Science, Technology and Development 37 (3): 139-148, 2018
ISSN 0254-6418 / DOI: 10.3923/std.2018.139.148

Overcoming Challenge of R&D and Innovation Financing in Developing Countries: A Proposed Way Forward for Pakistan

Tariq Bashir, Farid Bakhtiar and Anwar-ul-Hassan Gilani

Pakistan Council for Science and Technology, Islamabad, Pakistan

Abstract: Innovation is viewed as increasingly important for economic growth and social development of nations. In the context of knowledge-based economies, the extent of R&D performed by a nation indicates its capacity to innovate, while expenditure on R&D is considered to be as one of the leading indicators for benchmarking the R&D performance of countries within an international setting. Over time, in many parts of the world, especially in the developed countries, investments on R&D have increased significantly. However, lately R&D funding throughout the world, especially in the public sector, is facing serious challenges of sustainability. These challenges are even sterner for the developing countries as they have inefficient research systems and non-existent or deficient research commercialization mechanisms which make it harder to showcase direct societal benefits of R&D at the local level, and hence justify public spending on research. Review of the trend of R&D expenditure of Pakistan, during last 25 years, reveals that R&D expenditure of Pakistan, as percentage of GDP, has been fluctuating between 0.25% and 0.67%, it reached to its peak (0.67% of GDP) in 2006-07 and since then it has shown consistent decline. Current expenditure of 0.25% of GDP is the second lowest in the last 25 years. It is highly unlikely that government alone can increase country's R&D spending up to 1% of GDP in foreseeable future, as has been recommended by UNESCO for developing countries. To fill this gap, industry and civil society has to come forward. The present paper suggests a number of approaches and mechanisms which can be adopted to attract, encourage and engage industry and civil society in R&D funding in Pakistan.

Key words: R&D expenditure, R&D funding, Innovation funding, R&D challenge, Public sector R&D financing challenges, Pakistan R&D, Knowledge-based economy, STI policy, R&D policy.

INTRODUCTION

Research and Development (R&D) plays a major role in innovation, technical change, raising productivity, bringing competitiveness, enabling firms to reduce costs of production, increasing economic growth and improving societal living standards. In the current knowledge era, only those countries can stay ahead in economic global race that could prioritize R&D, create enabling innovative and competitive environment and adapt cross-cutting technologies. R&D not only creates new knowledge, which mostly forms basis of the economic development (Romer, 1990), but it also increases the ability to learn and use existing knowledge (Bar-Efrat, 2006) in a more productive way.

The importance of R&D for sustainable economic development has been fully recognized in the technological advanced countries. Resultantly, these countries have successfully used R&D and innovation for growth of their economies and betterment of their societies. For example, the success of Finland during 1990s has been attributed, at least partly, to "its efficient innovation policy that clearly focused on increasing R&D expenditures and supporting knowledge society initiatives" (Frinking *et al*., 2002). European Union, in its development agenda for the current decade "Europe 2020 Strategy" has identified R&D and innovation as important policy interventions for addressing "job creation through increased industrial competitiveness, labour productivity and the efficient use of resources and, finding solutions to societal challenges such as climate change and clean energy, security and active and healthy ageing" (European Commission, 2010).

Recently, the realization of using R&D and innovation for the socio-economic development has also grown in the developing world, especially in the emerging economies. In fact, R&D investment in emerging economies is considered as a fundamental prerequisite for economic development beyond the basic stages of development (Kroll and Stahlecker, 2012). During the past two decades, the share of

Corresponding Author: Tariq Bashir, Pakistan Council for Science and Technology, Islamabad, Pakistan
E-mail: drtariqbashir@yahoo.co.uk

United States and Europe in performance of world R&D has decreased from 37% to 30% and 26% to 22%, respectively. On the other hand during the same period, the Asian countries were able to increase their share from 25% to 34% (NSF, 2014). Actually, in the past two decades the understanding about the relevance of R&D to economic development has spread far beyond those countries which are traditionally regarded as leaders in science and technology. The technology-based catch-up of the "tiger economies"; most notably South Korea and Taiwan, and more recently China, has illustrated that investments in science and technology are crucial ingredients to emerge from the "middle income trap" (ADB, 2011). Countries, like Brazil, Malaysia and India, are also giving due recognition to R&D and innovation in their national agenda of growth and development.

Pakistan, in 2014, launched its development agenda for the next decade, i.e., Pakistan Vision 2025, which envisions to include Pakistan among the top 25 economies of the world by year 2025.The Vision also aims to "put Pakistan on the innovation map of the world through focused research and development" (PC, 2014). For achieving development goals of the Vision, it "envisages establishing the missing link between knowledge and production platforms through government, private sector and academia/research partnerships". However, it would require aligning the national R&D and innovation activities with the Vision 2025, on the one hand and providing sufficient sustained funding on the other hand.

Human resource is the key ingredient for R&D and innovation. However, availability of funding for R&D is equally important. Even the most competent R&D manpower cannot produce desired results if deprived of enough and sustained funding. In the developed world, both public and private sectors provide funding for R&D. However, in the developing world, public sector provides mostly the funding for R&D and innovation.

