chinese and Russian, and a smartphone app offers information on tourist spots and transportation. Zone staff publishes a medical tourism map, offer professional interpretation and hold a street festival for medical tourism. In conjunction with nearby accommodation facilities, development of MWT products are encouraged such as luxury lodging, selective treatments, traditional Oriental medicine, skin care and services for women.

Second, the newly developed Magok district of Seoul is just three kilometers from Gimpo International Airport, or five minutes away by car and 10 minutes away by subway. The airport is the country's main gateway to Japan as well as to the top domestic tourist destination Jeju Island. To take advantage of the area's proximity to the airport, the designation of Magok as an MWT zone will set the foundation for medical tourism in this area. By 2018, a government budget of US$70 million will be allocated for projects such as expansion of convenience facilities for medical tourists and setup of a tourist information center.

Finally, tax refunds for cosmetic surgery were introduced in 2015 to attract more medical tourists to the country in the aftermath of the outbreak of Middle East respiratory syndrome (MERS). Regardless of where a procedure is done, all eligible medical tourists can get a refund for the 10-percent value-added tax (VAT) on cosmetic surgery. This program is valid for a limited time (one year).

3.2.2.2. Promotion and Management by Public Agencies

Public agencies play a significant role in implementing measures under medical tourism policy on behalf of the MOHW and MCST of the Republic of Korea. Korea Healthcare Industry Development Institute (KHIDI) and Korea Tourism Organization (KTO) are the leading public agencies in medicine and tourism, respectively. KHIDI was established in 1999 under the Act on Korea Health Industry Development Institute. As a government-funded agency, it is the primary vehicle for overall administration of the national health industry. The law grants KHIDI the authority to undertake vital support programs intended to enhance the delivery of national health services and develop healthcare into a globally competitive industry. KTO was established in 1962 under the Act on Tourism Promotion. Early in its history, the organization focused on creating and supporting essential tourist facilities and services such as hotels, travel agencies and transportation infrastructure. It has since expanded its business areas to international promotion, development and modification of tourism infrastructure, and formation of tourist complexes to better accommodate the growing number of tourists (webpage of KTO, https: //kto.visitkorea.or. kr/eng/divisions.kto, accessed Feb. 10, 2017).

In addition to bureaus implementing government policy as discussed above, KHIDI and KTO are principal authorities managing medical tourism. The former enforces the registration of medical institutions and coordinators, collects and manages data for attracting foreign patients, and publishes reports on domestic and international trends. KTO hosts the Korea International Medical Tourism Convention (KIMTC), promotes medical tourism to influential media and celebrities abroad, develops medical tourism products and operates medical tourism information centers.

