Expert's Perception on Technology Transfer and Commercialization, and Intellectual Property Rights in India: Evidence from Selected Research Organizations

Ajay K. Singh*, Sanjeev Kumar*

School of Liberal Arts and Management, DIT University, Dehradun, India

JOMEINO
ISSN: 2522-381X (Print)
2521-7054 (Online)
DOI: 10.31039/jomeino

Received 10 October 2021
Revised 25 November 2021
Accepted 29 December 2021

check for updates

Citation: Singh A. K., Kumar S. (2022). Expert's Perception on Technology Transfer and Commercialization, and Intellectual Property Rights in India: Evidence from Selected Research Organizations, *Journal of Management, Economics, and Industrial Organization,* 6(1), 1-33.
http://doi.org/10.31039/jomeino.2022.6.1.1

corresponding authors:
a.k.seeku@gmail.com;
kumar.ajay_3@yahoo.com

Abstract

Technology transfer (TT) and commercialization is useful to develop new technology, innovation, device, design and product in manufacturing sector. TT and commercialization are essential drivers to create tech-based start-ups, entrepreneurship ecosystem, employment, new market, and increase output, productivity, efficiency and growth of manufacturing sector. However, TT and commercialization from research institutions to industries is relatively lower in developing economies as compared to developed countries. In these economies, researchers and scientists have insignificant understanding on intellectual property rights (IPRs) and its positive implication in manufacturing sector, and legal provision and procedures for utilization of IP protected technology in industrial filed. Therefore, this study provides the progress of IPRs in India during 2006–2007 to 2018–2019. Thereupon, it detects the opinion of 120 experts on TT and commercialization and IPRs. These experts were selected from 40 reputed research organizations of India. Research organizations were applying contractual agreements, licensing for limited time period, agreements with technology seekers and mutual contract for TT and commercialization in. Thus, this study claimed that most research organizations do not have a formal and uniform process for TT and commercialization. Appropriate estimation of economic values of existing technology and innovation are difficult in research organizations. Therefore,

Indian research organizations could not nurture a conducive ecosystem to increase TT and commercialization, and business-oriented association with manufacturing firms. This study provides barriers of TT and commercialization in research organizations. Accordingly, several policy proposals were given to resolve existing issues in TT and commercialization, and IPRs in Indian research organizations.

Keywords**:** *Intellectual property rights, Manufacturing sector, Researchers and scientists, Research organizations, Technology and innovation, Technology transfer and commercialization, India.*

JEL Codes: D73, L24, L26, N15, N35, O14, O34.

1. Introduction

Most production activities of manufacturing sector depend upon advance technology and innovation, knowledge, technology-know-how, idea, industrial design and process to increase their production scale (Osano & Koine, 2016; Singh & Ashraf, 2020; Singh, 2021). Aforesaid activities are also efficient to increase competition among the manufacturing sector and business organizations which produce new goods and services for the people (Kumar et al., 2015). Technology is a scientific outcome or innovation or fruit of research & development (R&D) activity in research organizations and medium-scale enterprises of manufacturing sector (Singh, Ashraf & Arya 2019). It may be a raw material for further process of technological innovation that would be helpful to create new products, process and design in manufacturing firms. Thus, innovation, technology know-how, idea, process and industrial design are the various forms of scientific or research & development (R&D) outcome which discover by research organizations and firms in manufacturing sector (Singh & Jyoti, 2020; Singh, 2021). Furthermore, existing technology can be used for further process through its transfer from research organizations to manufacturing industries or one firm to other firms. Technology transfer (TT) is a process to increase the transfer of scientific outcome from its creators to users. It also includes the transfers of the scientific outputs, knowledge, technology know-how, mechanical devices, product design from research organizations to industrial field (Manral et al., 2012; Kumar et al., 2015; Singh & Jyoti, 2020). Subsequently, knowledge, technology and process can be used to produce goods and services, and development of new technology in manufacturing sector (Muthoni et al., 2013). Therefore, transfer of technology and knowledge have an effective contribution to create more innovation for discovery of new goods and services in manufacturing sector. Also, transfer of innovation or technology from research organizations to other parties known as TT (Ravi & Janodia, 2021). It also includes the transfer of physical assets, knowledge and human skills which

are essential to increase production, efficiency, effectiveness, market share and profit of a business organization or manufacturing sector (Kumar et al., 2015; Osabutery & Jin, 2016; Ganzer et al., 2017). TT includes the transfer of scientific knowledge from one entity to another which may be research organizations, firms, enterprises, business organizations and manufacturing industries within a country or across countries. Technology can be transferred between two or more than two sectors (i.e., industries to agricultural or agricultural to industries) (Araújo & Teixeira, 2014; Ashraf & Singh, 2021; Singh et al., 2021). It disseminates the scientific ideas, device and other industrial applications from research organizations to industries (Mysore, 2015).