Public sector R&D funding, especially in the developing economies, always had adequacy and sustainability issues. At times, R&D organizations in the developing countries are only able to pay for the salaries of researchers/scientists but do not have enough funds for conducting any meaningful research. Likewise, in many developed countries, public sector R&D funding has decreased. Even in the United States, government funding for basic science has declined (Romney, 2010) and there are no indications of reversal of this trend as it is anticipated that US government's R&D spending is to stagnate in the coming decade. "The National Institutes of Health's budget is scheduled to drop 7.6% in the next five years. Research programs in energy, agriculture and defence will decline by similar amounts" (Plumer, 2013). A decreasing trend of public sector R&D funding may be less alarming for the developed countries as significant contributions towards their total R&D expenditure are made by the industry. However, recently the private sector has also shown reluctance in increasing expenditure on R&D due to its high risk nature.

It may be rightly stated that financing R&D and innovation on sustained basis, in both the developing and developed world, has emerged as a serious issue which needs viable solutions. However, nature and magnitude of the issues related to financing of R&D and innovation may be different in both sets of countries. In the developed world, it may be a matter of convincing the public and private sectors not to decrease funding for R&D, while in the developing world, efforts may be needed to persuade the governments to significantly increase R&D funding, with simultaneously motivating the private sector to play its due role in sharing R&D expenditure.

The current paper highlights the issues related to financing of R&D and innovation in the developing economies. It discusses limitations of the public and private sectors in the developing world in funding R&D as well as the financing issues unique to the R&D activities. The case of Pakistan has been discussed in more detail and a way forward for the country has been proposed to overcome the lack and unsustainability of the financial resources for carrying out R&D and innovation activities. This approach may be useful for other developing economies facing similar issues.

METHODOLOGY

The main objective of the study was to explore and recommend various approaches and alternative mechanisms which can be adopted to attract, encourage and engage industry and civil society in R&D funding in Pakistan. Secondary data sources, such as, the Pakistan Council for Science and Technology (PCST), UNESCO Institute of Statistics and internet sources, have been used to obtain relevant data for the study.

R&D AND INNOVATION FINANCING

1. Uniqueness of investing in R&D and innovation

Due to a number of characteristics, investment in R&D and innovation is not like an ordinary investment. For example, R&D investments usually take a long time (Diaconu, 2013) before they generate any profits. Majority of the research projects do not produce immediate commercializable results; this is especially true for basic research projects. More often or not, the first profit from a research project comes years after the investment is made (Hall, 2002).

As per Hall (1993), at least 50% of the total cost of an R&D project consists of salaries of the manpower (Hall, 1993). More recent studies suggest that the share of this expenditure of R&D activities may rise up to 60% (Bond *et al.*, 2005) or even beyond. The involvement of such huge sunk costs

makes the total cost of a research project very high (Binz and Czarnitzki, 2008). However, investment in highly qualified technical human resource is very important as it creates knowledge-base of an organization which is an intangible asset, responsible for generation of profits in future (Hall and Lerner, 2009). However, this investment can also be very fragile if the knowledge accumulated by the organization is tacit and not explicit, i.e., it is only in the minds of the human capital of the organization. In these cases, it is lost if the employees leave the organization or are laid off. This characteristic has important implications for investments in R&D.

A higher level of uncertainty about the results is another important characteristic of investment in R&D projects. These uncertainties are the highest at the start of a research project which may reduce during the course of the project. This means that for analysis of research projects a static framework should not be applied (Hall and Lerner, 2009). Scherer (1998) suggests that "the distribution of profits from innovation sometimes has a Paretian character where the variance does not exist. When this is the case, standard risk-adjustment methods will not work well".

One of the reasons for Pakistan to lag behind in spending on research and development as well as in scientific research is the reluctance of the government to allocate sufficient financial resources for research and development (**S**hahid, 2016). For example, the allocation for R&D in 2018-19 was roughly under 3.0 billion which is only Rs. 870 million more than last year. Whereas, the requirement of the Ministry of Science and Technology is much higher for the current year as it needed more than this to complete even the ongoing projects rather to start new projects. The funds released are even less than those released in 2007-08, adversely affecting activities in scientific research (Shahid, 2018). Furthermore, amongst the allocated budget the lion's share goes in the salaries of the human resource and only a very meager amount is spent on actual research and development.

2. Public sector financing of R&D and innovation

Many studies have shown that compared to ordinary investments, returns to R&D investments are higher; private returns to R&D investments are lower than social returns (Griliches, 1992; Hall, 1996; Ali-Yrkkö, 2005; Hall *et al*., 2009) and, the "private sector does not internalize the social benefits of innovation" (Howell, 2015); a greater responsibility rests with the public sector for financing R&D. Also a typical output of R&D activities is knowledge, which has many elements of a public good (Bar-Efrat, 2006) which justifies public sector investments in R&D. That is why even in the period of recession, some countries substantially increased their public spending on R&D. The countercyclical effect of R&D subsidies in Germany, during economic crisis, has been confirmed by Brautzsch *et al*. (2015). Many researchers, including Hall (2002), Czarnitzki (2006), Meuleman and De Maeseneire (2008), have provided evidence that public funding of R&D is crucial for sustaining R&D activities (Hall, 2002; Czarnitzki, 2006; Meuleman and De Maeseneire, 2008).

The main aim of publicly funded R&D is to provide benefits to the society, while remaining accountable to the taxpayer. In this context, the governments may finance R&D and innovation activities based on three distinct but interrelated rationales: backing scientific merit, supporting commercialization and, link to local needs (Kroll and Stahlecke, 2012).

Keeping in view that the basic research needs time to show its full potential and usefulness, and accepting the fact that the results of scientific research projects are unknown by nature; the governments may provide funding for R&D projects based on their scientific merit and long term potential opposed to their immediate and short-term benefits. Public sector should particularly focus such project as these projects are rarely funded by the private sector.

