

Excellence in Innovation and Knowledge Economy

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1 Introduction

This chapter addresses the challenge for middle-income and technologically developing countries to reach sustainable high levels of welfare based on R&D, innovation, and education. The initial discussion focuses on the middle-income trap, and subsequently proceeds to the discussion of the key components of an R&D, innovation, and entrepreneurship system intended to overcome this trap. The key components are built upon four categories of best practices. The first two categories are best practices to foster entrepreneurship (techno-entrepreneurship, venture, entrepreneurship culture) and mission-oriented programs, including mega projects. The third and fourth categories are stimulating research quality (performance-based funding schemes) and supporting the innovation system with R&D awareness. The best practices are drawn from leading examples of policy mechanisms from the Republic of Turkey, the US, South Korea, Japan, Brazil, India, China, Singapore, Mexico, and EU countries (UK, Sweden, Finland, and the Czech Republic). The chapter concludes with policy advice and key recommendations to improve innovation excellence in technologically developing countries, including implications for oil-rich countries.

2 R&D and Innovation to Overcome the Middle-Income Trap

The fast pace of technological developments in our age imposes a challenge to middle-income and less technologically developed, high-income countries to strive to reach the highest peak in R&D and innovation. This challenge is none

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other than the ambitious process of seeking to ascend an apex of excellence in a pursuit of ‘excellence in innovation.’ On this path, countries may be faced with barriers that may hinder them from making full use of their potential in order to rise toward the peak. Most notably, these barriers may be associated with the state of the innovation system and its integrity when compared to the progress of economic growth. In such a situation, countries must surmount another hurdle, this time to rise up to the challenge of transforming their economy into one that is based on knowledge and innovation. In a technical sense, countries must overcome the situation of what is known as the “middle-income trap” to reach the status of a knowledge-based economy in a relatively short period of time.

The concept of the ‘middle-income trap’ defines a condition in which middle-income countries are restricted in their ability to increase gross national income (GNI) per capita despite their efforts to do so. A similar situation applies to technologically less advanced, high-income countries, such as the Kingdom of Saudi Arabia (KSA), which need to develop ascending strategies other than the exploitation of natural resources. In this condition, the income of a country increases sufficiently to enable it to advance beyond low-skilled labor-intensive activities. Yet, since the innovation system, including its physical and human capital, has not been developed sufficiently, the quality of the outputs of the country remains underdeveloped. This limits the country’s capability to compete with high-income countries in highly sophisticated products. The country continues to remain behind advanced economies in higher-value products, that in turn affects their relative standing in GNI per capita values [1, 2].

Figure 1 compares countries based on the level of their progress in GNI per capita values over a 50-year timeframe. The axes are based on GNI per capita in 1963 and 2013, respectively. In Fig. 1, those countries that sustained their growth are positioned in the top-right corner, while those that escaped the middle income trap and experienced a quantum leap in GNI per capita values are grouped top center. The countries that remained in the middle-income trap are situated in the boxed area in the center of Fig. 1 (see red box), while those countries that become poorer are located in the bottom half. The axes are the logarithm of the ratio of GNI per capita values relative to the US values in 1963.

2.1 Comparative Perspectives for the Middle-Income Trap

Numerically, the threshold for escaping the middle-income trap and graduating to the high-income status is defined as requiring a GNI per capita of \$12,746 at 2011 prices [3]. The number of economies that made this transition is limited [4]. Only about one quarter of the current OECD member countries succeeded in doing so [5]. The middle-income trap is also persistent in emerging economies since economic growth tends to slow down once the lower hanging fruits of technology transfer are harvested. In contrast, those countries that succeeded in making the transition have one important feature in common: they have excelled in developing advanced, indigenous technologies and in investing in education.

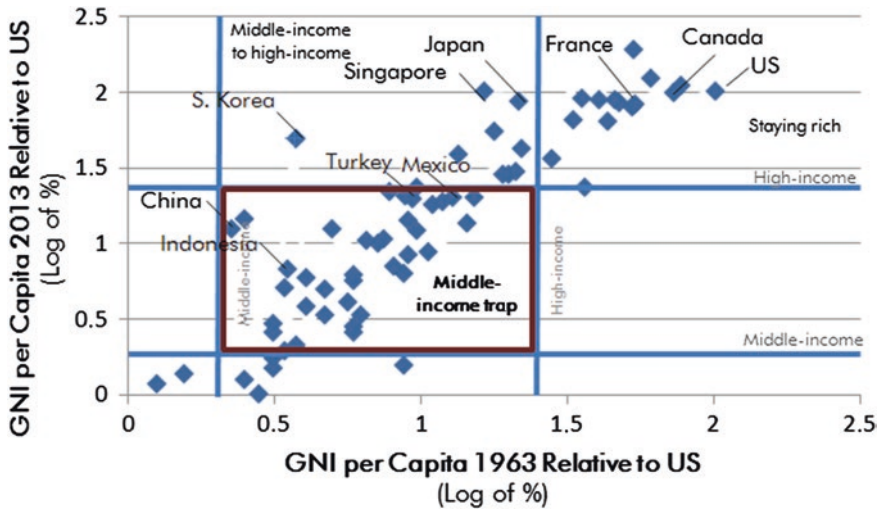


Fig. 1 Depiction of the relative standing of countries over a 50-year timeframe (redrawn for current years based on World Bank dataset [3]. Original graph is provided for 1960 and 2008 in Ref. [4])