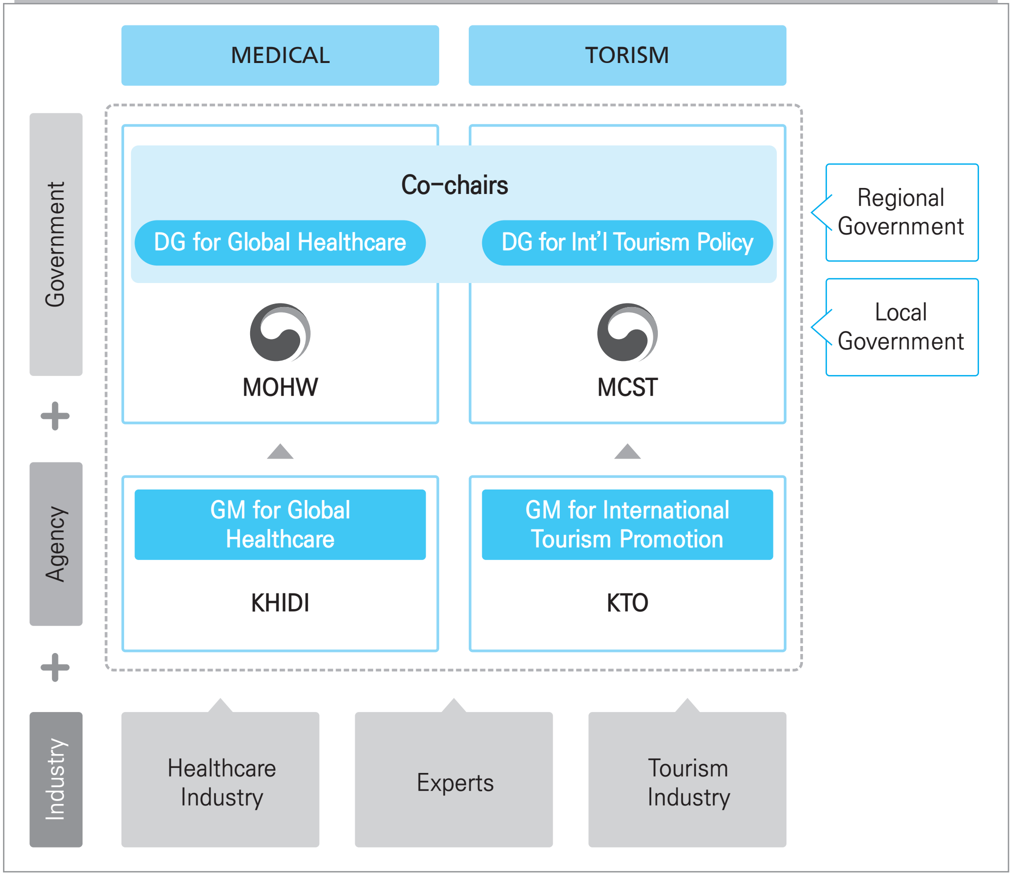
KHIDI's more prominent role is collecting and managing data for attracting foreign patients by operating a specialized information system (https://medicalkorea.khidi.or.kr/Index.aspx). Through this system, medical institutions and coordinators that woo foreign patients are registered and their performance is reported. KHIDI also provides information on market trends, legal systems, and domestic and global news.

Among KTO's marketing activities, two tactics stand out. The first is the use of medical tourism information centers at Incheon International Airport and the downtown areas of Seoul and Busan. The centers provide on-site information on medical institutions, tourist destinations, travel agencies, transportation, accommodations and event ticketing. Each center even has a café and prayer room. Visitors can also experience content featuring popular Korean celebrities via virtual reality and panoramic views at the "K-star Zone" within each center. The second marketing tactic is the use of influential global media and celebrities to promote medical tourism.

3.2.2.3. Collaboration Efforts

Realizing the inefficiency of conducting segmented operations, the MOHW and MCST of the Republic of Korea recently agreed to work together. In June 2016, both sides formed a medical tourism association to implement a more collaborative public policy. As schematically drawn in [Figure 4-17], the association is co-chaired by director generals from both ministries and includes general managers from KHIDI and KTO as permanent members. If needed, stakeholders are invited to take part from the public and private sectors including local governments as well as experts and businesspeople from healthcare and tourism.