For harnessing the socio economic transformation potential, both basic and applied research are needed. In this regard, the private sector also needs to play its due role along with the public sector.

Relation with the needs of the local communities is also an important consideration for the public sector funding bodies. Projects, which aim to address local demands and provide direct solutions to the current problems of the society, are also supported by public sector.

3. Private sector financing of R&D and innovation

In the developed countries, a significant share of the national R&D and innovation financing comes from the private sector. Although, financing by the well-established large companies constitutes the major portion of private R&D investments (Czarnitzki and Hottenrott, 2011), the role of SMEs is also very important to technological progress of a country (Acs and Audretsch, 1990; Audretsch, 2006). However, SMEs and new startups quite often face problems of finding financing for investments in R&D and new technologies. In order to address these problems, in some countries such as the US, some sort of financial assistance is provided to these firms by the governments, while in other countries, such as Canada, Israel, etc., the problems of SMEs and new entrants for financing R&D and innovation are addressed through private sector "venture capital" industry (Hall and Lerner, 2009). However, venture capitals can only partly mitigate the high costs of conducting R&D or innovation activities (Hall, 2002).

After the first major success story of venture capital in 1957, when investment in Digital Equipment Corporation was valued manifolds higher than the actual investment after its initial public offering in 1966 (Wikipedia, 2016) and the remarkable increase in the venture industry in 1980s,

it showed decline, particularly from mid 1990s to early 2000s (Hall and Lerner, 2009). Poterba (1987; 1989) believes that an increase or decrease in the demand for or the supply of venture capital may be the reason for the variability of the funds availability for funding. He also notes that a drop in the capital gains tax rates is inversely proportional to commitments to venture funds. Gompers and Lerner (1998) also endorse Poterba's argument that "small capital gains taxes have effects on venture capital supplied by tax-exempt investors".

Although venture capital is a relatively mature area of financing, however there are still unresolved issues such as globalization of the industry. Jeng and Wells (2000), while studying the elements influencing the venture fund raising abroad, has found that initial public offering (IPO) market is important for a successful venture industry. However, the IPO market influences the commitments more to later-stage funds than the early-stage ones.

4. Issues related to R&D and innovation financing in developing countries

As discussed earlier, the governments while making decisions regarding funding R&D and innovation projects consider three basic questions:

i) What is the scientific merit of the project?
ii) What is the scope of commercialization of the results expected from the project? and
iii) How useful the project would be in providing solutions to the local problems?

Governments in the developed countries may have the 'luxury' to give preference to a certain type of projects among these three, as the private sector can be expected to take responsibility for financing other types of project. Normally in the developed world, the former type of projects is undertaken by the public sector while the two latter types of projects are undertaken by the private sector. However, the governments in the developing world do not really have this liberty as private sector does not contribute much towards financing the R&D and innovation activities. This puts additional burden on public sector in developing economics.

Developing countries, in general, also do not have well-established research systems (Kroll and Stahlecker, 2012). In most of the developing countries, research systems are still in the elementary phase or going through the evolution stages and, lack the capacity to compete at the international level. This presents a three-pronged problem; first, a large portion of the public sector R&D funding goes towards building research systems instead of actual R&D activities; second, under-developed research system are unable to perform and produce desired results or direct socioeconomic benefits; and third, nascent research system cannot attract funds from international donors which results in their sole dependence on national public sector funding.

The efforts to support commercialization in the industrial sector are also less effective in the developing world due to various reasons such as low absorptive capacity of the local industry, lack of knowledge transfer through FDI, perceived lack of need for technological upgrading by the private sector etc. In many cases, R&D activities of the private sector in developing economies can be considered as "market adaptation" rather than "research" which does not provide a natural basis for science-industry co-operations.

R&D funding, in developing countries, faces several other problems such as unavailability of sufficient funding, little and inadequate incentives for private sector to invest in R&D, mismatch and inconsistency in the funding mechanisms and R&D activities. Quite often the funding agencies in the developing countries are unable to comprehend the nature of R&D activities. In order to carry out R&D projects, R&D organizations require sustained and long-term financing but very often public funding is short term and uncertain, which possesses many difficulties for the grant recipients (Wilson and Hecht, 2007).

Also, funding systems in developing countries are often inflexible and do not allow the rapid flow of funds to the most promising R&D organization or best project. Furthermore, the policies and funding mechanisms for encouraging private sector investment in R&D are not good enough to overcome the risks, both commercial and scientific, associated with investments in R&D. For example, in drug development forecasting, the demand or prices of certain product in the markets in developing countries is very difficult due to little information and lack of buy-back guarantee (Hecht *et al*., 2009).

In general, there is a long lag time between R&D funding and when the socioeconomic benefits reach to the society and, often these benefits are also indirect. This puts governments in the developing countries in a dilemma whether to allocate funds for R&D, or other activities which bring more immediate and direct socioeconomic benefits to the society.

R&D AND INNOVATION FINANCING IN PAKISTAN

1. Historical overview of R&D funding in Pakistan

R&D and innovation are regarded as increasingly important for social progress and economic growth. Over time, investments on R&D have increased significantly in many parts of the world. Expenditure on R&D is considered to be one of the leading indicators for benchmarking the R&D performance of countries within an international setting.

A review of the trend of R&D expenditure of Pakistan during the last 25 years reveals that Pakistan's total R&D expenditure (in Pak Rupees) has increased consistently from 1988-89 till the latest

available data, i.e., 2014-15, however, in terms of US dollars, it has shown fluctuation. R&D expenditure in US dollars reached to its maximum in 2006-07 when it was about US$ 960 million; since then it has shown consistent decrease with slight increase in 2014-15 (Fig. 1).