Based on relative GNI per capita values over the course of 50 years, Fig. 1 indicates that countries such as the US, Canada, and France have sustained their economic growth. South Korea, Japan, and Ireland have overcome the middle-income trap and are now their challengers. The next group of countries is the group that remains in the middle-income trap. China, Indonesia, Mexico, and Turkey are examples of countries in this area, although this does not necessarily signify lack of progress. Based on the Global Competitiveness Report [6], both Mexico and Turkey are indicated as countries in ‘transition’ to innovation-based economies. In contrast, some of the oil-rich countries, such as Saudi Arabia, will be placed above the middle-income trap. The GNI per capita of Saudi Arabia was \$26,260 [3] (log of percentage relative to US GNI per capita in 1963 is 1.71), close to the level of South Korea.¹

Table 1 compares three countries that have overcome the middle-income trap to become innovation-based economies with four countries that remain in the trap, but exhibit important signs of progress. The latter also includes the efficiency-based economies of China and Indonesia. For the sampled countries, Table 1 provides the values of gross domestic expenditure on research and development (GERD) and educational investment, both given as percentages over the values of gross domestic product (GDP).

For the innovation-based economies in Table 1, the average value of GERD over GDP is 3.2 %. For South Korea, Japan, and Taiwan the values are 3.4, 3.3, and 2.9 %, respectively. The average value for educational investment as a

¹Saudi Arabia is not included in Fig. 1 due to lack of data for 1963 in the World Bank dataset.

Table 1 Comparison of countries based on GERD and educational investment over GDP (2012) [7–12]

Innovation-based economies		
Countries	GERD/GDP (%)	Educational investment/GDP (%)
South Korea	3.4	7.6
Japan	3.3	4.9
Taiwan	2.9	5.8
<i>In transition to innovation-based economies</i>		
Mexico	0.4	3.5
Turkey	0.9	3.2
<i>Efficiency-based economies</i>		
China	1.7	3.3
Indonesia	0.7	3.3

percentage of GDP is 6.1 %. For example, South Korea invests in education at 7.6 % of its GDP, whereas Taiwan and Japan invest at 5.8 and 4.9 %, respectively. Certainly, GERD and educational investments over GDP are relatively high in these countries.

For those countries that are in the middle-income trap, the values of GERD and educational investment over GDP are comparably lower. The average values for Mexico and Turkey that are in the middle-income trap, but in the process of transition to innovation-based economies, are 0.7 % for GERD and 3.4 % for educational investments, both over GDP. The GERD of Mexico stands at 0.4 % of GDP while investment in education is relatively higher at 3.5 % of GDP. The GERD of Turkey is higher at 0.9 % of GDP and the investment in education is 3.2 % of GDP. The average values for China and Indonesia, which are in the middle-income trap as efficiency-based economies, are 1.2 % for GERD and 3.3 % for investment in education, both over GDP. Indonesia invests the same share in educational investments as China but spends less on R&D as a share of GDP. In contrast, while the value of GERD over GDP is only 0.7 % in Indonesia, it is 1.7 % in China. Even within the middle-income trap, GERD and educational investments over GDP vary for countries that are in a state of transition to innovation-based economies and efficiency-based economies.

2.2 *The Key Role of R&D, Innovation, and Education*

Clearly, the ability of countries to realize an ‘exit strategy’ to escape the middle-income trap requires an intense effort marked by high levels of investment in GERD and education as shares of GDP. At the same time, these key investments must be matched by an efficient innovation system to transform these inputs into high value-added outputs. This two-pronged approach defines the paradigm shift that countries must implement in order to provide the necessary groundwork for the opportunity to escape from the middle-income trap and become

innovation-based economies. While there is no single method for countries to execute such a paradigm shift, countries have to develop strategies to increase outputs of knowledge-intensive technologies and high value-added products. This, in turn, depends on the ability to establish the necessary “ecosystem” between actors to trigger R&D, innovation, and entrepreneurship activities as a launch pad to excel in innovation.