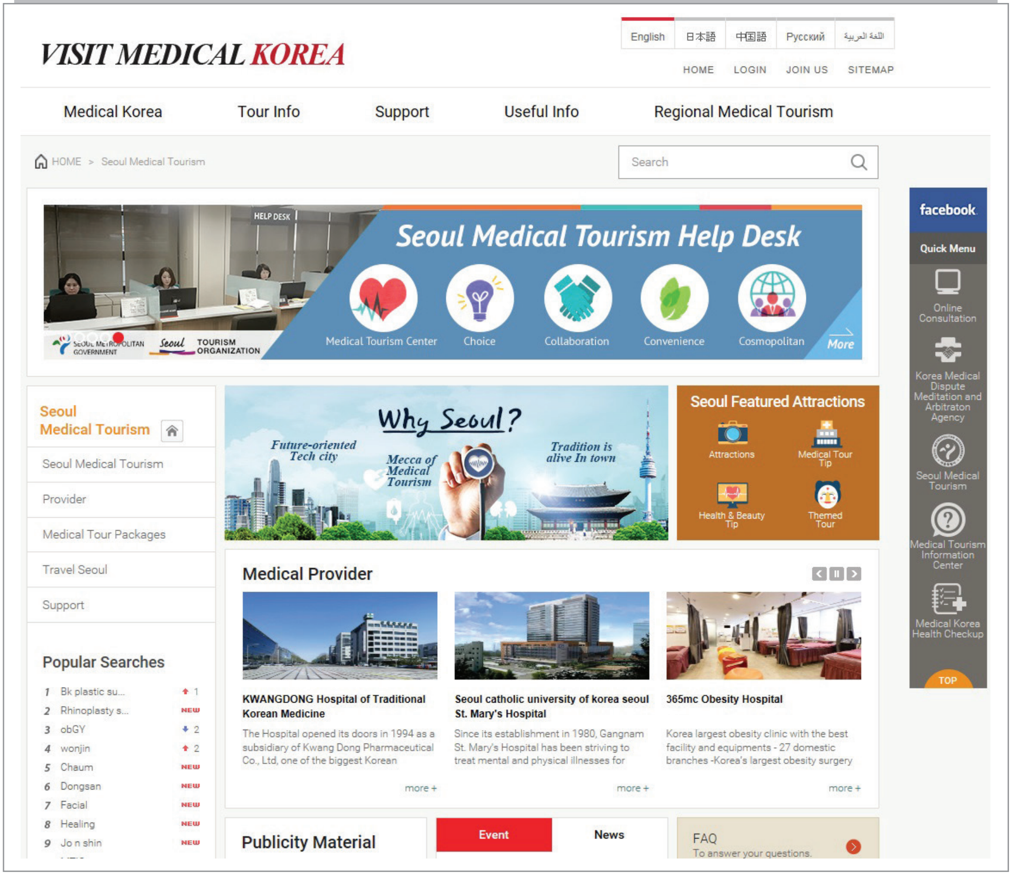
[Figure 4-17] Medical Tourism Association in Republic of Korea



Source: Author's analysis.

Though the association is new, it has accomplished a few integrative achievements. First, the online platforms for attracting and supporting foreign patients, which had been separately run by KHIDI and KTO, have been integrated into a homepage (http://www.visitmedicalkorea.com) as shown in [Figure 4-18]. The platform provides information on medical providers and tourist destinations by region. Detailed information on medical institutions can be provided from the registration and evaluation system.

[Figure 4-18] Integrated Online Platform for Medical Tourism: Visit Medical Korea



Source: http://english.visitmedicalkorea.com/english/pt/index.do, accessed Feb. 13, 2017.

Second, KHIDI and KTO provide comprehensive service at the Medical Korea Support Center and medical tourism information centers through the creation of integrated manuals, and offer regular joint education for 16 medical tourism support centers nationwide operated by local governments.

Third, the two agencies cooperate in overseas marketing. KTO has 31 branches abroad and KHIDI six. A branch office in a country (or region) run by either agency conducts integrated promotions and marketing. Where both agencies have a branch office, a consultative body is formed between branch offices to form a collaborative system of overseas bases.

Fourth, statistics held by KTO and KHIDI on medical tourism and attraction of foreign patients are shared to the extent permitted by relevant laws and ordinances to enhance business efficiency. Related surveys are also jointly conducted by both agencies.

Fifth, the MOHW and MCST of the Republic of Korea collaborate in fostering the economy outside of Seoul. The MOHW has promoted the development of leading medical technology projects and the MCST the formation of MWT clusters. Both have agreed to foster marketing and medical services systematically through joint consulting and evaluation.

4. Policy Suggestions for Costa Rica

Based on the lessons learned from the knowledge and experience accumulated in the Republic of Korea, this section will conclude with policy suggestions for Costa Rica on stimulating the latter's markets for medtech and MWT.

4.1. Technology and Health

4.1.1. Creating Medical Device Cluster

For the medtech sector, one recommendation is to consider building a cluster specialized in medical devices for domestic SMEs based on lessons learned from the Republic of Korea's experience. Costa Rica can benchmark the creation and development of the successful cluster WMIT.

WMIT is a case study of best practices for several reasons. First, it greatly contributes to production, export and employment in the sector. Second, domestic participants constitute a well-established ecosystem surrounding the cluster including a think tank, hospital, high school and university. Third, support from the municipal and central governments are sufficient and effective.