Intellectual property rights (IPRs) regime provides the legal security of intellectual property (IP) of researchers and scientists in research organizations and manufacturing sector (Sattar & Mahmood, 2011; Singh et al., 2020). IPRs are useful to established the legal term and conditions for further transfer of technology among the various entities (Laik, 2015; Shugurov, 2015; Odilpova, 2016; Singh, 2021). Anyone cannot use IP protected technology or innovation without prior consent of its creators (Singh et al., 2020). Thus, IPRs is useful to reduce the imitation rate of technologies and innovation in a country (Singh et al., 2020). Consequently, it is helpful to increase the trust of entrepreneurs or businessmen to buy the IPRs protected technology from the research organizations. Feng et al. (2010) also reported that patented technology developed by research organizations has high viability to be transferred from research institutions to the industries. Hence, IPRs regime is highly effective to increase TT and commercialization (Falvey & Foster, 2006; Yueh, 2007; Ray, 2012).

Furthermore, TT and commercialization are helpful to generate revenues for research organizations to recover the high cost of research & development (R&D). It is essential driver to increases the involvement of scientists and researchers to discover more technologies for manufacturing sectors to generate enough revenue (Kang et al., 2013). Consequently, TT and commercialization have effective contribution to meet the latest technological requirement of manufacturing sector (Muthoni et al., 2013). Discovery of new goods and services motivates to the new entrepreneurs and manufacturers to start new start-ups or ventures. Thus, it may be helpful to create conducive start-ups and entrepreneurship ecosystem (Kim et al., 2018; Singh & Ashraf, 2020; Singhai et al., 2021). Accordingly, TT and commercialization works as an important driver to increase industrial development of a nation (Ray, 2012; Osano & Koine, 2016). TT maintains the term and legal procedures for further transfer of technologies (which are protected by IPRs regime) between two or more parties to discover more goods and services, and develop more technologies for manufacturing sector (Manral et al., 2012; Singh et al.,

2019). Collaborative research among the research organization and industries plays a key role to increase TT and commercialization (Sengupta & Ray, 2015).

TT is useful to create new business opportunities, new goods and services and new markets. E-commerce is good example of technological advancement and technology transfer which provides the online trading of goods and services for public (Sultana & Akter, 2021). Subsequently, it is helpful to generate new employment opportunities for skilled and unskilled workers in a country (Mysore, 2015; Muthoni et al., 2013). Thus, it is effective to increase the economic ability of people and social-economic development. TT would be supportive to increase the skills and efficiency of working population in manufacturing and other sectors. Most specifically, TT and commercialization originate new production technology for entrepreneurs and idea to promote tech-start-ups to produce new goods and services. Introduction of new start-ups or new businesses would reflect the overall entrepreneurial activity of a country (Jyoti & Singh, 2020; Ravi & Janodia, 2021). Competition among the manufacturing industries and infrastructure development will increase as TT and commercialization increase in a nation (Kumar et al., 2015; Ravi & Janodia, 2021). Subsequently, economic growth is likely to be increased due to increase in TT and commercialization. For instance, Osano & Koine (2016) observed the positive impact of FDI, TT, trade facilitation and knowledge management on economic growth in Kenya. New technology derived through R&D activity in research organization is useful to increase innovation and production capabilities of manufacturing sector (Franco-Giraldo & Gentilin, 2021). TT is effective to increase the useability of existing technologies for its users in industrial sector at large scale. Accordingly, manufacturing industries can develop new goods and services using available technology or innovation in production activities (Ganzer et al., 2017). Thus, TT keeps the bridge between technology developers and its seekers based upon their mutual interest. Commercialization of technology is a monetization of a technology or innovation which is protected through IPRs regime. Thereafter, a technology can be used in production activities of manufacturing sector (Alina & Diana, 2016; Singh et al., 2019; Singh & Ashraf, 2019; Singh, 2021). TT and commercialization are helpful to bring new idea and knowledge or technology bring in domestic and international market (Jun & Ji, 2016). TT is also a vital driver to increase collaboration among the research organizations and manufacturing sector (Sengupta & Ray, 2015).