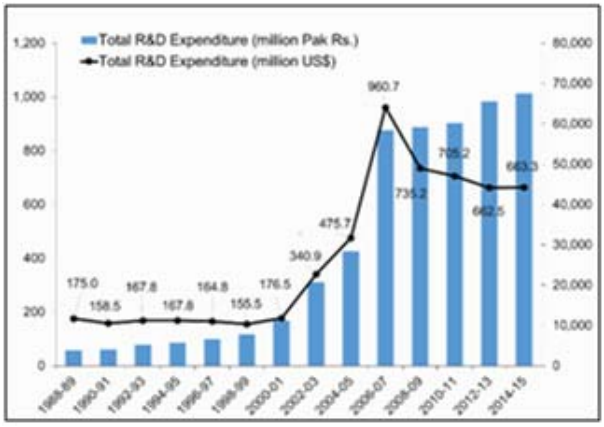

Fig. 1: Trend of total R&D expenditure in Pakistan.

Source: Pakistan Council for Science and Technology, Islamabad.

Generally, the measure of R&D expenditure as percentage of GDP is used for comparison between countries. Study of the R&D expenditure as percentage of GDP of Pakistan, over-time, shows that it has been fluctuating between 0.25% and 0.67% (Fig. 2). It reached to its peak (0.67% of GDP) in 2006-07 and since then, it has shown consistent decline. Current expenditure of 0.25% of GDP is the lowest in last 25 years (Fig. 2).

The figure of 0.67% of GDP (the highest for Pakistan) was even quite short of the world average spending on R&D (0.99% of GDP; calculated on the basis of 117 countries for which data was available) and the minimum recommended by UNESCO for developing countries (1% of GDP).

Fig. 2: Trend of R&D expenditure as percentage of GDP in Pakistan.

Source: Pakistan Council for Science and Technology, Islamabad

R&D spending is considered as an important indicator of competitiveness of a country's economy; therefore, many countries have set a target of investing at least one percent of their GDPs on R&D. Most of the developed countries spend more than 2% of their GDP on R&D, while the countries like South Korea and Israel spend more than 4% of their GDP on R&D. The pace of technological progress of any country is directly proportional to its R&D efforts. The expenditure level on R&D, therefore, could act as a reliable indicator of the country's priorities and prospects to enhance its national technological and innovative competence.

Comparison of R&D expenditure of Pakistan as % of GDP with other countries shows that Pakistan is spending much less than the industrialized countries and the countries which are observing rapid economic growth like Malaysia, Brazil, Turkey and India (Fig. 3). Pakistan's total expenditure (in Pak Rupees) has shown consistent increase (Fig. 1), however, when compared with other countries, a huge gap is observed (Fig. 4). Pakistan's R&D expenditure is more than 216 times less than USA and about 73 times less than Japan. It is even about 22 times less than India and about 7 times less than Turkey.

National Science, Technology and Innovation Policy 2012 of Pakistan required the "declaration of the political will that S&T capacity building would be a central pillar of national development strategy and the R&D expenditure would be enhanced to 2.0% by 2020". However, there are no obvious signs of this happening.

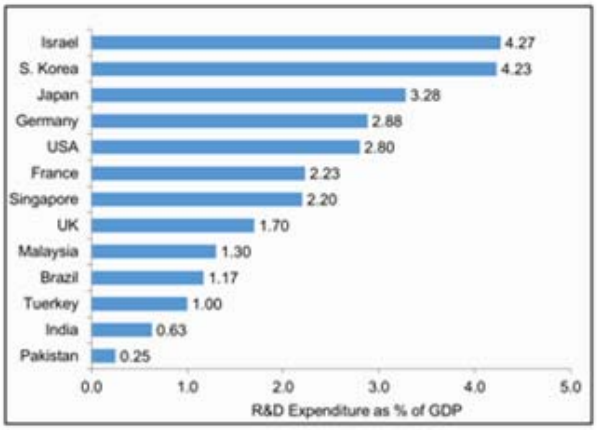

Fig. 3: Comparison of R&D expenditure as % of GDP of Pakistan with some selected countries.

Source: UNESCO Institute of Statistics database.

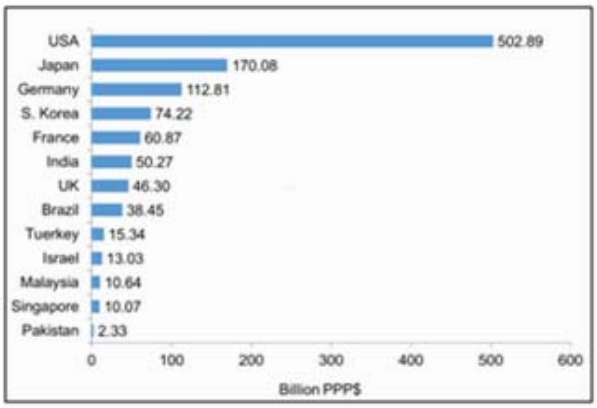

Fig. 4: Comparison of total R&D expenditure (Billion PPP$) of Pakistan with some selected countries.

Source: UNESCO Institute of Statistics database.

2. Share of private sector in financing R&D in Pakistan

The private sector (industry and civil society) has increasingly assumed more responsibility in financing R&D and innovation in developed countries, while government's role is that of a coordinator between relevant public and private institutions. As a result thereof, the private sector has become the major sponsor of R&D activities in many parts of the world. In Israel and Japan, the share of the private sector in the total national R&D expenditure is about 80%. Even in India, the share of private sector in the national R&D expenditure is estimated about 29% while in Pakistan, share of private sector is negligible (only 5% which is a broad estimate, as no real data is available) (Fig. 5).