So the WMIT model can both enhance global competitiveness and foster an area's economy. It proves its effectiveness by strengthening global competitiveness with a higher contribution to exports compared to production. Moreover, it shows that an underdeveloped area can succeed as long as residents are willing to cooperate. This model can also serve as a tool to narrow the gap between multinationals and domestic SMEs since it provides grounds for domestic SMEs.

Yet the application of the WMIT model to Costa Rica should follow a few guidelines. First, a strategic location is crucial. WMIT was spontaneously initiated by an area university in collaboration with the city government and the university had technological items to be commercialized. So the site should be geographically adjacent to technology providers including universities, multinationals and think tanks. A free trade zone accommodating multinationals such as COYOL would be a good neighbor because of the high potential spillover effect.

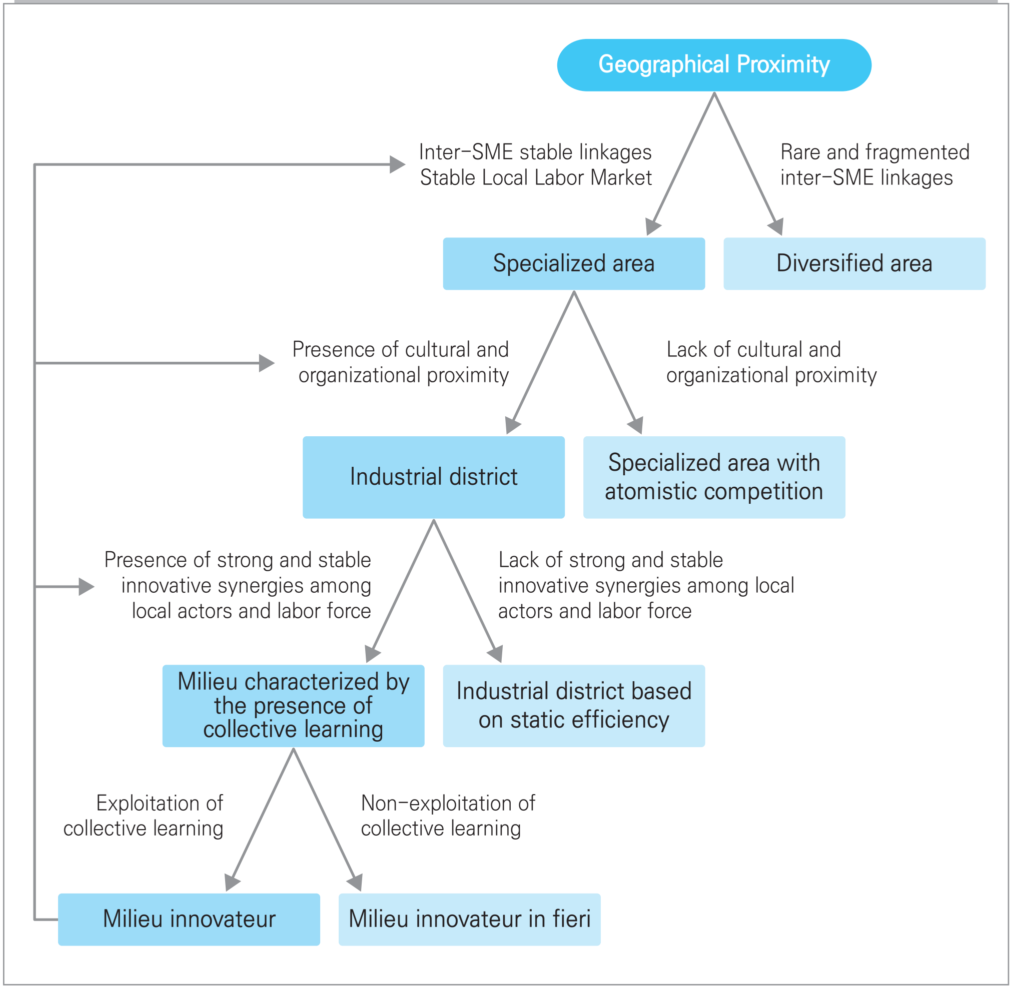
Second, the division of labor needs extra attention. Ideally, universities and/or think tanks in the area must play a significant role. If they are not readily available in a region outside of the San Jose metropolitan area, those possessing capacity such as CENIBiot can take part in collaboration though they are remotely located. Furthermore, the central and local governments need to assume adequate roles.

