BACKGROUND NOTE

The Role of Government Research & Development in Fostering Innovation in Asia

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DISCLAIMER

THE ROLE OF GOVERNMENT RESEARCH AND DEVELOPMENT IN FOSTERING INNOVATION IN ASIA

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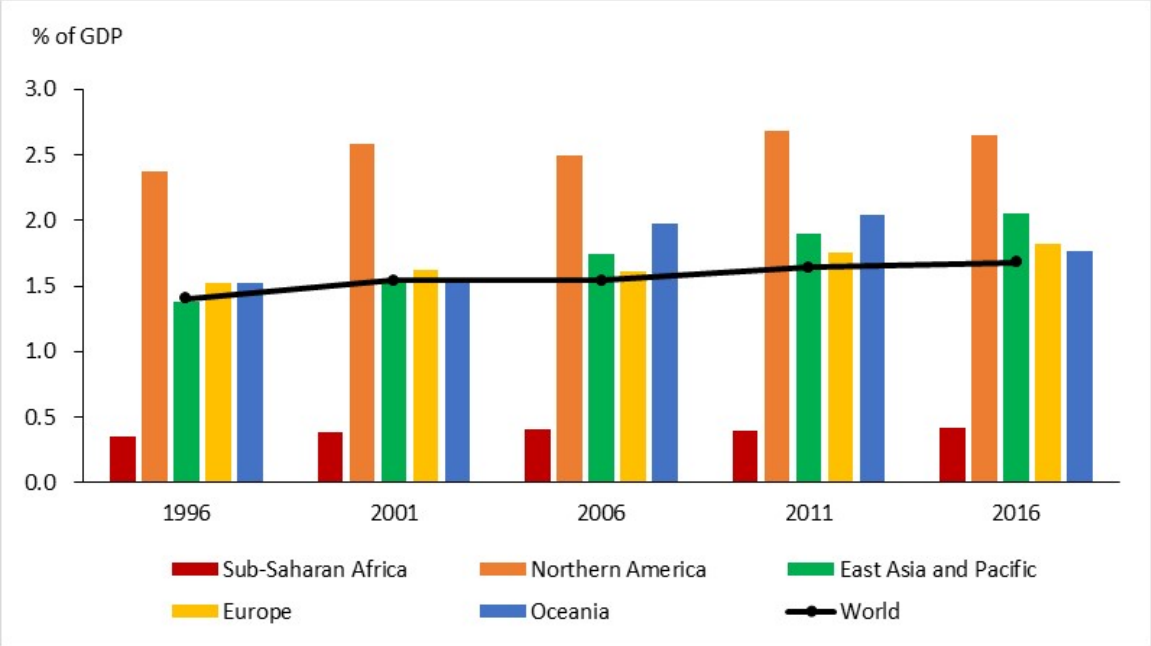
As the global economy is moving towards the implementation of more protectionist policies emanating from the Brexit and the United States–People's Republic of China (PRC) trade war, the prospect of sustainable economic growth in Asia is not so promising since most Asian countries depend significantly on the global trade. In addition to this new protectionist policy, the emergence of the fourth industrial revolution within the global economy also supports the importance of enhancing the country's innovation level. In promoting innovation, a government can play a significant role in actively supporting the research and development (R&D) that contributes to advancing productivity and opens up new channels of economic activity. The proposed paper will discuss the importance of the role of government R&D in fostering innovation in Asia and the policies that could be implemented to promote R&D. The key components of this study include (i) present descriptive statistics on government R&D, (ii) layout of the distinctive differences between public and private sector R&D, (iii) review the nature of government R&D, and the interaction that exists between the effects of public versus private R&D, (iv) explanation of how to effectively allocate public sector R&D in a way that maximizes innovation in Asia, and (v) conclusion for public R&D promotion policy measures, which foster innovation in Asia

I. DESCRIPTIVE STATISTICS ON RESEARCH AND DEVELOPMENT

In research and development (R&D) statistics, gross domestic expenditure on R&D (GERD) is mostly used measure. As presented in Figure 1, GERD as a share of gross domestic product (GDP), remains concentrated in the highly developed countries, North America, Oceania, and Europe. However, in more recent years, GERD as a percentage of GDP has increased swiftly in some emerging market economies, most notably in East Asia and Pacific nations.

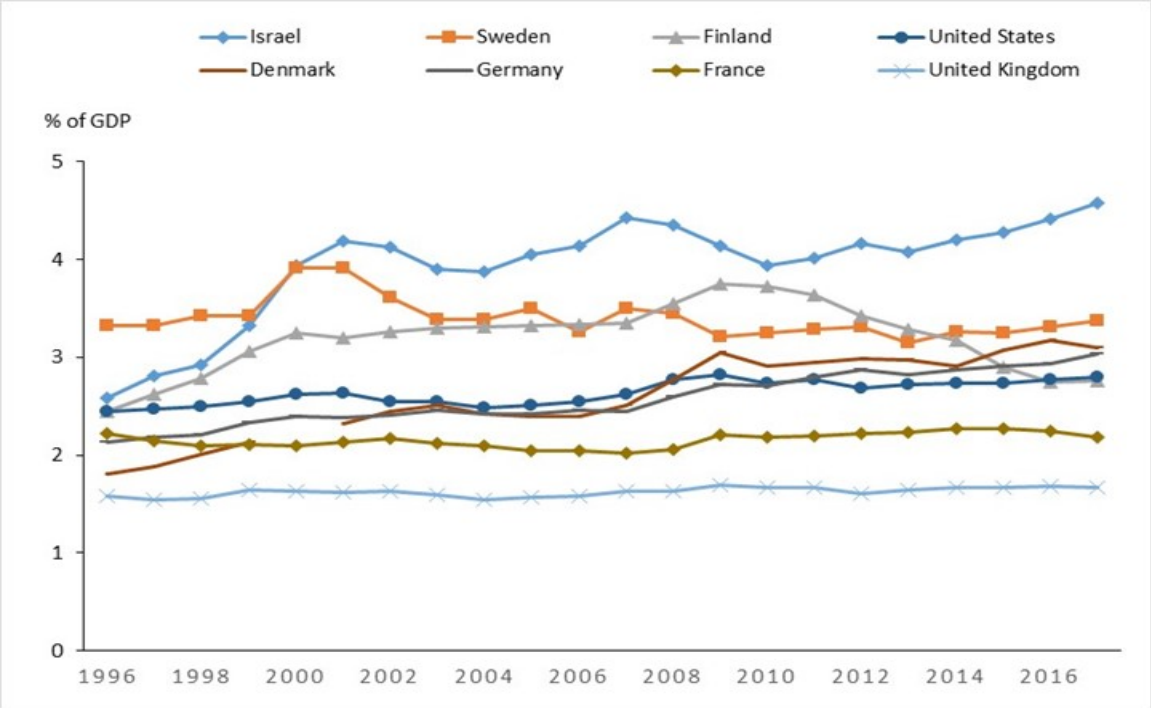
Figure 1: Gross Domestic Expenditure on Research and Development[a]