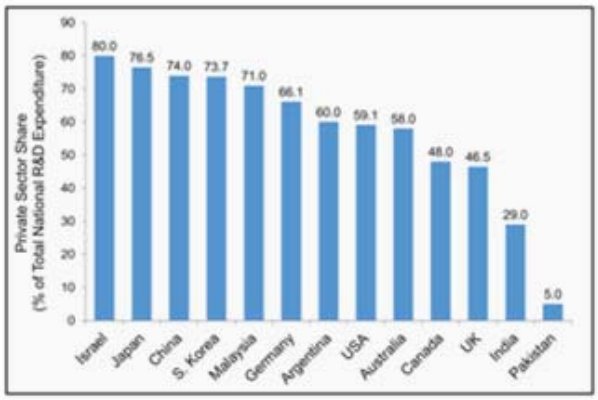

Fig. 5: Comparison of share of private sector in total national R&D expenditure of Pakistan with some selected countries.

Governments in the developing economies, through appropriate incentives, can enable industrial sector to function as "engines" of growth. The incentives to the industry for undertaking R&D and innovation activities may be either in terms of monetary benefits like tax and custom duty rebates or through direct support, such as provision of R&D funding, testing facilities and trained manpower. The incentives should be designed to promote indigenization, promotion and diffusion of technology and promote R&D at the firm level. The Federal Board of Revenue (FBR) is fully cognizant of the fact that industries in Pakistan need to develop capabilities for carrying out innovation and intensive R&D activities for producing products which can meet local needs as well as compete in the world markets. In this connection some incentives in the form of rebate/exemption of custom duty on R&D materials and equipment and income tax have already been approved and granted. However, they have failed to produce desired results; the reason may be that they are not sufficient or it may be due to the lack of realization (by the industry) of the importance of R&D and innovation to compete and survive in the global market.

Pakistan's telecom industry has registered extraordinary growth and, as a result, the government has mandated the telecom service providers to allocate a certain percentage of their gross revenue to R&D in the ICT sector. For this purpose, an ICT R&D Fund (IGNITE) has been created with the vision to transform the country's economy into a knowledge based economy (https://ignite.org.pk)

Under the Ministry of Health, a 'Central Research Fund' has been created for the promotion of research and development, where the pharma companies are contributing 1% of their profits since 1976. Unfortunately, this research fund has mostly remained unused resulting in very little research with negligible impact on pharma industry (PPMA, 2017).

PROPOSED WAY FORWARD FOR PAKISTAN

Pakistan has successfully establishment a good S&T infrastructure in the form of a network of 174 Higher Education Institutions (HEIs) and around 85 S&T/R&D organizations. However, in general, R&D activity in Pakistan has been neither linked with industry nor oriented to society. Consequently, overall performance of national innovation system is not up to the mark resulting in positioning Pakistan towards the lower end of the ladder in international comparisons. Pakistan has very low ranking in the Global Innovation Index 2017 i.e. 113 out of 127 countries (GII, 2017) and the Global Competitiveness Index 2017-18, i.e., 115 out of 137 countries (GCR, 2018).

To rectify the situation, Pakistan needs to increase its national R&D spending manifold within a relatively short span of time. This is extremely difficult particularly if private sector is not involved in conducting and sponsoring R&D in the country. It is pertinent to mention here that the developed economies, over time, have been successful in engaging industry in funding and conducting R&D activities; today a significant portion of R&D funding in these countries comes from the industry. In the United States, industry's share in total R&D expenditure raised up to 69% in the year 2000 from only 31% in 1963. In 2012, 63% of all R&D spending in the U.S. came from industry sources (SSTI, 2015).

In the developing countries like Pakistan, a major part of the budget of the public sector R&D organizations is spent on salaries of their human resources, the administrative expenditure and other non-R&D activities. Budget allocation for conducting actual research in these organizations is very low. Although salaries are important to attract and retain highly qualified scientists and engineers which constitute the knowledge-base of an R&D organization but without funding for carrying out actual R&D work, the technical human resource is less effective and productive. It is, therefore, of utmost importance that the public sector R&D organizations properly clarify the traditional sub-heads of spending within the S&T budget. They may earmark at least 30% to 40 % of the overall budget for conducting the actual "R&D". This will improve the performance of the public sector R&D organizations

and the socioeconomic benefits derived from their output.

There is no doubt that the public sector of Pakistan urgently needs to increase its R&D spending and take initiatives to elevate the standard of science and technology in the country. However, current study focuses on the contribution of the private sector and proposes different mechanisms and approaches which may be considered and adopted for encouraging and engaging industry and civil society in patronage of R&D activities in Pakistan. Effort has been made to identify models from within the country so that they can be replicated at the larger scale. Where such models do not exist in the country, examples have been provided from other countries.

1. Endowment professorships/chairs

Industry and civil society organizations or individuals, through an endowment fund, provide emoluments of persons with appropriate qualifications and experience who are employed by an institution (university or R&D organization), where they are involved in teaching and/or conducting research in specified fields.