Furthermore, TT includes different entities or organizations, while, technology commercialization is a process which bring new knowledge or advance technology in the market without involvement of various entities (Jun & Ji, 2016). TT is useful to create a conducive ecosystem for industrial development (Ray, 2012; Muthoni et al., 2013; Osano & Koine, 2016). Manufacturing industries produce various goods and services to meet

the current requirement of consumers and increases the social welfare. Further, new technology is essential to increase the efficiency and productivity of available resources in manufacturing sector (Muthoni et al., 2013). Furthermore, TT and commercialization also provide several alternatives to develop new goods and products with the help of scare resources in a nation. Accordingly, it is supportive to increase the marginal contribution of each factor or input in production of goods and services in manufacturing sector. TT is also helpful to increase comparative advantage and global value chain for international trade in a nation. Thus, TT is also fruitful to increase the foreign trade between two or more than two countries under bilateral and multilateral agreements. TT is useful to increase the competition among the manufacturing firms in different sector (Kumar et al., 2015). Thus, monopoly in the market can be reduced through TT and commercialization.

TT and commercialization include various factors and activities at institute and industry level. Therefore, research team in research organizations and its associated variables (e.g., R&D expenditure, research quality or outcome, technical and research instruments, laboratory, etc.), and technological adoption capacity related variables (e.g., size of firms, technical staff, skilled workforce, availability of raw materials, financial restrictions, market size, etc.) of firms in manufacturing industries are the key determinants for TT and commercialization (Zuniga & Correa, 2013; Bigliardi et al., 2015; Ravi & Janodia, 2021; Hou & Lim, 2021). TT and commercialization are useful to solve technological, economic, environmental and social problems of society in developing or developed countries (Kumar et al., 2015). Subsequently, TT and commercialization, and IPRs have positive and significant impact on per capita income, economic growth, social-economic development, inclusive growth, human well-being and sustainable development (Lov & Roper, 1999; OECD, 2000; Zuniga, 2011; Muthoni et al., 2013; Kirchberger & Pohl, 2016; Singh, Singh & Negi, 2020; Jyoti & Singh, 2020).

India has large number of research institutions and universities in different field of studies in higher education. Most research organizations have well R&D ecosystem and significant contribution in science & technological up-gradation in the country. Furthermore, Indian research organizations and manufacturing industries have granted and registered a huge number of patents and other forms of IPRs (e.g., industrial design, geographical indicators, trademarks and copyrights) in applied science, engineering, pharmaceutical, information technology, automobile, construction, environmental and artificial intelligence. Furthermore, India has developed and discovered technology and innovations in various sectors such as applied sciences, engineering, pharmaceutical, automobile, information technology and other discipline of studies. Recently, the Government of India (GoI) has introduced several policies such as Science & Technology & Innovation (2013), Make in India, Start-up India (2015), Skill India (2015), Atal

Innovation Mission (AIM) (2016), and establishment of TT offices (TTOs) and technology business incubator centres in research organizations to increase TT and commercialization (Singh, Ashraf & Arya 2019). These policies were desired to create appropriate entrepreneurship and start-ups ecosystem, to increase the share of manufacturing sector in India's GDP, and to create extensive jobs for skilled and unskilled work force in India. Subsequently, there is seemed significant improvement in number of start-ups in various fields of technology in India after 2016.[1] Despite that, TT and commercialization rate is low due to ineffective mechanism of TTOs, extreme flexibility in IPRs regime and insignificant association of universities and research organizations with manufacturing sector in India (Singh et al., 2020; Singh, 2021). Indian manufacturing industries have low trust to buy technology and innovation from research organizations which have large number of unprotected IPRs technology (Abhyankar, 2014). Therefore, Indian manufacturing firms have low collaboration with research organizations. Also, research organizations could not meet the current technological requirement of manufacturing industries in India (Ravi & Janodia, 2021). Furthermore, large, medium and small enterprises have low communication with each other in India (Abhyankar, 2014). Therefore, Indian research organizations could not generate enough revenue through from TT and commercialization (Abhyankar, 2014).