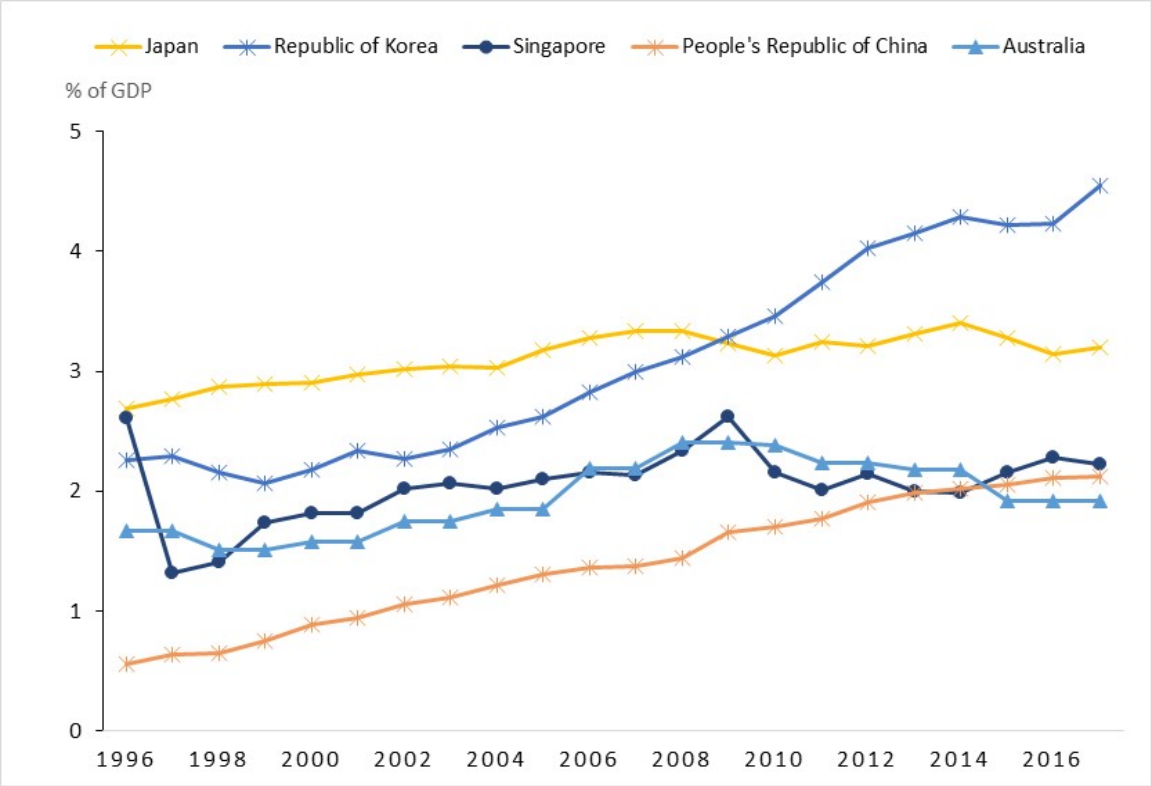


[a] Gross domestic expenditure on research and development as a percentage of gross domestic product is the total intramural expenditure on research and development performed in the national territory during a specific reference period expressed as a percentage of gross domestic product of the national territory.

Source: Authors' own calculation using data from UNESCO Institute for Statistics, http://data.uis.unesco.org/ (accessed 28 August 2019).

Figure 2: Gross Domestic Expenditure on Research and Development—Leading Group



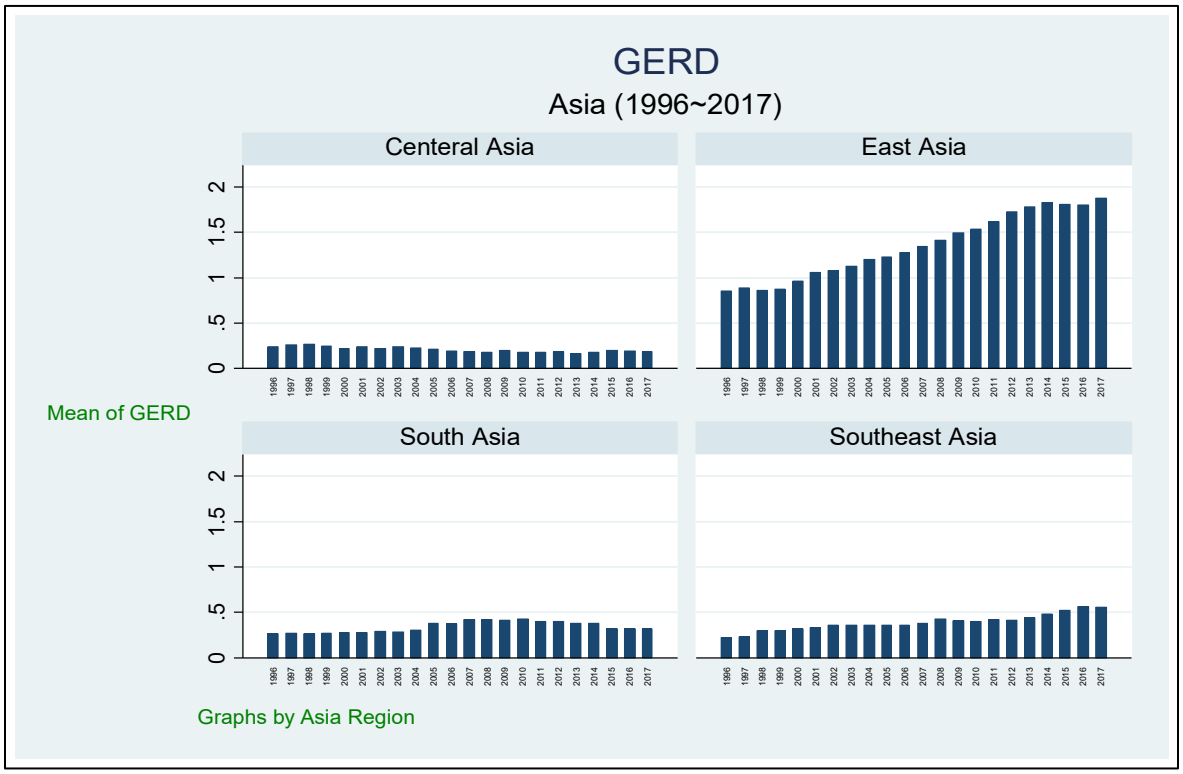


Source: Authors' own calculation using data from UNESCO Institute for Statistics, http://data.uis.unesco.org/ (accessed 28 August 2019).

As presented in Figure 2, among the leading group of countries, such as Israel, Sweden, and Finland, the GERD as a percentage of GDP is higher over the 1996–2016 period. However, countries like the Republic of Korea (ROK) and the PRC have increased their R&D expenditure rapidly during this same timeframe. In particular, since 2005, the increase in R&D expenditure by the ROK and the PRC is very evident and significant. However, in comparison, the R&D expenditures by developed economies such as United States, France, or Australia has declined or remained at a relatively stable level.

Figure 3.1 compares the GERD of Asian countries in the different region. East Asian countries are much higher than the countries of the other region of Asia. In case of South Asia, there are smooth increases over the period while Central Asia shows the declining of GERD during the same period. GERD of South Asia shows steadily increasing patter but in the recent years, there has been a little decrease.