A successful local example, in this regard, is the Aga Khan University, where 'endowment professorships/chairs' exist in almost every department. As per information available on the website of the University, "an endowed professorship is a position permanently paid for with the revenue from an endowment fund specifically set up for that purpose. Typically, the position is designated to be in a certain department. Endowed professorships help the University by providing a faculty member who does not have to be paid entirely out of the operating budget, allowing the university to either reduce its student-to-faculty ratio, and direct money that would otherwise have been spent on salaries toward other University needs. Endowed professorship is not only considered as a high academic award for a faculty member but is also a recognition of their contributions at various levels of their academic career" (AKU, 2016).

Universities in the US like Massachusetts Institute of Technology (MIT), Yale and Stanford have set up endowments. For example, at the end of the fiscal year ending 30th June 2015, "MIT's endowment funds totaled $13.5 billion, excluding pledges. MIT's endowment is intended to support current and future generations of MIT scholars with the resources needed to advance knowledge, research, and innovation" (MIT, 2016).

2. Donations/grants for establishing/upgrading institutions

With the donations/grants from industry or civil society the 'Centers of Excellence' can be established. The institutes can be renamed on the donator's name as an acknowledgement of the donation. A prime example of this approach is the prestigious HEJ Research Institute of Chemistry, Karachi. In 1976, one of the leading philanthropist/industrialist, Mr. Latif Ebrahim Jamal donated, the largest donation of its time in Pakistan, on behalf of the Husein Ebrahim Jamal Foundation to upgradge the postgraduate Institute of Chemistry in the Department of Chemistry, University of Karachi which was originally established in 1967. In recognition of this support the institute was renamed as "Husein Ebrahim Jamal (HEJ) Research Institute of Chemistry" that was further established as International Center for Chemical and Biological Sciences (ICCBS). Currently, it comprises Dr. Panjwani Center for Molecular Medicine and Drug Research (PCMD) and the H.E.J. Research Institute of Chemistry. At present, the number of doctorate level students at HEJ is over 280 conducting research in areas like natural product chemistry, protein chemistry, computational medicinal chemistry and plant biotechnology, etc. (HEJ, 2018).

Another example could be the infrastructure of Aga Khan University and Hospital where majority of the buildings, including research centers (e.g., Juma Research Centre), university auditorium and lecture halls are established through donations from the community. One of the prominent elements of the university infrastructure, where, high quality research is being carried out since 1999, is the Research Laboratory of the Juma Building. Some key areas of research in this facility include immunohisto-chemistry, bacteriology, cell and molecular biology, virology, genetics, parasitology, cancer and tissue banking.

3. Endowment grants to institutions for specific activities

Industry and civil society organizations or individuals, provide endowment grant to a non-profit organization usually working in a specific area or specialized field of research. The non-profit organization may be a research institute (independent or affiliated to a university), center of excellence or specific laboratory in a specialized field. A simple example of this is the Natural Sciences Linkage Programme (NSLP) of the Pakistan Science Foundation, where R&D projects are being funded from the profit of an endowment fund received from the government of US.

4. Collaborative research

Collaborative research is undertaken by a team comprising researchers from academia/public sector R&D organizations and private industry. The project can be either funded by government, industry or a third party. Usually, this sort of project runs for a specific period of time and it has pre-set targets.

The joint research projects are supported by the Carnegie Trust for the Universities of Scotland' under its 'Collaborative Research Grants Scheme' for collaborative research by researchers from multiple universities of Scotland for advancement in the areas of expertise of the researchers; provided that the

planned research is of high quality and benefits to the research consortium. Project duration may vary from 1 to 3 years.

5. Sponsored research/contracted research

Since long, universities have been playing central role in solving problems of the industry and society. In the sponsored or contracted research, R&D organization (normally, a university) enters into a contract with industry wherein responsibilities of both parties are fixed. Under the contracted research, industry fully sponsors the research project and university is responsible for undertaking the research activities to achieve the target as suggested by the industry.

6. Matching grants

The concept is in practice in advanced and some developing nations whereby government funds 50% of the total amount and 50% is contributed by industry or civil society organizations. Matching grant is conditional grant for the projects of applied nature. It is also important to mention here that government releases the amount to an R&D organization/ university only when the equal amount is received from the beneficiary (industry/society).

OECD countries have successfully implemented the concept of matching research funding. For example, the Florida High Tech Corridor Council Matching Grant Research Program (MGRP) rewards Florida-based high technology companies that partner with the University of South Florida researchers. Matching funds are available from US $10,000 to 150,000/-, subject to the condition that a partner from the private sector provides at least two ratio one (2:1) matching cost either in cash or kind or both. During 2013-14, 21 new projects with 18 companies were awarded to the University of South Florida, under the Matching Grants Research Programs of the university.

The awards totaled US$ 1,233,086 from the Florida High Tech Corridor Council with industry partners providing cash of US$ 1,092,683. Additionally, industry sponsors provided US$ 1,449,955 worth of in-kind support for a total investment of US$ 3,775,724 in the program. The matching ratio was more than 2:1. The average total project value was US$ 175,796 with an average award of US$ 58,718. These projects supported 52 students and 32 faculty members.

7. R&D tax credit incentive

This is a mechanism in which incentive of tax credit is provided to a firm for carrying our R&D initiatives both inside and outside of firm through sponsorship.

Many countries including advanced, newly emerged and fast emerging economies enhance their domestic business growth by supporting their R&D initiatives through efforts such as incentives on tax. For example, in Australia, up to 45% eligible R&D expenditure is provided as tax credit, whereas, China provides 150% of eligible R&D expenditure in the form of super deduction.

For a comprehensive detail of R&D incentives being provided in different countries, “Worldwide R&D Incentives Reference Guide 2014-15” (EY, 2015) and Global Survey of R&D Incentives 2015 (Deloitte, 2015) may be referred.