Third, the creativity and efficiency of the private sector should be fully utilized. A lesson learned from the WMIT case is that the autonomous and enthusiastic initiative driven by a private university played a critical role in the early stage. Forming a cluster does not necessarily require an initiative by private institutions, but their active participation should be strongly encouraged throughout the development process. So the Costa Rican government should consider offering financial incentives to private participants at least in the early stages of development such as the entrepreneurial and collectivity stages shown in <Table 4-6>. Benchmarking the financial and tax incentives offered in Costa Rica's free trade zones for attracting foreign investment will help determine the level of incentives for domestic SMEs. In general, the Republic of Korea's experience has shown that financial incentives for tenant companies are a major attraction of an industrial cluster including subsidies for rent, employment, education and training, and equipment. To pursue balanced regional development, tax incentives for domestic SMEs have concentrated on companies moving from the Seoul metropolitan area to regions outside of the latter. The tax breaks include reduction or exemption of both national (i.e., income and corporate) and local (e.g., acquisition and registration) taxes.

Fourth, the government needs to occasionally make bold decisions and exercise patience. For WMIT, support has been consistent as well as generous. Though this is not the only reason for the cluster's success, WMIT's fast settlement and growth were largely fueled by such support.

Finally, the Costa Rican model of a cluster might not need to be identical to that of WMIT. Though geometrical proximity between participants is needed, many other models can be attained as shown in [Figure 4-19]. The Costa Rican government must decide and clearly define the identity of the planned cluster. In so doing, creating strategies to foster inter-SME interactions and synergies is also crucial. For example, clustering around an "anchor" company like a large multinational could facilitate technology transfers and knowledge spillovers but also hurt inter-SME relations due to severe competition.

[Figure 4-19] Examples and Preconditions for Local Systems



Source: Capello (1999), p.358, Fig. 1.

4.1.2. Supporting Startups

Observing the migration from Class I to II or III over recent years, Costa Rica seeks to foster high-tech production and export in medtech. One model to benchmark in pursuit of this policy goal is TIPS, as introduced in the previous section.

TIPS can well be adjusted to meet Costa Rica's conditions including support amounts, composition of partners (incubators) and supervising ministry. The spirit of the program needs to be kept, however. The beauty and value of TIPS stem from the private investment that leads it. The government merely matches the private investment autonomously determined and made by the partners again to fully utilize the private sector's creativity and efficiency.

So the program's success depends heavily on the capacity and role of private sector participants. Most importantly, partners (i.e., incubators) should have the capacity to pick and cultivate technology with high potential, as well as be fair in the selection and commercialization processes.