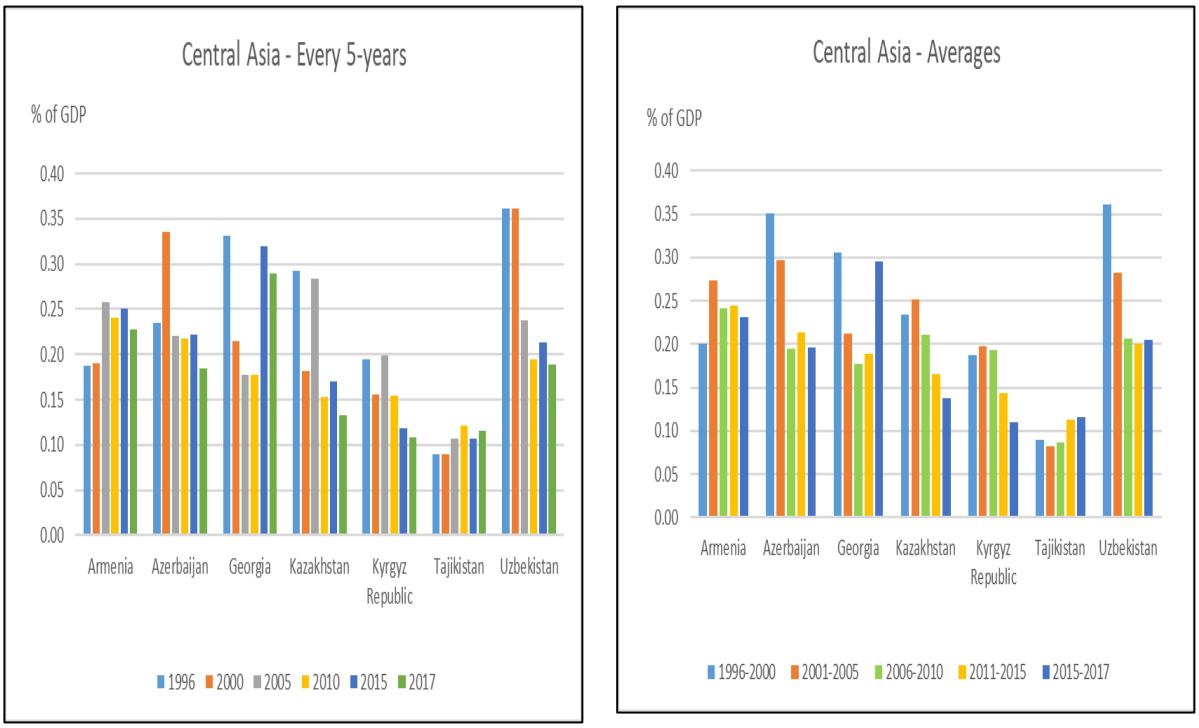
Figure 3.1: Gross Domestic Expenditure on Research and Development as a Percentage of Gross Domestic Product in Asian Countries in the Different Region



GERD = gross domestic expenditure on research and development.
Source: Authors' own calculation using data from UNESCO Institute for Statistics, http://data.uis.unesco.org/ (accessed 28 August 2019).

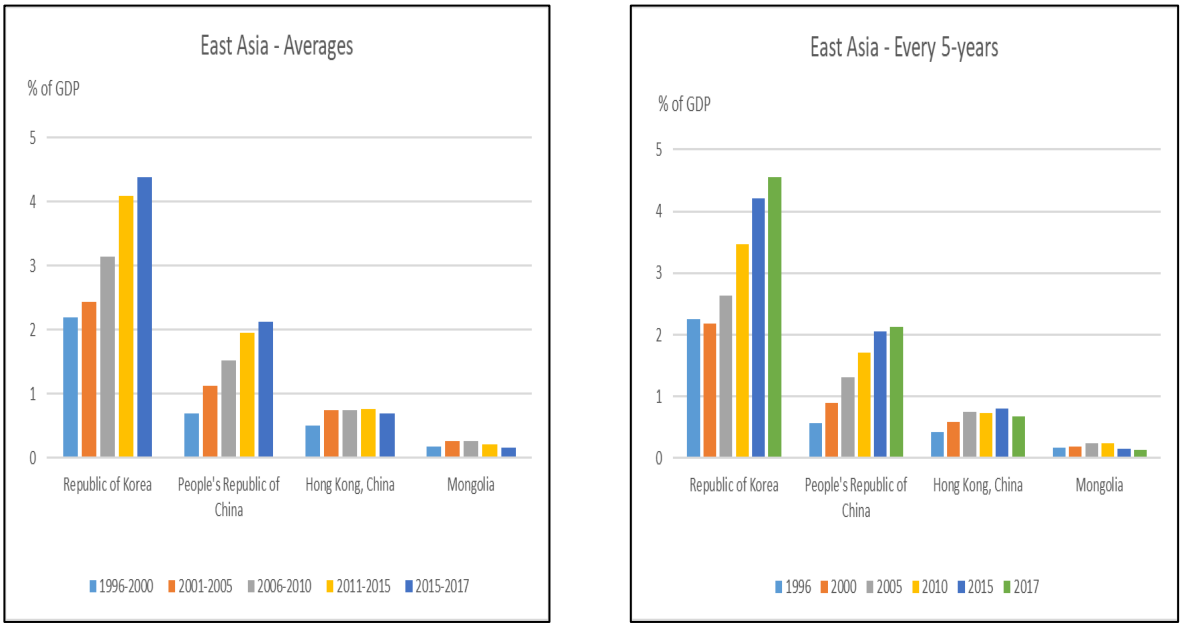
From Figures 3.2 to 3.5, we present the GERD of each region in Asia. GERD as a percentage of GDP of economies in East Asia, especially the ROK and the PRC has increased rapidly in recent years.

Figure 3.2: Gross Domestic Expenditure on Research and Development in Central Asia



Source: Authors' own calculation using data from UNESCO Institute for Statistics, http://data.uis.unesco.org/ (accessed 28 August 2019).