8. Fellowships/Scholarships

Industry or civil society organizations or individuals may provide fellowships/scholarships (which may include fees for hiring R&D experts, grants for chemicals, equipment and stipends for students’ research, etc.) for M.Phil and/or Ph.D scholars at higher education institutions to conduct their research work on topics which are of interest of industry or civil society organizations or individuals. Fellowships/scholarships may be provided through endowment funds or on the basis of ‘one-time’ donations. Higher education institutions link the award of student degrees with the successful completion of the task or goal of the industry/society.

This sort of fellowships/scholarships is offered by various national and international firms/companies, such as, Procter & Gamble, Toshiba, Glaxo-Smith-Kline fellowships or scholarships.

9. Awards/Prizes

Industry or civil society organizations or individuals may institute awards/prizes to be awarded on regular basis to individual researchers or organizations for their R&D achievements in a specific area.

Each year the American Chemical Society (ACS) recognizes the creativity and innovativeness of scientists that has a commercial value, in the field of chemical engineering and chemistry, through its Heroes of Chemistry program.

In 2015, The American Chemical Society bestowed awards to six (6) teams of scientists from different companies for their achievements. To encourage and motivate research and innovation NUST also gives “Best Researcher Award” and “Best Innovation Award” amounting to Rs. 100,000/-, each to young researchers and scientists every year (NUST, 2016).

CONCLUSION

According to the reviewed literature developing countries have their own limitations to finance innovation and other R&D activities particularly in public sector. Also provision of funds in sufficient quantities and its sustainability is a major issue. Private financial instruments, such as, venture capital, has its limits, e.g., its focus is on a few areas at a time, has minimum investment limits that are too high for SMEs and new entrants. Also the initial stage investors are dependent on market size and stability for their exit strategy. More importantly there are not many venture capital companies in the developing

countries which can provide financing for R&D and innovation projects. The investors are reluctant to invest in R&D and innovation activities and projects due to their uniqueness.

Studying and analyzing the financing of R&D and innovation in Pakistan reveals that almost all of the funding comes from the public sector. The private sector funding is assumed to be negligible, however, no exact data is available. This is in sharp contrast to the private sector spending in the R&D by the emerging and developed economies, where the private sector share can go as high as 80% of the total R&D spending. In the public sector funding of R&D in Pakistan, there are serious sustainability issues as extensive fluctuation has been observed in the data of last 25 years; R&D spending fluctuated between 0.25% and 0.67% of GDP. Therefore, it can be concluded from the overview of the R&D funding in Pakistan that insufficient and unsustainable funding are the two major issues of R&D funding in Pakistan.

Due to the limited financial resources available and pressing immediate needs of the society, the public sector, in Pakistan and other developing countries, alone cannot meet the level of funding required to be devoted to R&D and innovation activities for deriving long term socioeconomic benefits from these activities. Therefore, both the private sector and civil society have to be engaged in sharing funding of R&D and innovation.

Different approaches and mechanisms need to be explored and adopted for attracting, and a meaningful engagement of the industry and civil society and encouraging them to play their due role to promote and patronize R&D and innovation activities in Pakistan.

REFERENCES

Acs, Z.J. and D.B. Audretsch, 1990. Innovation and small firms. MIT Press, Boston.

Audretsch, D.B., 2006. Entrepreneurship, innovation, and economic growth, Edward Elgar Publishing, Cheltenham, UK.

ADB, 2011. Asia 2050: Realizing the Asian Century. Metro Manila: Asian Development Bank (ADB).

Ali-Yrkkö, J., 2005. Impact of public R&D financing on private R&D: Does financial constraint matter? European Network of Economic Policy Research Institutes (ENEPRI) Working Paper No. 30/ February 2005.

AKU, 2016. Supporting AKU. https://www.aku.edu/supportus/where-to-give/Documents/giving-guidelines.pdf

Bar-Efrat, O., 2006. Research and development in Israel: Successes and challenges. http://www.boi.org.il/deptdata/papers/paper10e.pdf.

Binz, H. and D. Czarnitzki, 2008. R&D investment and financing constraints of small and medium-sized firms. Discussion Paper No. 08-047. Centre for European Economic Research (ZEW), Mannheim. ftp://ftp.zew.de/pub/zew-docs/dp/dp08047.pdf

Bond, S., D. Harhoff and J. Van Reenen, 2005. Investment, R&D and financial constraints in Britain and Germany. Annales d'Économie et de Statistique, 79/80: 435-463.

Brautzsch, H.U., J. Günther, B. Loose, U. Ludwig and N. Nulsch, 2015. Can R&D subsidies counteract the economic crisis? – Macroeconomic effects in Germany. Res. Policy, 44(3): 623–633.

Czarnitzki, D., 2006. Research and development in small- and medium-sized enterprises: The role of financial constraints and public funding. Scottish J. Polit. Econ., 53(3): 257-335.

Czarnitzki, D. and H. Hottenrott, 2011. R&D investment and financing constraints of small and medium-sized firms. Small Bus. Econ., 36(1): 65–83.

Deloitte, 2015. Global survey of R&D incentives 2015. Deloitte Touche Tohmatsu Limited.

Diaconu, M., 2013. The financing of R&D: Challenges for Romanian firms. Studies and Scientific Researches (Economics Edition). No 18, 2013.

European Commission, 2010. Europe 2020 strategy – A strategy for smart, sustainable and inclusive growth. European Commission, Brussels.