A diverse array of tools and mechanisms are implemented by various countries to promote a flourishing ecosystem for the innovation actors. These mechanisms are discussed from the perspective of international comparison in Sect. 3, based on best practices in emerging, fast-growing, and developed countries. For the purposes of this chapter, these best practices are grouped into four main headings that define ways and means to stimulate and sustain the R&D, innovation, and the entrepreneurship ecosystem. The first two headings are best practices to foster entrepreneurship, including techno-entrepreneurship and venture capital, and best practices in mission-oriented programs and mega projects. The subsequent two headings involve best practices for the stimulation of research quality and best practices for supporting the innovation system through raising awareness and fostering a culture in R&D, innovation, and entrepreneurship among the related actors. In analogy, these best practices provide some of the “keys” that countries can use to “unlock” a path to exit the middle-income trap. For ease of reference, the key concepts can be identified as entrepreneurship, prioritization, fostering research quality and quantity, and raising awareness of R&D culture.

Some of these best practices may be equally valid for countries that appear to be high-income economies. Some countries have attained this level based on the abundance of their natural resources. Other countries have combined assets from both their stocks of human and natural capital in creating new value-added products and technologies. These best practices will allow innovation systems to rely, not only on abundances in natural resources, but also on wealth in human capital. KSA for example, as a high-income economy, invests only 0.07 % of GDP as GERD [4]. For oil-rich countries such as KSA and other similar countries, this implies that further investment in GERD and education can better mobilize their potential to ameliorate human welfare. For this reason, in a highly competitive world, even those countries that have reached the status of high-income economies need to pursue excellence in innovation to maintain their performance and allow their innovation systems to flourish and excel to the next level.

3 Best Practices to Be an Innovation and Knowledge Economy

For a well-functioning innovation system, it is crucial to strengthen each component of the “ecosystem” in a systems approach. The business sector and entrepreneurs should be at the core of this ecosystem and interact robustly with all other actors. Research activities without business sector linkages will not yield

the desired results, especially for the aim of escaping the middle-income trap. Therefore, it is mandatory to develop the correct set of support tools and mechanisms to manage a ‘complex ecosystem’, while strengthening even the weakest component. These mechanisms should also provide a particular emphasis to the process of commercialization. From the perspective of policy-making and policy design, this approach requires a strategic combination of both qualitative and quantitative policy tools.

3.1 Best Practices to Foster Entrepreneurship

One of the vital aspects of improving the efficiency of the R&D and innovation ecosystem is promoting entrepreneurship based on technological and innovation-driven research. Recently, many countries have realized that the main challenge for the innovation system is not the lack of knowledge or technology, but often the inability to drive these innovations to the market. This realization has resulted in a shift of focus in direct R&D funding among OECD countries. Most OECD countries have now channeled their funding opportunities across the entire R&D and innovation value chain, including the integrated processes leading to commercialization.

Direct support to aid commercialization includes support to encourage collaboration and knowledge transfer among or between firms and scientific institutions. It further includes direct support to foster the growth of high technology start-up firms, stimulate venture capital activity, and accelerate innovation activity relevant to societal challenges. Such forms of direct support allow governments to target specific barriers that persistently affect innovation performance. For entrepreneurship, these barriers may include the lack of co-operation, barriers for small businesses and individual entrepreneurs to commercialize, or high risk in areas that also have high social returns [13]. In this context, best practices to foster entrepreneurship are examined under the topics of techno-entrepreneurship, venture capital, and entrepreneurship culture. These best practices can further improve the ease of doing business within the ecosystem [14].

3.1.1 Techno-Entrepreneurship

The value of an innovative idea increases with commercialization potential. It further increases with the presence of a skilled and qualified techno-entrepreneur capable of taking the idea to the market. For this reason, countries have designed and implemented support mechanisms and programs to encourage techno-entrepreneurship endeavors. Programs that encourage small domestic businesses and/or individuals to engage in R&D and innovation activities with commercialization

potential include the SBIR Program (USA), the Individual Entrepreneurship Multi-Phased Support and Co-Financing Programs (Turkey), and the PRISM Program (India).

The Small Business Innovative Research (SBIR) Program, coordinated by the US Small Business Administration, is one of the most well-known schemes. The program enables small businesses to explore their ideas' technological potential and provides an incentive to profit from their commercialization potential. Eleven federal agencies that have a total extramural R&D budget in excess of \$100 million allocate a certain percentage of their budget to the SBIR Program. Approximately \$2.5 billion is awarded through this program annually [15]. The program has three phases with monetary contracts and/or grants awarded in Phases I and II [16]. At the end of the third phase, small businesses are expected to meet specific R&D government needs and commercialize their ideas.

- Phase I (start-up phase) supports the exploration of the technical merit or feasibility of an idea or technology and awards up to \$150,000 for approximately six months.
- Phase II provides grants to facilitate the expansion of the results that are obtained from the start-up phase. Up to \$1 million for two years is awarded to Phase II grant holders, who will perform R&D work and evaluate the commercialization potential of their idea.
- Phase III is designed to accommodate the time for an innovation to move from the laboratory into the marketplace. Small businesses must find private sector funding or non-SBIR federal agency funding. No SBIR funds are awarded in this phase.