Figure 3.3: Gross Domestic Expenditure on Research and Development in East Asia

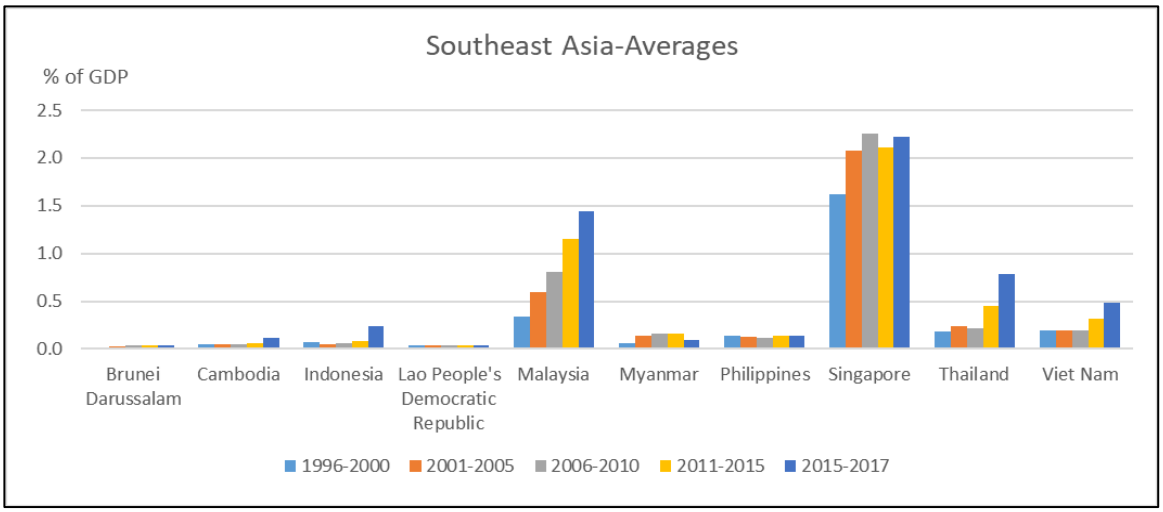


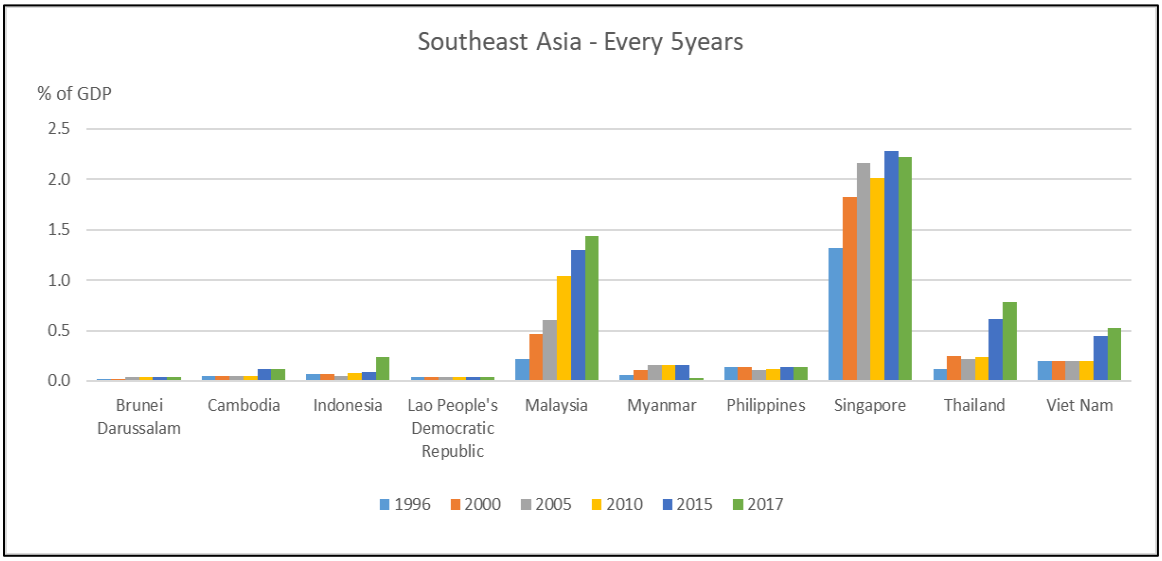
Source: Authors' own calculation using data from UNESCO Institute for Statistics, http://data.uis.unesco.org/ (accessed 28 August 2019).

Figure 3.4: Gross Domestic Expenditure on Research and Development in South Asia

Source: Authors' own calculation using data from UNESCO Institute for Statistics, http://data.uis.unesco.org/ (accessed 28 August 2019).

Figure 3.5: Gross Domestic Expenditure on Research and Development





Source: Authors' own calculation using data from UNESCO Institute for Statistics, http://data.uis.unesco.org/ (accessed 28 August 2019).

II. CLASSIFICATION OF RESEARCH AND DEVELOPMENT

According to the OECD Frascati Manual (2015) classification,[1] the sources of GERD are classified to the following five categories: government (GOV), higher education (HE), business enterprise (BE), private nonprofit (PNP), and the rest of the world (RW).

[1] We quoted the description provided from OECD Frascati Manual (2015).

Government funds (GOV) refer to funds allocated to R&D by the central (federal), state or local government authorities. These include all departments, offices and other bodies which furnish but normally do not sell to the community those common services, other than higher education offerings, which cannot be conveniently and economically provided the state with the economic and social policy. Public enterprise funds are belong to the business enterprise funds sector. These authorities also include private nonprofit institutes that are controlled and mainly financed by the government.

Higher education funds (HE) include the funds allocated to R&D by institutions of higher education, which compromises of all universities, colleges of technology, other institutes of post-secondary education, and all research institutes, experimental stations, and clinics operating under the direct control of or administered by or associated with higher educational establishments.

Business enterprise funds (BE) include the funds allocated to R&D by all firms, organizations, and institutions whose primary activity is the market production of goods and services (other than the higher education sector) for sale to the general public at an economically significant price, and those private nonprofit institutes mainly serving these firms, organizations, and institutions.

Private nonprofit funds are funds (PNP) allocated to R&D by nonmarket, private nonprofit institutions serving the general public, as well as by private individuals and families.

Funds from abroad refer to funds (RW) allocated to R&D by institutions and individuals located outside the political frontiers of a country except for vehicles, ships, aircraft, and space satellites operated by domestic organizations and testing grounds acquired by such organizations, and by all international organizations (except business enterprises) including their facilities and operations within the frontiers of a country.

Among the different sources of R& D, government plays a significant role as performers and funders of R&D activities at the same time both domestically and in the rest of the world. While R&D may be outsourced to external organizations, government units may have assigned teams to

conduct research, such as ex-ante and ex-post appraisals or evaluations. Business enterprises tend to be risk avoiding in areas of high uncertainty and markets may fail where the necessary investment is too large to be undertaken by one company.

Public financing of private R&D may also take place where the competitiveness or other market thresholds are seen to be overly high for a society or institution, but where a public interest is apparent. This would be another prominent reason why Public R&D that supports the private sector which may be regarded as public intervention. The effectiveness of public financing of business R&D has important policy dimensions. Governments' providing funds for business R&D can be carried out in spite of considerations such as market and business failure. Public investments in R&D are seen as a key aspect for promoting overall economic performance in many countries.

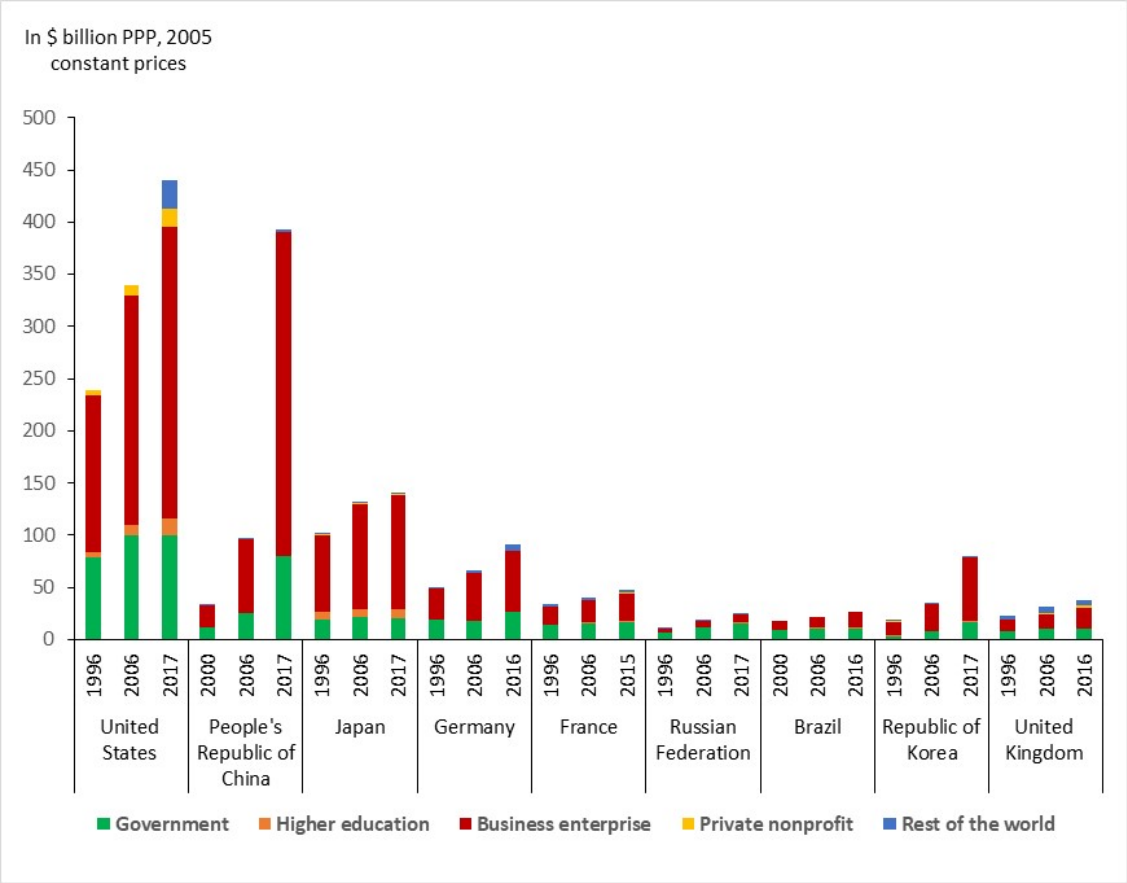
A. Sources of Research and Development: Public versus Private

The classification of R&D as being either public or private status is usually determined by whether or not the activity is controlled by government. The OECD Frascati Manual (2015) states that it is commonly reported as R&D statistics, which identify the combination of the higher education and government sectors as being "public sector", while business enterprise and private nonprofit broadly represents the "private sector". However, a unit in the business enterprise sector can be classified as being in the public sector R&D on the basis of its operation being directed by the government. In contrast, a university that is commonly described as "public", but has its own board which can decide all aspects of its management without approval by government authorities can be classified as being private.[2]

Figure 4.1 shows the source of R&D funds in terms of public and private status for top group countries from 1996 to 2017, measured in '000 purchasing power parity (PPP) $, constant prices, 2005.