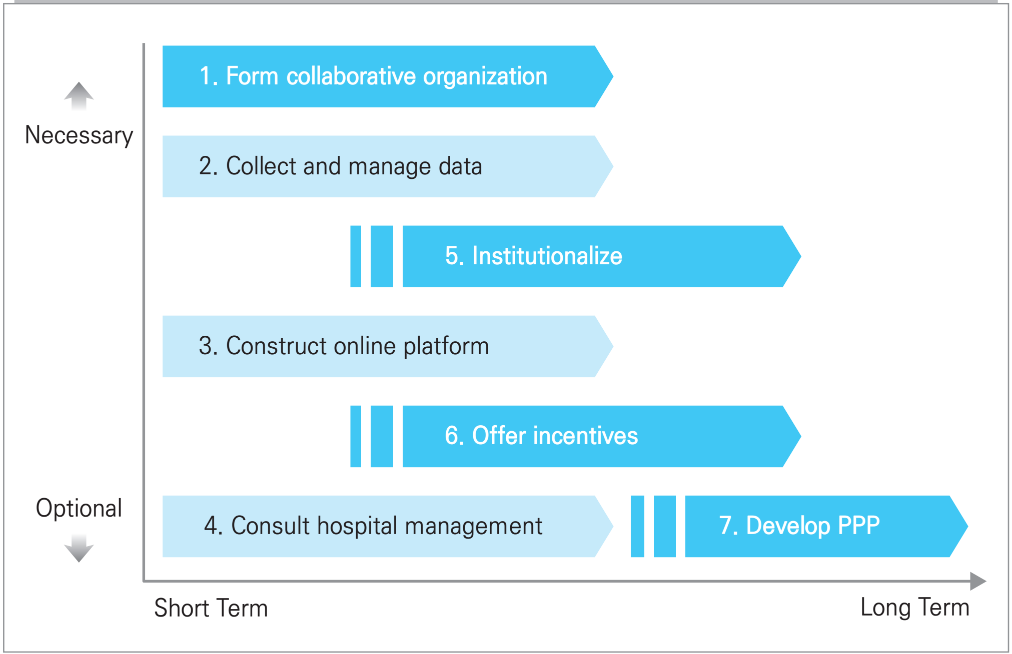
The government's key role, of course, is monitoring the behavior of participants and providing institutional support. Collusion between partners and startups is a major area to monitor and regulate. Moreover, certain partners could secretly demand a rebate or excessive stake in a startup. On top of maintaining market order, the government also needs to promote the market with measures such as financial incentives and reduction of red tape.

Finally, one of the most significant factors for R&D of the complex and sophisticated technology in medtech is well-educated human resources. Though Costa Rica has comparative advantages in education relative to other Latin American countries, it still needs mid- to long-term strategies for supplying qualified workers to medtech. The findings and suggestions mentioned in the previous chapter thus need to be applied carefully to medtech areas.

4.2. Medical and Wellness Tourism

In MWT, several suggestions for policy measures can be arranged by level of urgency and necessity as shown in [Figure 4-20]. While all measures need the government's initiative, those colored darker indicate those requiring the government's leading role in particular, and the group with lighter color specifies those relying heavily on the active participation of public agencies and the private sector. Also, measures for the mid to long term do not necessarily mean that the government has to postpone the launch. Rather, they demand lengthy discussions and agreements to be realized. Likewise, measures located toward the bottom are not supposed to be mistakenly overlooked since the vertical distribution of measures are intended to highlight the relative necessity of certain measures.

[Figure 4-20] Timeline of Policy Suggestions for Costa Rica



Source: Author.

4.2.1. Forming Collaborative Organization

First and foremost, forming an association is recommended for collaborative and cooperative policymaking and implementation.

Costa Rica has public institutions supporting MWT in one way or another, as well as others that include global healthcare within their work scopes. Nevertheless, this is not reflected in real public policy that sets the proper conditions for sustainable, coordinated and funded development of the sector.

Examples of the lack of institutional alignment in Costa Rica are the refusal of the Tourism Authority to include medical tourism in its national tourism plan or a regulation of free trade zones that bars healthcare providers from operating within a free trade area.

Despite its relatively short experience after the enactment of a law promoting medical tourism, the Republic of Korea has felt the need to set up a formalized system so that related policy can be discussed and mediated by ministries governing health (MOHW) and tourism (MCST). The association launched last year shares and coordinates the policies of both ministries, checks items to implement and finds new areas for cooperation.

In Costa Rica, not only health and tourism authorities but others administering and promoting commerce and trade such as COMEX and CPC could effectively participate in the collaborative organization. The organization's status could be an inter-ministerial committee as in the Republic of Korea or a higher body like a presidential committee. Encouragement of agencies and stakeholders such as PROCOMER and PROMED to participate is highly recommended for more effective policymaking and implementation.

Forming the collaborative committee might require legal and institutional backgrounds. Based on the Republic of Korea's experience, mutual agreement between participating ministries by signing a memorandum of understanding is sufficient to launch the committee. Over the long run, however, a presidential decree or executive order will empower the committee's functions and eventual enactment of or amendment to the related law will provide a strong and stable legal background.

4.2.2. Collecting and Managing Data

In designing policy measures, analysis of related data is both fundamental and critical. The Republic of Korea has also found that accurate data on medical tourism enormously helps policymaking. In particular, the registration system for medical institutions and coordinators provides accurate data on foreign patients.