The National Science Foundation's (NSF) implementation of the SBIR Program provides direct linkages between SBIR and some of the other support programs. As one of the schemes, I-Corps provides private sector co-financing and mentorship. Similarly, the National Institutes of Health (NIH) presents the Commercialization Assistance Program (CAP) as a supplementary tool to the SBIR program. CAP aims to provide small businesses in the health sector with business mentorship to raise the commercialization potential of the outputs of SBIR projects.

In Turkey, entrepreneurs are supported for their activities across the entire spectrum from the idea creation to the commercialization stage in an integrated manner. The Individual Entrepreneurship Multi-Phased Support Program (TÜBİTAK 1512) [17] aims to support individuals or technology-based start-up firms with ideas that hold promise for transformation into innovative products and services for the domestic or international markets. The program, which is designed and implemented by the Scientific and Technological Research Council of Turkey (TÜBİTAK), targets various stages of maturity in R&D-based entrepreneurship activities. The program, which has a total of four phases, integrates grant-based financial support with mentorship support opportunities. Entrepreneurs, including academics not familiar with business matters, are given opportunities to receive

training on technical, commercial, and executive issues, as well as mentorship from industrially experienced mentors.

- Phase 1: The program starts with the presentation of a business idea by the entrepreneur to TÜBİTAK. Upon a positive evaluation, the entrepreneur is provided the option of obtaining entrepreneurship training. Phase 1 corresponds to the stage of idea creation and ends with the detailed preparation of the business plan and training.
- Phase 2: Upon further successful evaluation, the entrepreneur receives grant support to realize the business plan and establish the start-up. The start-up is supported with about \$50,000 of seed capital with the aim of having a technological validation of the proposed idea within 12 months. The activities that may be undertaken at this phase include conceptual design, technical and economic feasibility studies, and technological affirmation (pre-prototype, demonstration, simulation, code algorithm, etc.). The entrepreneur also has the option to request mentorship support. Those firms that demonstrate commercial potential in their outputs may directly skip to Phase 4.
- Phase 3: This phase provides grant support to conduct any additional R&D studies that may be needed to further develop the commercialization potential of the outputs of the previous phase. To receive funding for this phase, the entrepreneur must submit a project application, now as an established firm, to the SME R&D Grant Program (TÜBİTAK 1507). In this phase, 75 % of eligible project expenses up to \$250,000 are grant support entitled. These activities may include detailed design, development of a commercial prototype, experiments, and field tests. Projects that pass the technological affirmation phase are evaluated using special criteria. For those projects that complete this phase successfully, firms may receive approval to pass to Phase 4, upon the preparation of a robust commercialization business plan.
- Phase 4: This phase corresponds to the process of facilitating the entrepreneur's access to finance. Upon the request of the firm, TÜBİTAK sends letters to risk capital firms inviting them to be a partner to the project output. In addition, TÜBİTAK organizes project brokerage events to facilitate the commercialization process of the products.

In the two years since the program's inception, a total of 239 R&D start-ups have been successfully created, the majority of which have commercialized their research outputs.

In addition to TÜBİTAK 1512, an additional version of the program was established as the Individual Entrepreneurship Multi-Phased Co-Financing Program (TÜBİTAK 1512/B) with the purpose of facilitating the access of start-ups to equity financing. In this version, large firms are invited to partner with TÜBİTAK to support start-ups by providing incubation, co-financing, mentorship, and the potential of being the first customer of their products. The program increases the entrepreneur's chances of survival in the market. As a means to complement the TÜBİTAK 1512 Program, this version enables entrepreneurs to take advantage of the experience of the private sector and their provision of seed capital

support, office or rent support for a year, technical expert personnel, and business development [17].

In the Indian context, Promoting Innovations in Individuals, Start-Ups and MSME's Program (PRISM), is implemented by the Department of Scientific and Industrial Research (DSIR) of India and applies a multi-staged approach to supporting entrepreneurs. Any individual with an idea can be supported to transform the idea into a commercially viable product or process. In the proof-of-concept stage, up to \$35,000 or 90 % of the eligible project costs are supported. In the following stage, which may include real site tests and demonstration, an additional \$350,000 or 90 % of the eligible project costs can be supported. The duration of the projects can vary between six months and three years, depending on the scope of the idea. As the name of the program suggests, PRISM seeks to 'open up' the full commercialization potential of the idea [18].

3.1.2 Venture Capital

Since R&D investments yield their returns in the medium or even long term, rather than the short term, finding financial support can be a cause of concern for start-ups. This concern has recently triggered developments in designing programs to support or establish venture capital funds. For example, in China different financing opportunities aim to support the quantity and effectiveness of venture capital firms. A government-based funding agency that is related to the Ministry of Science and Technology (MOST), namely the Torch Center, operates the Tech-based SMEs Venture Capital Introductory Fund [19]. The Torch Center provides funds to venture capital firms to subsidize SMEs with seed capital in the approach of supporting the 'fund of funds.' In this scheme, Torch Center encourages and motivates venture capital firms to make equity investments in, and provide investment subsidies to, technology-based SMEs.