[2] Although R&D statistics often identify the combination of the higher education and government sectors as public and business enterprise and private nonprofit and private sector, it is not always accountable because, very often, public enterprises are part of the business enterprise sector, while private and independent universities are part of the higher education sector.

Figure 4.1: Gross Domestic Expenditure on Research and Development Source of Fund: Top Group Countries (1996~2017)



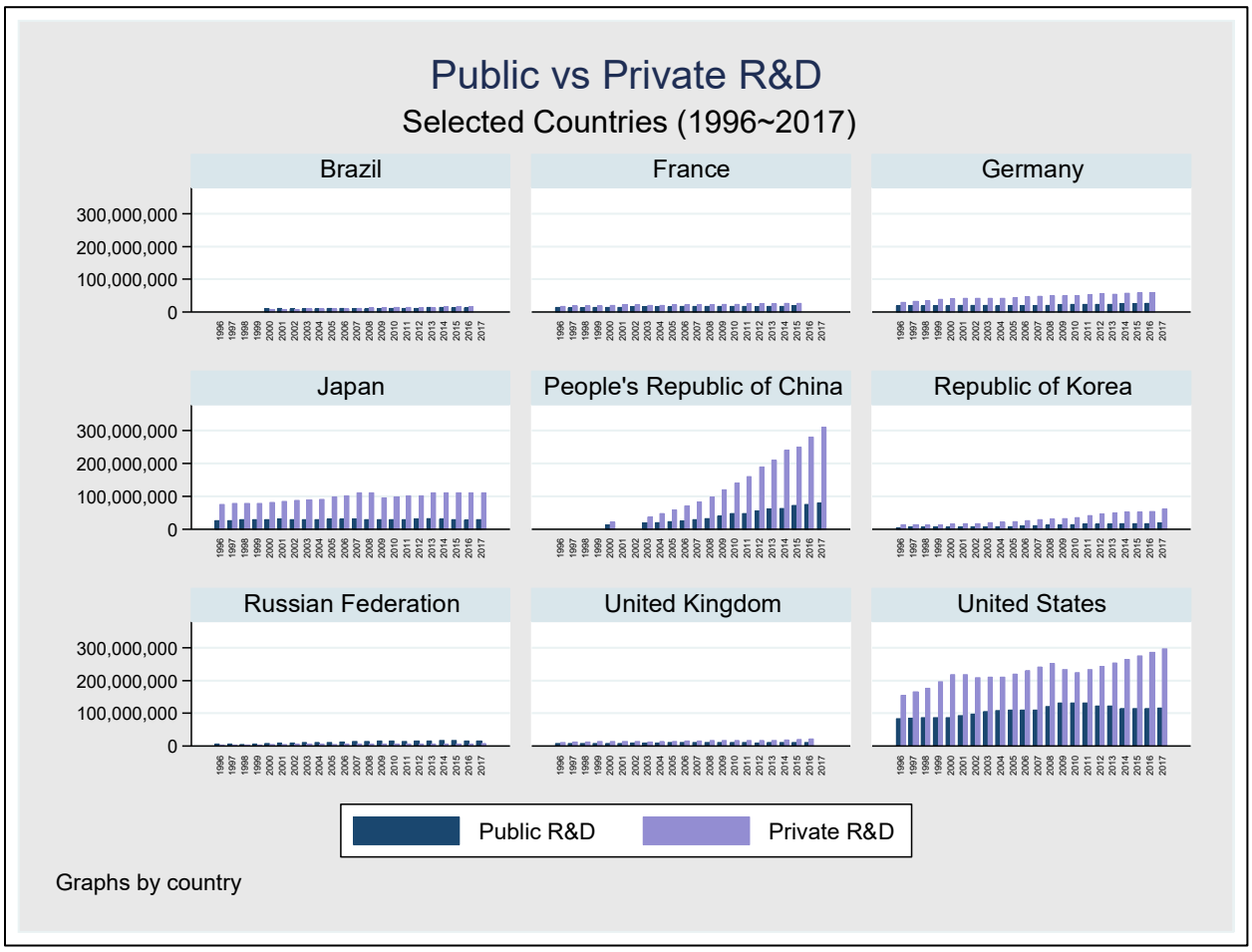
PPP = purchasing power parity

Note: Earliest available data for the People's Republic of China and Brazil is 2000; latest available data for France is 2015; and Brazil, Germany, and the United Kingdom is 2016.
Source: Authors' own calculation using data from UNESCO Institute for Statistics, http://data.uis.unesco.org/ (accessed 28 August 2019).

Countries with a higher value in government funding (in absolute value) for the public sector include the United States (US), the PRC, Japan, and Germany. Up until 2016, the US was the highest among this group in terms of business enterprise of the private sector funding. However, the PRC has superseded that of the US from 2016.

In terms of public and private R&D, the increase of private R&D of the PRC is so evident especially after global final crisis (2007~2008). In case of the US, the patterns of both private and public R&D are quite stable over the period.

Figure 4.2: Gross Domestic Expenditure on Research and Development Source of Fund: Public versus Private Research and Development (1996~2017)
(unit: '000 purchasing power parity $, constant prices – 2005)



Note: Earliest available data for the People's Republic of China and Brazil is 2000; latest available data for France is 2015; and Brazil, Germany, and the United Kingdom is 2016.
Source: Authors' own calculation using data from UNESCO Institute for Statistics, http://data.uis.unesco.org/ (accessed 28 August 2019).

Table 1: Gross Domestic Expenditure on Research and Development: Source of Fund in Average Percentage (1996~2017)

Country	Public		Private		
	GOV	HE	BE	PNP	RW
Australia	40.4%	0.2%	54.6%	2.3%	2.5%
Brazil	46.0%	2.3%	51.7%	0.0%	0.0%
Canada	32.2%	7.7%	47.5%	3.2%	9.5%

Country	Public		Private		
	GOV	HE	BE	PNP	RW
France	37.5%	1.2%	52.8%	0.9%	7.7%
Germany	30.2%	0.0%	65.7%	0.3%	3.8%
Italy	42.3%	1.0%	45.0%	2.7%	8.9%
Japan	17.2%	6.0%	75.7%	0.7%	0.4%
People's Republic of China	22.9%	0.0%	76.0%	0.0%	1.0%
Republic of Korea	23.9%	1.1%	74.1%	0.4%	0.5%
Russian Federation	63.9%	0.6%	29.3%	0.2%	6.1%
Spain	42.5%	4.1%	46.2%	0.7%	6.5%
United Kingdom	30.2%	1.1%	46.3%	4.7%	17.7%
United States	28.0%	2.8%	60.9%	3.1%	5.2%

Note: Gross domestic expenditure on research and development measured with '000 purchasing power parity (PPP)$, constant prices – 2005
Source: Authors' own calculation using data from UNESCO Institute for Statistics, http://data.uis.unesco.org/ (accessed 28 August 2019).