Costa Rica needs a properly functioning and established system of data collection and management. Thus one recommendation is to set up a structured procedure in dealing with data. The mandatory registration system of the Republic of Korea can serve as a good reference. For this system, one of the agencies and groups from the private sector such as PROMED or PROCOMER can serve as a channel to administer the procedure on the government's behalf. It can collect and manage data as well as provide evaluation results from analyses using the data and its expertise. For more efficient operations, designation of a single authority to perform this function is advised.

4.2.3. Constructing Online Platform

The Republic of Korea's experience has found that an online platform helps promote medical tourism abroad. It provides information on medical providers and tourist destinations by region. Meanwhile, the information's credibility is enhanced thanks to the registration and evaluation system. Only qualified medical institutions are listed and their details are presented on the platform.

Again, the online platform can be operated by PROMED or PROCOMER in conjunction with the government. In the long run, however, a private entity in MWT can establish an online platform autonomously.

4.2.4. Consulting Hospital Management

An option for medical providers is to improve their services by consulting with hospital management. Enhancing such services eventually ensures the improvement of the medical providers' reputations.

Also, external consultation opportunities should be utilized for raising efficiency in hospital management, which can increase profitability and sustainability. For example, medical institutions in the Republic of Korea run education programs on efficient hospital management and services.

In sum, consultations can include promotion, specialization, service upgrading and cost-effectiveness improvement.

4.2.5. Institutionalizing Medical and Wellness Tourism

As mentioned above, legal and institutional setups are required for more sustainable and streamlined implementation of policy measures not only in MWT but also medtech.

Costa Rica seems to have an urgent need for a presidential decree defining global healthcare as a national priority and requiring every public institution to define a specific strategy to support the sector, including the policy suggestions in this section. Several political experts advise Costa Rica to make a decision on a group of key industries (or clusters) to emerge as its main future engines. And global healthcare covering MWT and medtech should be one of them.

A significant amount of time is needed to fully form legal and institutional settings. Though the aim will be met over the midterm, the discussions must be initiated as soon as possible.

4.2.6. Introducing Incentives

In institutionalizing MWT, incentives should be adequately introduced. The Republic of Korea has taken advantage of incentives from different perspectives. Incentives for medical institutions have helped stimulate domestic suppliers, while those for foreign patients have paved the way to highlight the country's attraction as a medical tourism hub.

In accordance with related laws, the Costa Rican government can introduce support measures to medical institutions as well as foreign patients, including financial and non-financial subsidies and tax breaks.

4.2.7. Developing Public-Private Partnership Projects

Over the mid to long term, the Costa Rican government can consider the development of public-private partnerships (PPP) integrating medical institutions and recreational facilities such as hotels, resorts and eco-parks.

The OECD (2008) defines a PPP as:

> *"An agreement between the government and one or more private partners (which may include the operators and the financers) according to which the private partners deliver the service in such a manner that the service delivery objectives of the government are aligned with the profit objectives of the private partners and where the effectiveness of the alignment depends on a sufficient transfer of risk to the private partners."*

Two main arguments have been outlined for the use of PPP: efficiency and fiscal constraints. First, the private sector is considered to have greater incentive and ability to deliver (design, build, operate and maintain) cost-effective capital assets than public provision alone (OECD, 2010, p. 22). Second, the fiscal constraint argument for PPPs is driven by pressure on governments to reduce public spending to meet political, legislative and/or treaty-mandated fiscal targets (OECD, 2010, p. 22). So implementing PPPs for MWT in Costa Rica is a good option for more efficient construction and operation as well as more secure fiscal sustainability.

For more than two decades, the Republic of Korea has accumulated PPP experience in many areas including transport, cultural and sports complexes, and environmental facilities. Though no PPP project has been implemented in MWT, a recent example close to it is under construction. The TPC of this tourist complex by a lake is US$1.4 billion, all covered by private investment.

Success of PPPs requires many prerequisites including a strong legal background, good governance and dedicated PPP units. A long time is needed to build capacity and set up institutions for proper implementation of PPPs.