Another similar structure is the Start-up Enterprise Development Scheme (SEEDS), run by the government agency that supports Singapore's SMEs, namely SPRING Singapore [20]. The SEEDS Program provides additional capital opportunities for Singapore-based start-up firms that are less than 5 years old. The selection of the start-ups is based on the criteria of the products' innovativeness and/or processes within the domain of the intellectual property of the start-up. These products and/or processes are expected to have strong growth potential across international markets as well as to be in receipt of initial investment by external investors. It is an equity-based co-financing option that enables SPRING to acquire ownership in the company proportional to its investment up to the maximum rate of 20 % and an exit strategy of five years. Based on SEEDS, SPRING acquires the opportunity to be involved in managerial level decisions and to leverage start-ups that have sufficient capability to proceed to the market.

SPRING provides another investment opportunity for start-ups, namely the Business Angel Scheme, which involves a different scheme. In this scheme, the start-up firm is funded by the registered Business Angels in SPRING's portfolio

as opposed to any other external investor. If the start-up is able to obtain investment interest and commitment from any of the Business Angel investors, SPRING has the capacity to potentially match the intended amount (dollar-for-dollar) up to a maximum of \$1.5 million [20]. In addition, like SEEDS, the Business Angel Scheme can acquire equity stakes in the company proportionate to its investments. An advantage of both schemes is that these programs involve experience sharing from SPRING to the start-up. They also provide opportunities for start-ups to benefit from SPRING's investor network.

Another emerging country, Mexico, provides venture capital funds to start-ups as a means to stimulate the entrepreneurial spirit of innovative Mexican firms. The Mexican Ministry of Economy (SE) [21] provides a seed capital co-investment fund for innovative companies, namely the Co-investment Fund Seed Capital. This fund aims to increase the accessibility of seed capital for entrepreneurs and/or companies and seeks to promote the entrepreneurship ecosystem. The funds go directly into the assets of the fund and/or the project in exchange for equity shares in the newly established firms (up to one-year-old firms). Due to the nature of involving equity shares, the ministry invests up to 50 % in the firm. This threshold is based on the concern of not capturing any control of the start-up. The ministry is careful to contribute with equity shares in the innovative firms to promote firms which have market potential. In addition, SE operates a 'fund of funds' initiative that invests in venture capital funds. The Mexico Venture Program targets domestic and foreign funds that aim to trigger innovative activities in the country. With the Venture Program, Mexico enhances the awareness of venture capital investment opportunities throughout the country by sharing risk with the other investors.

Another example from Turkey is the Venture Capital Funding Program (TÜBİTAK 1514). This program was launched to contribute to the creation of a venture capital ecosystem. The program encourages the establishment of new funds that provide venture capital to innovative SMEs by providing grants to fund managers [17]. This ensures the sustainability of the venture capital ecosystem and enhances the financial support that is specific to the maturity level of the venture capital firms. Accordingly, TÜBİTAK can provide grants to domestic and foreign venture capital funds up to 20 % of the size of the fund. The fund is expected to focus on the early stages (seed and start-up) of equity investments and innovative SMEs that have the potential to develop innovative products, services, and/or production processes and domestic technology. The total size of the venture capital funds that received support from TÜBİTAK and are available to invest in start-ups in Turkey has risen to about 700 million USD. Of this amount, about 470 million USD has been raised from foreign venture capital funds [22].

3.1.3 Entrepreneurship Culture

In the process of promoting entrepreneurship, programs that support entrepreneurial activities are a commendable start but are only one of the series of steps required to establish a sufficiently fostering environment. For this reason,

developing ‘entrepreneurial culture’ is as important as launching programs to enable entrepreneurs to enter the innovation arena. At the same time, the Knowledge Triangle [23] emphasizes the key role of linkages among education, research, and innovation actors in order to utilize education and research for innovation. Fostering innovative capacity and entrepreneurship in universities has thus recently been an important policy tool.

The Singapore Government establishes a council in every university to promote the environment of innovativeness and entrepreneurship. Moreover, specific support mechanisms are used in the system to encourage such activities in universities. The University Innovation Fund provides support for various ranges of activities to generate a climate of innovation in universities, such as entrepreneurship trainings, awards, consultancy service procurement from professors with private sector experience, and internships.

As a ranking index including entrepreneurship, the Entrepreneurial and Innovative University Index was prepared for the first time in Turkey in 2012. Now in its fourth year, the 50 most entrepreneurial and innovative universities are announced annually. Through ranking universities according to their entrepreneurial and innovative performances, the index increases positive competition among universities, hence fostering an entrepreneurial and innovative ecosystem. The universities are ranked according to data collection across a set of 23 indicators in five pillars. These pillars are scientific and technological research competence, intellectual property pool, cooperation and interaction, entrepreneurship and innovativeness culture, and last but not least, economic contribution and commercialization [24].