Public sector R&D, especially the portion of government R&D funding of countries like the Russian Federation. Brazil, Italy, Spain, and Australia, was more than 40% on average during the 1996–2017 period. On the contrary, in the US, the PRC, Japan, Germany, and the ROK, private sector funding for R&D is more than 60%. Very interestingly, in countries such as the United Kingdom and France, Canada, and Spain, the proportion of R&D funding from the rest of the world accounts for a higher proportion than other countries.

Table 2: Gross Domestic Expenditure on Research and Development Source of Fund in Average Percentage: Asian Economies (1996~2017)

Country	Public Sector		Private Sector		
	GOV	HE	BE	PNP	RW
Central Asia					
Azerbaijan	74.8%	0.5%	23.0%	0.0%	0.3%
Georgia	46.5%	35.8%	0.0%	0.0%	14.6%
Kazakhstan	46.9%	9.4%	40.1%	0.4%	1.5%
Kyrgyz Republic	66.4%	1.2%	26.5%	0.0%	5.9%
Tajikistan	97.9%	0.3%	1.4%	0.6%	0.3%
Uzbekistan	52.7%	0.0%	45.8%	0.0%	1.5%

Country	Public Sector		Private Sector		
	GOV	HE	BE	PNP	RW
East Asia					
Hong Kong, China	48.5%	0.1%	46.8%	0.0%	4.6%
Mongolia	83.8%	3.4%	8.0%	1.3%	3.5%
People's Republic of China	22.9%	0.0%	76.0%	0.0%	1.0%
Republic of Korea	23.9%	1.1%	74.1%	0.4%	0.5%
South Asia					
Pakistan	73.0%	23.6%	0.0%	1.8%	1.5%
Sri Lanka	58.2%	9.6%	24.0%	0.9%	7.3%
Southeast Asia					
Brunei Darussalam	80.9%	10.5%	4.0%	0.0%	4.6%
Cambodia	19.7%	0.1%	29.1%	21.6%	29.5%
Indonesia	89.9%	0.1%	10.0%	0.0%	0.0%
Lao People's Democratic Republic	8.0%	2.0%	36.0%	0.0%	54.0%
Malaysia	32.0%	6.4%	59.9%	0.0%	1.7%
Myanmar	77.4%	0.0%	0.0%	0.0%	22.5%
Philippines	32.1%	7.0%	56.2%	0.4%	4.3%
Singapore	38.1%	1.3%	55.2%	0.0%	5.4%
Thailand	29.2%	12.8%	55.6%	0.6%	1.9%
Viet Nam	41.9%	1.3%	53.2%	0.0%	3.6%

Note: Gross domestic expenditure on research and development measured with '000 purchasing power parity $, constant prices – 2005.
Source: Authors' own calculation using data from UNESCO Institute for Statistics, http://data.uis.unesco.org/ (accessed 28 August 2019).

Among Asian countries, the PRC and the ROK show a higher proportion of R&D funding from the public sector. In contrast, countries such as Malaysia, Singapore, and Thailand, the proportion of private sector R&D funding is relatively high. Moreover, in countries such as the Philippines and Thailand, the proportion of R&D funding from the rest of the world accounts for a higher proportion than that of other countries.

B. The Research and Development Activity

According to the OECD Frascati Manual (2015), the term R&D[3] includes three kinds of activity: basic research, applied research, and experimental development. Basic research is described as being experimental or theoretical work commenced primarily to obtain new knowledge of the underlying foundation of phenomena and noticeable facts, without having any specific application or use in view.

Applied research means the original study which is begun to attain new knowledge while focusing on a precise, actual aim or objective.

Experimental development is defined as organized work and reflects the knowledge gained from research and practical experience. Such experiences can be used to create new products or processes or to upgrade existing products or processes.

Governments can engage with activities such as health provision, data collection for natural or social systems, or the development of infrastructure, whose provision may benefit internal or external R&D performance. The intellectual and physical properties generated from R&D activities of government may be used as the main components of R&D projects of other sectors. Apart from basic research, applied research, and experimental development, governments occasionally make meaningful investments in large fixed assets where potential contributions to innovative activities are expected.

Figure 5 represents the countries' R&D activities (measured with '000 PPP$, constant prices – 2005) over the 1996–2017 period. As for basic R&D activity the US, Japan, and France are highest among this sample group while the R&D activity for the experimental development is led by the PRC and the ROK. As for applied research, the US is the highest all the way through.

Governments in many countries directly support scientific and technological research through tax incentives such as the R&D tax credit or subsidy.

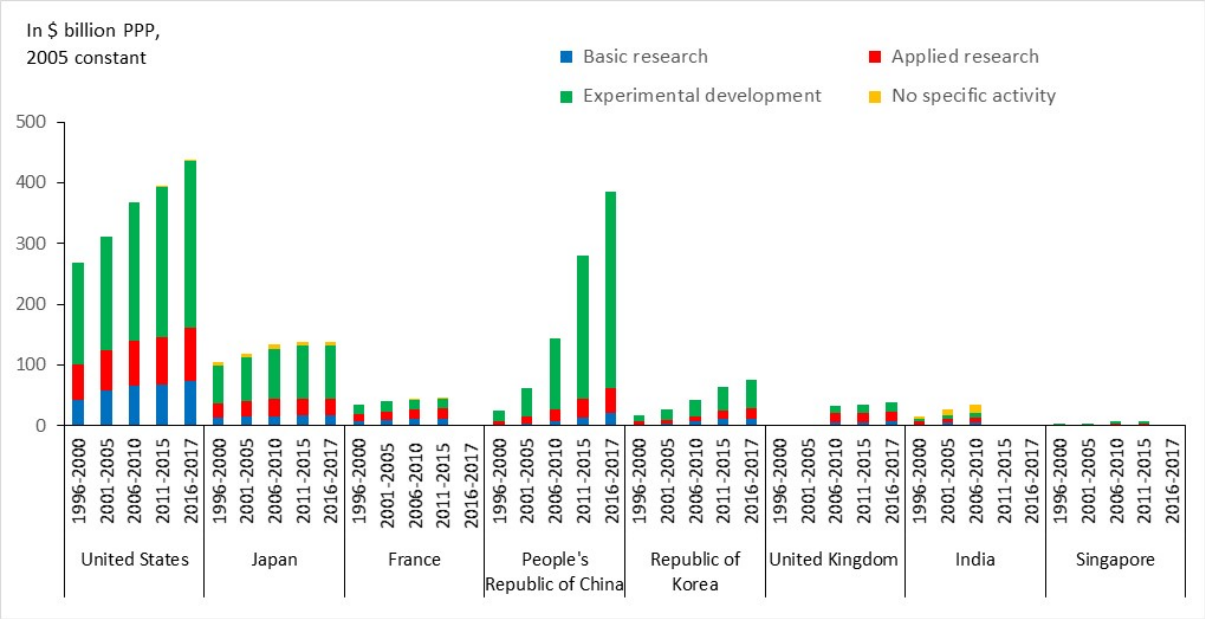
Very often, governments institute their own research centers. The primary economic

[3] The classification by product field (or industry served) includes natural sciences, engineering and technology, social sciences and humanities and arts, and lastly the classification in accordance with socioeconomic objective includes economic development, health, environment, and education.

rationale for the government role in R&D is that, without such involvement, the private market would not sufficiently produce certain types of R&D. In this concern, the governments of many countries are major players in innovation. An important facet of the government's role will be on how government supports should be placed so that resources can be used more effectively.