EY, 2015. Worldwide R&D incentives reference guide 2014-15. EYGM Limited.

Frinking, E., M. Hjelt, I. Essers, P. Luoma and S. Mahroum, 2002. Benchmarking innovation systems: Government funding for R&D. national technology agency, Helsinki, Finland.

GCR., 2018. The Global Competitiveness Report 2017–2018. World Economic Forum, Geneva.

GII., 2017. The Global Innovation Index 2016. Cornell University, INSEAD, and the World Intellectual Property Organization.

Gompers, P. and J. Lerner, 1998. Venture capital distributions: Short-run and long-run reactions. J. Finance, 53: 2161-2183.

Griliches, Z., 1992. The search for R&D spillovers. Scand. J. Econ., 94: 29-47.

Hall, B.H., 2002. The financing of research and development. Oxf. Rev. Econ. Pol., 18(1): 35-51.

Hall, B.H., 1996. The private and social returns to research and development. In: B.L.R. Smith and C.E. Barfield (Eds.). Technology, R&D, and the Economy. 140-83. Brookings Institution and the American Enterprise Institute, Washington, DC.

Hall, B.H., 1993. R&D tax policy during the eighties: Success or failure? Tax Pol. Econ., 7: 1-36.

Hall, H.B. and J. Lerner, 2009. The Financing of R&D and innovation. In: Handbook of the Economics of Innovation. Vol. 1, edited by

Bronwyn H. Hall and Nathan Rosenberg. Elsevier, 2010.

Hall, H.B., J. Mairesse and P. Mohnen, 2009. Measuring the returns to R&D. Working Paper 15622. National Bureau of Economic Research, 1050 Massachusetts Avenue Cambridge, Massachusetts. http://www.nber.org/papers/w15622.

Hecht, R., P. Wilson and A. Palriwala, 2009. Improving health R&D financing for developing countries: A menu of innovative policy options. Health Aff., 28(4): 974-985.

Howell, S.T., 2015. Financing constraints as barriers to innovation: Evidence from R&D grants to energy startups. http://scholar.harvard.edu/files/showell/files/howell_innovation_finance_jmp_jan17.pdf

HEJ, 2018. Hussain Ebrahim Jamal Research Institute of Chemistry. https://en.wikipedia.org/wiki/Hussain_Ebrahim_Jamal_Research_ Institute_of_Chemistry

Jeng, L. and P. Wells, 2000. The determinants of venture funding: evidence across countries. J. Corp. Finan., 6: 241–89.

Kroll, H. and T. Stahlecker, 2012. Global review of competitive R&D funding. Fraunhofer Institute for Systems and Innovation Research (ISI), Karlsruhe, Germany. P. 33.

Meuleman, M. and W. De Maeseneire, 2008. Do R&D subsidies affect SMEs' access to external financing? Vlerick Leuven Gent Working Paper Series 2008/12.

MIT, 2016. MIT releases endowment figures for 2015. http://news.mit.edu/2015/institute-endowment-figures-0911

NSF, 2014. US lead in science and technology shrinking. National Science Foundation, USA. http://www.nsf.gov/news/news_summ.jsp?cntn_id=130380

NUST, 2016. Centre for Innovation and Entrepreneurship Research, Innovation & Commercialization (RIC) Policy Document, 2012, (www.nust.edu.pk /Research/Site Assets /Pages/.../RIC_Policy_Final_17_May_12.pdf)

PPMA, 2017. Pakistan's Pharmaceutical Industry. http://www.ppma.org.pk/wp-content/uploads/2017/09/Final-Report-Pharma-Industry_August-10.pdf

PC, 2014. Pakistan 2025. Planning Commission, Ministry of Planning, Development and Reform, Government of Pakistan. P. 106.

Plumer, B., 2013. The coming R&D crash. https://www.washingtonpost.com/news/wonk/wp/2013/02/26/the-coming-rd-crash/

Poterba, J., 1989. Venture capital and capital gains taxation. In: L. Summer, (Ed.), Tax Policy and the Economy. MIT Press, Cambridge, MA.

Poterba, J., 1987. How burdensome are capital gains taxes? Evidence from the United States. J. Public Econ., 33: 157–72.

Romney, M., 2010. No apology: The case for American greatness. St. Martin's Press, United States, p. 336.

Romer, P.M., 1990. Endogenous technological change. J. Polit. Econ., 98(5): 71-102.

SSTI, 2015. The Changing nature of U.S. basic research: Trends in funding sources. http://ssti.org/blog/changing-nature-us-basic-research-trends-funding-sources

Scherer, F.M., 1998. The size distribution of profits from innovation. Ann. Econ. Stat., 49/50: 495-516.

Shahid, J., 2018. Is research and development still not a priority for the government? Dawn. https://www.dawn.com/news/1404297

Shahid, J., 2016. Govt urged to increase spending on R&D. Dawn. https://www.dawn.com/news/1244723

Wilson, P. and R. Hecht, 2007. Financing of vaccine R&D – gaps and opportunities for innovation. In: Global forum update on research for health – Equitable access: research challenges for health in developing countries, 4: 88-93. Pro-Book Publishing Ltd.

www.https://en.wikipedia.org/wiki/Venture_capital

https://www.aku.edu/research/facilities/Pages/research-lab.aspx

http://www.carnegie-trust.org/schemes/research-schemes/larger-grants.html

http://www.floridahightech.com/assets-why-the-corridor/research-grants/

http://www.pcst.org.pk/docs/STIIndicators2013.pdf

http://www.uis.unesco.org

https://ignite.org.pk

..