From a system’s perspective, the index is part of a larger strategy to develop a culture and entrepreneurship capability in universities. While the index measures performance, the Capacity Building for Innovation and Entrepreneurship Support Program (TÜBİTAK 1601) supports universities, NGOs, and firms to provide mechanisms for activities including mentorship, training, brokerage events, investor readiness programs, and fundraising events. Under this program, the first call was launched as the University Certification Program for Entrepreneurship (1601.1) that supported undergraduate and graduate entrepreneurship certification programs. In this call, universities are supported in implementing certification programs of a minimum of 120 h aimed at undergraduate and graduate students as well as academic staff for building entrepreneurship capabilities. Following the training program, certificates are granted to the successful entrepreneurs who pass the evaluation examination [17].

3.2 Best Practices for Mission-Oriented Programs and Mega Projects

Even the most successful countries with the most active researchers and facilities may fall short of realizing the potential of their research base. In this situation, it becomes vital to concentrate the dispersed research efforts in a country

around mission-oriented programs. Such an approach combines the bottom-up demand coming from the research base with top-down policies, to focus the country's research effort to increase the impact of research activities. At the international level, there is an increasing trend toward designing policies that combine top-down and bottom-up approaches based on targeted policies. Policymakers, together with relevant stakeholders, tend to analyze the local dynamics as well as global technological developments in pursuit of determining the areas that are to be supported.

The rationale for these policies is generally linked to the need to stimulate innovation in areas where societal needs are pressing (e.g., energy, health, and environment) and/or where government action can complement market mechanisms with minimal financial outlays. To be efficient, such policies must target specific market or systemic failures and their objectives [13]. The priorities may be selected in areas of relative competitive advantage or in areas that need to be developed in the country to address present or future needs. In mission-oriented approaches, programs in areas of priority and large-scale “mega projects” help to accelerate the emergence of technologies for which there is an urgent and time-bound societal need.

3.2.1 Mission-Oriented Programs

As an example from fast-growing BRICS economies, the innovation system of China is known for its mission-oriented approaches for supporting specific R&D and innovation projects in priority areas. China has systematically used the support instrument, namely the National High-Tech R&D Program (863), to develop cutting-edge technologies that are identified in the “National Medium and Long-Term Program for Science and Technology Development of China.” This program is intended to stimulate the development of advanced technologies in a wide range of fields, for the purpose of allowing China to increase its technological capability and to be more independent of the financial burdens of importing foreign technologies [25].

The 863 Program focuses on developing a number of key technologies in the next five to ten years and establishing technological systems of significant value for societal applications. It aims to accelerate the socio-economic development of the country and enable China to approach or catch up with international pioneers in select fields [26]. Projects are implemented and monitored by a related ministry in the sector, with project budgets differing from one subject to another. One project that has received considerable attention in China and throughout the world is the 863 Key Technology and System Integration Project for Electric Vehicles. Nearly 42 % of the total budget is allocated for critical battery components and electric vehicle integration.

In Turkey, following the adoption of the National Science, Technology, and Innovation Strategy 2011–2016, there has been a paradigm shift toward mission-oriented approaches. Traditionally, project funds had solely been granted

to researchers through a bottom-up approach where the researcher decided the area/topic on which to work as curiosity-driven research. Based on the strategy [27], nine priority areas were evaluated and adopted by the Supreme Council for Science and Technology (SCST), namely automotive, machinery-manufacturing, information and communication technologies (ICT), energy, water, food, health, space, and defense. Following the adoption of the priority areas, high-level prioritization group meetings prioritized sub-fields of the nine areas. This effectively combined top-down direction setting through the SCST with the bottom-up direction setting of the innovation actors. In yet another level of stakeholder evaluations, TÜBİTAK coordinated multi-staged processes based on the use of technology foresight methods, including Delphi surveys, to determine the prioritized topics under the sub-fields. The results of these processes are used in policy design, technology roadmaps, and preparation of project calls. With the wide participation of different stakeholders, Turkey has now completed 10 technology roadmaps and launched over 150 technology roadmap-based calls.

Defining priority areas inevitably calls for revisions and elasticity in support mechanisms. Thematic and call-based programs are most useful when they are adaptable to changing needs. In 2013, TÜBİTAK developed two new call-based, mission-oriented support measures to improve R&D performance in priority research areas. The Support Program for Research, Technological Development and Innovation Projects in Priority Areas (TÜBİTAK 1511) [28] targets private sector companies. The Support Program for Research, Technological Development and Innovation Projects in Priority Areas (TÜBİTAK 1003) [29] is directed toward researchers from both academia and private/public research institutes. While the target audience that will lead the project is different, both programs incentivize the collaboration of private industry and academia/research institutes. Under the aegis of these programs, TÜBİTAK announces calls for project proposals addressing Turkey's priority areas. Applicants submit project applications in response to the calls. Each call is designed to cover specific research areas with the potential of strengthening areas in which Turkey may have a comparative advantage or a demand to accelerate the closing of technological gaps.