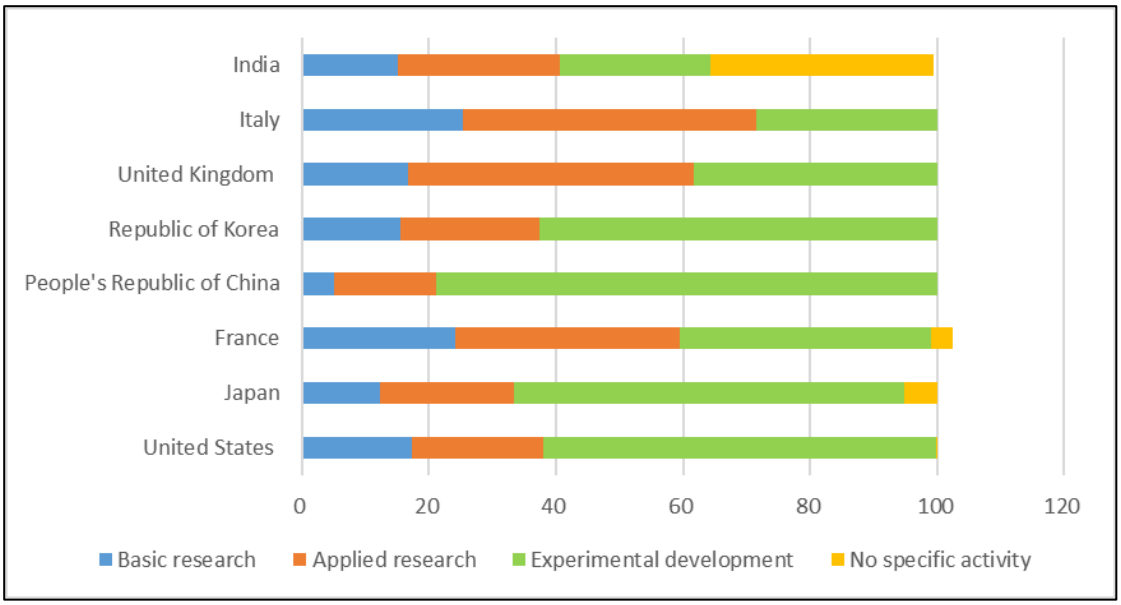
Figure 6 shows the average percentage of R&D activity over the 1996–2017 period. The US, Japan, the PRC, and the ROK's R&D for experimental development exceeds more than 50%, while R&D for basic and applied research of European Union countries, for example, France, the United Kingdom, and Italy, accounts more than 50%.

Figure 5. GERD R&D Activity, Selected countries (1996-2017)



GERD = gross domestic expenditure on research and development, PPP = purchasing power parity.
Source: Authors' own calculation using data from UNESCO Institute for Statistics, http://data.uis.unesco.org/ (accessed 28 August 2019).

Figure 6: Average Percentage of GERD R&D Activity, Selected Countries (1996~2017)



GERD = gross domestic expenditure; R&D = research and development.
Notes: GERD measured with '000 PPP$, constant prices – 2005. Not all countries have complete data for the whole duration.
Source: Authors' own calculation using data from UNESCO Institute for Statistics, http://data.uis.unesco.org/ (accessed 28 August 2019).

Table 3: GERD–R&D Activity in Asian Countries (1996~2017)

Country	Basic Research	Applied Research	Experimental Development	No Specific Activity
Central Asia				
Azerbaijan	123,698	81,283	26,820	35,122
Kazakhstan	122,746	306,858	128,282	
Uzbekistan	66,932	115,391	88,733	65,583
Georgia	5,788	1,757		12,507
East Asia				
People's Republic of China	7,660,760	19,100,000	126,000,000	
Republic of Korea	6,624,158	8,631,586	25,700,000	
Mongolia	19,374	24,231	3,833	5,490
South Asia				
India	4,176,428	6,511,846	6,260,157	9,883,063
Sri Lanka	30,469	102,450	62,624	
Southeast Asia				

Malaysia	1,323,773	4,146,062	823,958	
Singapore	929,306	1,658,168	2,560,144	
Thailand	690,240	1,342,314	1,740,220	389,430
Viet Nam	315,566	1,200,727	170,418	98,711
Myanmar	27,017	24,125	28,314	2,441
Cambodia	7,281	35,597	10,884	

GERD = gross domestic expenditure; R&D = research and development.
Notes: GERD measured with '000 PPP$, constant prices – 2005
Not all countries have complete data for the whole duration.
Source: Authors' own calculation using data from UNESCO Institute for Statistics, http://data.uis.unesco.org/ (accessed 28 August 2019).

Table 3 presents the R&D activity of Asian countries in the different regions. Among Asian countries, the R&D activity for experimental development of the PRC and the ROK is especially higher, while the R&D activity for basic and applied research of countries such as India, Malaysia, the Philippines, Singapore, Thailand, and Viet Nam accounts for quite a significant proportion of the overall total.

The other important tendency is that, when compared with increases in R&D for basic research and applied R&D activities for the US, Japan, and France (Figure 6), the increase in R&D activity for Experimental development is especially higher in most of Asian countries. Such tendency is more obvious in countries such as the PRC, the ROK, and in many other Southeast Asian economies.

According to Martin et al (1996), public research, usually in a large extent, focuses on basic research because of the uncertainty related with basic research for commercialization or final application. The produced results from basic research however are so important for the agents of the economy (Nelson 1959). Private sector can utilize this knowledge during the process of commercialization or final applications. Basic research therefore increases the 'knowledge base' available to companies and other participants of the economy to source the innovation information.

At the same time, basic research often produces new techniques, methodologies, and instruments that are indispensable for the production of applications. New instrumentation produced from basic research can be used by scientists to expand their study and sometimes introduce new fields of

research, e.g., artificial intelligence (von Hippel 1987 and Rosenberg 1992). Studies shows that private sector's companies have tendency to license mainly research tools and techniques from outputs of public sectors' basic research (for example, Nelson et al. 1996 and Arundel et al. 1995).

Because of the potentially high social return in basic research, expanded government support for R&D can significantly promote economic growth in Asian countries.

High levels of investments in basic research from the US and other advanced countries have produced considerable volumes of knowledge. This factor can partially explain why the PRC's R&D pattern is so much concentrated in experimental development, R&D of the final process of production. It also explains the background rationale for a severe technical hegemony competition between the US and the PRC trade war.[4]

Providing additional funding for more basic research is, thus, very important policy option for public R&D activity. More attention should be paid to rectify a tendency to provide less emphasis on basic research in Asian countries.

III. INTERACTION BETWEEN PUBLIC VERSUS PRIVATE RESEARCH AND DEVELOPMENT

The economic justification for public sectors' support to R&D is related to the presence of market failures associated with R&D activities, e.g., an inadequate supply of R&D from private sectors due to high risk of investment. However the expected spillover effect is usually larger than the input (Leyden and Link 1991 and David et al. 2000). Due to such market failures, firms in a competitive market are less likely investing in R&D up to the socially optimal level (Nelson 1959 and Arrow 1962). Another market failure comes from the unforeseeable outcome of R&D investment. This uncertainty, coupled with asymmetries in information between capital markets and R&D investors, hinders access to finance for risky innovation projects. This will be more evident for small size firms or individuals.

[4] The US argues that the PRC has been stealing technical knowledge and information or forcing technology transfers for the precondition for entry into the PRC (USTR 2018 and 2019).

The discussion on whether public R&D expenditures or government fiscal incentive, such as a subsidy or tax credit, stimulates private R& D or it substitutes for and tends to crowd out private R&D were widely discussed in many prior literatures.