References

Bamber, P. and G. Gereffi, Costa Rica in the Medical Devices Global Value Chain: Opportunities for Upgrading, Center on Glovalization, Governance, and Competitivenes, Duke University, 2013.

Capello, R., "Spatial Transfer of Knowledge in High Technology Milieux: Learning Versus Collective Learning Processes," Regional Studies, Vol. 33, No. 4, 1999, pp. 353–365.

Cho, K.-H., "An Exploratory Study on the Activation Plan of Medical Tourism in Korea," Korean Journal of Hospitality and Tourism, Vol. 15, No. 4, 2006, pp.189–203. [In Korean]

Enea, C. and C.M. Mungiu-Pupăzan, "Oltenia Northern Medical Tourism and Development in Terms of the Possibility of Regional Sustainability," Annals of the Contantin Brâncuşi University of Târgu Jiu, Economy Series 3, 2013, pp. 54–57.

Espicom, The World Medical Markets Factbook 2015, 2015.

Greiner, L., "Evolution and Revolution as Organizations Grow," Harvard Business Review, Vol. 50, 1972, pp. 37–46.

ITA, 2016 Top Markets Report: Medical Devices, 2016.

KHIDI, Report on Performance of Attracting International Patients 2015, 2016. [In Korean].

KTO, 2013 Korea Medical Tourism Overview, 2013. [In Korean]

Kim, D.-Y. and M.-S. Kim, "Advanced Medical Devices in Gangwon Province and Their Tasks," Policy Memo 243, Research Institute for Gangwon, 2013. [In Korean]

Kim, J.-M., S.-J. Kim, and I.-J. Kim, "Structural Equation Analysis: A Study on the Model of Marketing Strategy for the Medical Tourism," Korea Journal of Tourism and Hospitality Research, Vol. 22, No. 2, 2008, pp. 261–281. [In Korean]

Lee, J.-H., High-Quality Medical Services Model Development for Medical Tourism Activation, Research Institute for Healthcare Policy, 2012. [In Korean]

MCST, 2015 Budget Guide to Promoting Medical Tourism Projects, 2015. [In Korean]

MOHW, "Asking for Directions in 'Region' to Take Leap Forward in Attracting Foreign Patients," Press release, March 8, 2011. [In Korean]

MOHW, 2016 Plan to Promote Regional Development in Medical Technology to Stimulate Attraction of Foreign Patients, 2016. [In Korean]

OECD, Public-Private Partnerships: In Pursuit of Risk Sharing and Value for Money, OECD Publishing: Paris, 2008.

OECD, Dedicated Public-Private Partnership Units: A Survey of Institutional and Governance Structure, OECD Publishing: Paris, 2010.

OECD, Attracting Knowledge-intensive FDI to Costa Rica: Challenges and Policy Options, Making Development Happen Series No. 1, 2012.

Peraza-Valverde, J. and A. Vega-Espinoza, “Estudio de Oferta de Servicios Odontológicos: Costa Rica 2012-2014,” Revista Científica Odontológica, Vol. 10, No. 1, pp. 9–22. [In Spanish]

Swann, G.M.P., “Towards a Model of Clustering in High-technology Industries,” in Swann, G.M.P., M. Prevezer, and D. Stout, eds., The Dynamics of Industrial Clustering, Oxford: Oxford University Press, 1998, pp. 52–76.

Woodman, J., Patients Beyond Borders: Everybody’s Guide to Affordable, World-Class Medical Travel, Chapel Hill, NC: Healthy Travel Media, 2015.

Yu, P.-J. and S.-I. Han, “The Development and Collective Strategies of Innovative Cluster: The Case of Wonju Medical Instrument Cluster,” Journal of Governmental Studies, Vol. 14, No. 2, 2008, pp. 73–102. [In Korean]

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Ministry of Strategy and Finance
Government Complex-Sejong, 477, Galmae-ro, Sejong Special Self-Governing City 30109, Korea
Tel. 82-44-215-7762 www.mosf.go.kr

Korea Development Institute
263 Namsejong-ro, Sejong Special Self-Governing City 30149, Korea
Tel. 82-44-550-4114 www.kdi.re.kr

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