The calls of the TÜBİTAK 1511 and 1003 coded support programs are determined using thorough analysis of technology roadmaps' outputs, high-level prioritization groups, and private sector problems capable of being solved by means of R&D activities. Detailed analysis of foreign trade data was also integrated into the process of determining call topics. Presently, these programs satisfy the need of the ecosystem to support product and technology-oriented projects that preferably involve university–industry cooperation. These programs provide a larger budget per project in comparison to curiosity-driven programs so as to encourage R&D activities to be conducted in prioritized topics. In addition, there are budget-related incentives for university–industry cooperation. The number of applications also indicates that researchers are interested in the call-based, mission-oriented approach. The number of applications to both programs has been in excess of 3700 applications.

3.2.2 Large-Scale Mega Projects

In China, 16 National Mega Projects have been launched under the Development Plan (2006–2020). While three are classified as confidential, 13 are characterized as civil-purposed projects and military-purposed projects as listed below [30]. For example, the ‘Mega New Drug Development Program’, under the aegis of the National Mega Projects Initiative, received about \$2 billion to be used in the years from 2011 to 2015.

Civil-purposed projects

1. Core electronic devices, high-end general chips, and fundamental software
2. Mega-scale integrated circuit manufacturing technologies
3. Next generation of broadband wireless mobile networks
4. Advanced digital control machines and fundamental manufacturing equipment
5. Wastewater control and treatment
6. Key new drug innovation
7. Prevention and treatment of key infectious diseases (e.g., HIV/AIDS, hepatitis)
8. Large-scale development of oil & gas fields and coal-bed gas
9. Breeding of new variety for transgenic biology

Military-Purposed Projects

1. Large-scale advanced pressurized water reactor and high temperature gas-cooled nuclear power plants
2. Mega-airplanes
3. High-resolution earth observation system
4. Manned space flight and lunar exploration

Similarly, the Korean Government is securing new growth engines for a sustainable economy and improving the quality of life by developing fundamental technology in biology, nano-science, energy, environment, and other promising fields. There are six thematic umbrella support programs being implemented by the National Research Foundation of Korea [31]. The themes are identified and several full-scale projects have been supported under each umbrella program. The mission-oriented, thematic programs are as follows:

1. Bio-Medical Technology Development Program
2. Nano-Material Technology Development Program
3. Next-Generation Information Computing Program
4. High Technology Convergence Technology Development Program
5. Public Welfare & Security R&D Program
6. Global Frontier Program

For example, the “Development of New Medicine” is one of the themes that are adopted under the aegis of the Bio-Medical Technology Development Program. This theme’s target is to develop 10 commercial therapeutic drugs by the year

2019. Another initiative for the health sector is The Korea Drug Development Fund. The Ministry of Knowledge Economy (MKE), the Ministry of Health, and the Ministry of Education, Science and Engineering have created this fund for drug development, which has received a total of 27 million USD in contributions.

In addition, mega projects, which are seen to be flagship “landmark” projects, are launched as a special kind of mission-oriented approach in Turkey. Most notably, this includes electric vehicle technology, through the Public Institutions Research and Development Projects Support Program (TÜBİTAK 1007) [32]. The aim of TÜBİTAK 1007 is to solve technological problems and satisfy public institutions’ needs by means of R&D projects. Through the use of TÜBİTAK 1007, it has been possible to launch large-scale, high budget mega projects targeting the country’s needs. Examples of such projects are the high-resolution communication satellite project, the electric vehicle project, and the wind turbine project. Most of these mission-oriented projects involve large-scale budgets of over 30 million USD.

3.3 Best Practices for Research Quality Based Stimulation

Programs to increase the quality of R&D and innovation outputs are as necessary as new programs to support R&D, innovation, and entrepreneurship. Since R&D and innovation are one of the main drivers of countries’ future growth, prosperity, and wellbeing, it is important to ensure that money is invested in projects with the greatest potential to return effective and quality research outputs [33]. Since universities are one of the main pillars of the innovation ecosystem, increasing the quality of research outputs in the university research environment has been receiving much attention as a policy focus. One of the policy tools that have been introduced are performance-based research funding systems [34]. Overall, best practices to stimulate the quality of research outputs in the innovation system can be classified under the topics of performance-based funding schemes for universities, schemes to increase publication quality in researchers, and performance-based schemes for fast-growing, innovative firms.

3.3.1 Performance-Based Funding Schemes for Universities

One of the oldest performance-based research funding systems is the Research Assessment Exercise (RAE) in the UK [35]. Since its launch in 1986, many countries have followed suit and introduced performance-based research funding schemes. Such widespread adoption of performance-based funding schemes for universities has also represented shifts in the quality of research outputs, since universities are so central in many innovation systems. According to international best practices, one of the most important tools of performance-based research funding to foster R&D facilities in universities is project overhead. Numerous countries

exert project overhead. Recently, however, a fixed project overhead rate has been widely deemed to be less effective than varying project overhead rate based on performance. This change in methodology allows a boost in R&D in universities since it fosters increased competition.