For example, some views that increases in public R&D will eventually reduce private R&D activities. They argued that if the government has done the necessary research, firms would no longer be able to engage in private R&D (Wallsten 2000 and Toivanen and Niininen 1998). Wallsten (2000) finds that public and private R&D investments are rather substitutes. In particular, if the firm aggregation level is used (Toivanen and Niininen 1998), 18 out of the 38 cases are supportive of a clear substitution of public investment in research over private investment, while at the sector level, 4 instances out of 28 demonstrate a substitution effect.

Some literatures showed a mixed result of the effect of public versus private R&D (Levy 1990, García-Quevedo 2004, and Capron and van Pottelsberghe 1997). For instance, Levy (1990) finds that five countries reveal significant complementary effects between public and private investment, whereas two countries show significant substitution effects.

In recent studies however, major portions of the analysis suggest that a positive and complementary relationship between public and private R&D investments (González and Pazó 2008, Almus and Czarnitzki 2003, Czarnitzki and Fier 2002, Czarnitzki 2011, Guellec and van Pottelsberghe 2000, Lach 2000, David et al. 2000, European Commission 2007, Reinthaler and Wolff 2004, and Falk 2006). David et al. (2000) shows that between public and private, R&D expenditure at the country level, the complementarity effects are stronger than the substitution effects. Cin et al. (2013) empirical findings that partial support to the Government of the ROK R&D promotion policy for small and medium-sized enterprises through subsidy have enhanced firm performance. The public R&D, which stimulates or encourages private sectors to take part in R&D projects with financial risk and not guaranteed for the short-term economic gains for private sectors to conduct R&D, is mostly needed in the area of health care, environmental projects, or national defense.

The effect of various kind of public R&D measures, public subsidies are, together with tax incentives, one of the most used tools for technology policy to stimulate R&D private expenditure (Afcha and Guillén 2014). Guellec and Bruno (1997) investigated whether fiscal incentives and

direct subsidies stimulated business-funded R&D in 17 OECD countries over the period 1981–1996. They found that at least in the short run fiscal support such as tax credit and direct subsidies stimulate private sectors' investments to R&D. In the longer run, direct subsidies are more effective than fiscal incentives (Reinhilde 2016 and; Yang 2102)

Receiving of public support enables companies somehow to prove financial viability, and quality of scientific and technical R&D activities of the companies. It reduces uncertainty and helps to correct information asymmetries that hinder the company access to external financing and marketing of its products in the technology market (Hall and Lerner 2010).

The volumes of literatures agreed that public and private R&D are mainly complementary. To sustain innovation and accelerate economic growth, both public and private sectors should focus on win-win situations by collaboration in which both parties can fully dedicate themselves to the success of new opportunity of innovation.

IV. PUBLIC SECTOR RESEARCH AND DEVELOPMENT TO FOSTER THE INNOVATION OF ASIA

The innovation prospective and the research outputs of the industry in technology-intensive sectors depend on the combination of different technologies, techniques, methodologies, and research personnel. Public R&D investment builds innovation resources that the private sector can further utilize and companies can commercialize their research potential (Patel and Pavitt 1995).

Several literatures confirmed that the higher level of public R&D expenditure induces more private R&D investment. Martin (2007) discussed the effect of public R&D and find that the rate of return to public-funded R&D was approximately 20%–50% while the social rate of return on the private R&D is 20%–30%. Klevorick et al (1995) argues that publicly funded R&D intensified the opportunities of the industry to engage in R&D. Publications produced from public-funded research also expand the opportunities for companies to access to this accumulated knowledge and engage with further R&D process (Dasgupta and David 1994).

Publicly funded R&D create the trained R&D personnel thus private sector can use them in their innovation process (Senker 1995 and Elissavet and Arnold 2008). According to the empirical study of Falk (2006) about the business enterprise sector of 21 OECD countries, public R&D subsidies significantly foster private R&D investment. The study of Economic Insight (2015) is also consistent with a crowding-in effect of public expenditure on R&D. According to them, 1% increase in public expenditure on R&D will lead to between 0.48% and 0.68% increase in private expenditure on R&D. Public funding of research also generates positive spillover effects that induce the private sector to spend more on R&D. For example, basic research funded by the public sector could lead the private sector to invest more in related applied research. Thus, public spending on R&D would crowd-in private expenditure (Economic Insight 2015). Hall and Lerner al (2000 and 2010) confirm that the social or economy-wide returns from public R&D are usually much higher than the private R&D returns to individual firms.

As for the effect of public R&D, David et al. (2000) find that government subsidies intensify the rate of return from private R&D whereas tax credits reduce the marginal cost of private R&D. According to Elissavet and Arnold (2008), public R&D expenditures[5] positively affect the overall research base in the European Union 27 countries with a time lag of up to 2 years. They also find that R&D performed by the government showed a positive relation with the share of R&D personnel[6] in the R&D systems and the scientific outputs such as publications and patents, which are the important source of innovation.

The most important issue in public sectors' efforts to sustain innovation and accelerated commercialization is that both public and private sectors should focus on win-win situations in which both parties can fully dedicate themselves to the success of new opportunity of innovation.

Wide range for market failure in the case of R&D investment for economic growth requires governments' intervention to stimulate private R&D investment closer to the socially optimal levels. To reduce these market failures, governments invest on R&D through public funding and supporting the private sector with incentives for undertaking R&D. Governments also can support

[5] R&D performed by the government and the higher-education sector

[6] R&D personnel as percentage of total employment. It includes researchers and scientists as well as people providing direct services to the research/innovation process, e.g., R&D managers, administrators, etc.

pilot programs that can reduce not only the level of technical risk but also other commercial and financial risks as well.

A large volume of studies agrees that in certain extent, increasing public R&D investment builds innovation resources, essential for private sectors' further application, and the social or economy-wide returns from public R&D are usually much higher than the private R&D returns to industry, especially in knowledge-intensive industries. Actively supporting in the initial stage of R&D projects such as supporting pilot programs can reduce not only the level of technical risk, but also other commercial and financial risks related with R&D investment. At the same time, the higher level of public R&D expenditure will eventually induces more private R&D investment.

V. CONCLUSION

Technology plays an important role in fostering innovation. Under the situation with growing protectionism within the global trade and production fields, innovation can be a key instrument of launching stronger economic activity in Asian economy where the role of trade is essential for their growth. On the other hand, the technical system is undergoing a profound transformation based on new information technologies and other developments such as artificial intelligence, biotechnology and nanotechnology, which has a profound impact on the way we live.

The various studies confirm that public and private R&D are mainly complementary. To sustain a technological innovation and accelerate economic growth, both the public and private sectors should look for the collaboration in which both parties can fully dedicate themselves to the success of new opportunity of innovation.

Research provided by publicly funded R&D usually in a large extend focuses on basic research that has no guarantee for extension to product commercialization or final application. Yet the output of basic research is so essential for the economic participants because basic research increases the 'knowledge base' available to companies and other agents in the economy, thus fosters the economic actors can source the knowledge for product commercialization or final application. Providing additional funding for more basic research will enhance the chance for development of new technological innovations and scientific progress.

Public R&D also reduce the risk related with uncertain outcomes and financial burden in the early stage of R&D investment thus governments should initiate R&D investment through public funding and support the private sector with incentives for undertaking R&D. Such initiation will reduce the risk of R&D project, thus simulate the private sectors' engagement with R&D and result the increase of innovation capacity.

Innovation is a key driver of both economic growth and enhancing the social well-being of a country. Therefore, policies that promote innovation should be top priority for any government at any developmental stage. Governments can inspire innovation by creating policy instruments that ensure the private sector's ability to provide appropriate returns to innovative investments. In terms of the suitable types of R&D policy for Asian countries, it is important that the level of economic development of each country should be considered.

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