Countries that implement varying project overhead rate include the US, the UK, Sweden, and Ireland. The efficiency factor implementation in the UK is one of the leading examples. This practice, initiated in 2011, allows Research Councils UK (RCUK) to evaluate the funded money based on performance. This reduces amounts allocated, if needed, when there are decreases in performance [33]. In this methodology, every university determines a project overhead rate and applies to RCUK annually. At a later date, RCUK uses the method of defining efficiency groups that provides the research organization with the autonomy to make minimal impact savings. This aids in removing uncertainty and does not require the research organization to collect huge amounts of data or RCUK to build expensive monitoring systems.

In the UK, research organizations are categorized into five efficiency groups A to E. The efficiency group A represents the most efficient and E the least efficient. The association with an efficiency group is based on a research organization's absolute indirect cost rates and the relative change in the rate compared with the previous year. Higher Education Institutes (HEIs) in the least efficient group would be subject to increased scrutiny and pressure to reduce their indirect cost rates. The assignment of research organizations to efficiency groups is also subject to annual review. Furthermore, it is important that in the revised methodology to calculate the current rate, the previous year's rate is duly taken into consideration. This allows accounting for the growth rate as the percentage change for higher performing universities.

Some countries continue to exert fixed project overhead rate for universities. At the same time, the possibility of changing to the varying project overhead rate methodology is becoming increasingly up for debate. In Finland, the fixed rate is exerted, namely 46 % for TEKES and 12.5 % for the Academy of Finland. In Ireland, this rate is up to 35 % and there are aims in place for increasing it further [36]. An average of 52 % overhead is used in Sweden, which further plans to implement UK's efficiency factor model in the coming few years. Within the context of the EU Framework Programs, different models are applied with 20 % fixed rate and 60 %, conditionally.

Since 2004, a fixed overhead rate at 10 % has been exerted in Turkey for every project. In the new implementation of project overhead, the aim is to raise the rate of R&D funds in university budgets to 25 % from its current rate of 2 %. Therefore, the practice of fixed project overhead rate has been changed and increased from 10 to 50 % based on universities' performance that will be assessed annually based on objective criteria. According to new practice, the project overhead will vary from university to university depending on their performance. A higher level of performance will lead to a higher project overhead for universities. This also means an additional R&D budget for universities that compete to raise their level of performance.

Another example of a performance-based funding scheme for universities is awarding successful R&D outputs, such as publications and patents, and providing incentives based on their success. Recently, such revisions have been implemented in the Czech Republic [37]. The Czech Republic aims to motivate HEIs to increase the quality and the number of students as well as to affect the universities' annually allocated budgets. The revision includes all categories of the R&D outputs that are measured by awarding them with a certain defined amount. System indicators include several types of publications, e.g., Jimp—article in an impacted periodical, Jneimp—a critical article in an international database such as SCOPUS or ERIH, patents and other results of applied research. The proportion of points that are gained by various categories of research institutions varies according to levels of success in these categories.

3.3.2 Performance-Based Funding Schemes for Researchers

With the new Project Performance Award in Turkey, successfully completed projects are awarded to increase the effects of funded projects based on performance. For performance assessment, a total of 36 sub-criteria are taken into consideration. These include the number of indexed articles in A, B, and C class journals, the number of other refereed articles, and the number of citations according to nine main criteria [38]. The nine main criteria include articles, scientific papers, books, awards, patents, products/models/firms, dissemination, researcher trainings, and new projects. The points that are gained with respect to these criteria and the successfully completed projects are awarded with up to \$48,000 in addition to the project grant, incentive premium, and project overhead. In practice, this incentive bonus may pass to the researchers as an additional \$1500 in monthly income.

Another example of performance-based funding for researchers is the Incentive Program for International Scientific Publications (UBYT), which has been initiated in Turkey to boost the quality of scientific publications. The program has been revised to increase the rate of international citations per publication, which is a quality indicator. According to the program, journals that are included in international citation indexes are evaluated using objective parameters, such as the impact factor and citation half-life. In this respect, publications are compared to their counterparts in their research areas and every publication receives a certain mark. Higher incentives are granted for better quality [38].

3.3.3 Performance-Based Funding Schemes for Firms

In China, the Beijing Zhongguancun Sci-Tech Financing Guaranty Co. Ltd., which is a company in the Zhongguancun Park [39], known as the “Silicon Valley of China,” identifies its fast-growing ‘gazelle’ firms and provides performance-based incentives. Based on the Gazelle Plan, the above-mentioned company determines the 3000 most innovative gazelle firms annually and facilitates banks to provide