Indian manufacturing industries, particularly MSMEs and research organizations could not consider the importance of IPRs in production activities (Singh et al., 2020). Subsequently, manufacturing sector could not contribute significant share in India's GDP in last decade as its share in India's GDP has declined from 16.14% in 2011 to 13.65% in 2019 (World Bank, World Development Indicators, 2021). Also, Indian manufacturing firms and industrial sector could not absorb the disguised work force of agricultural sector (Singh & Kumar, 2021). Still, livelihood security of large segment of the society depends upon agricultural sector in India (Ashraf & Singh, 2021). Therefore, the growth of manufacturing sector is likely to absorb disguised work force of agricultural sector and would provide jobs security of most people in India. Hence, Indian MSMEs and research organizations need to protect their intellectual property (IP) through strong IPRs regime (Singh et al., 2020). In above perspectives, previous studies theoretically and empirically discussed the TT and commercialization affecting factors in Indian research organizations (Ravi & Janodia, 2021; Singh et al., 2020; Singhai et al., 2021) and manufacturing firms in different dimensions (Kumar et al., 2015). However, existing studies could not address some useful research questions which are given below:

[1] https://dipp.gov.in/sites/default/files/lu2912_0.pdf.

- What are basic challenges and obstacles in TT and commercialization in Indian research organizations?
- How research organizations can increase the TT and commercialization in India?
- How IPRs regime is useful to increase TT and commercialization in Indian research organizations?
- How growth of the manufacturing sector depends upon TT and commercialization, and IPRs rule in India?
- What is the role of TT and commercialization, and IPRs rule to maintain the association of research organizations with manufacturing industries in India?

Accordingly, this study achieved following research objectives:

- To provide the progress of IPRs of India during 2006 – 2007 to 2018 – 2019.
- To observe the expert's opinion on TT and commercialization, and IPRs in Indian research organizations using field level information.

2. Review of Literature

2.1. Factors Affecting TT and Commercialization

Many forms of IPRs have a crucial contribution to increase TT and commercialization from research organizations to industries and one firm to another in manufacturing industries in a country. The process of TT can be technology-push or demand-pull (Jun & Ji, 2016). Technology-push transfer depends upon needs and demand of technology in the market. Demand-pull transfer of technology depends upon need or demand and source of a specific technology (Jun & Ji, 2016). TT is a challenge for individual researcher or scientist in research institutions and manufacturing sector due to several reasons (e.g., estimation of economic value of technology or innovation, decision on time period of licensing, mutual agreements among the technology developer and its users, etc.) (Kumar et al., 2015). IPRs regime prescribed the legal term and condition for further use of a technology or innovation. Hence, IPR protected technology has high possibility to be commercialized for technological development. TT can be disseminated between two researchers, research organizations and manufacturing industries. Therefore, institute level R&D activities and ecosystem have greater contribution to increase the TT from research organization to manufacturing sector (Kumar et al., 2015). Accordingly, R&D activities, R&D expenditure, R&D support by government, technical staff, scientists, engineers, human skills and technology seekers, bargaining power of research institutions, technology learning capability, marketing capability are the key determinants of TT from research organizations to manufacturing industries. Existing studies have identified several factors such as law and government policies, technology licensing

models, technology commercialization model, communication, technological capabilities of firms, human resources, technology localization, technology traits, cooperation among the industries which have significant impact on TT and commercialization (Feng et al., 2010; Singh and Singh, 2020; Singhai et al., 2021). User and suppliers of technology and communication between them are also the key drivers to increase TT and commercialization (Jun & Ji, 2016).

2.2. TT from Research Organizations to Industries

Technology and innovation are output of R&D activities in research organizations and medium scale enterprises (MSMEs) (Lov & Roper, 1999). R&D investment by public and private players is essential to increase the motivation of researchers and scientists to be involved in R&D activities in engineering, pharmaceutical, applied sciences and other emerging area of technology. Internal R&D ecosystem and motivation of researchers for further research are prime determinant of TT and commercialization (Zhao & Grier, 1991; Muthoni et al., 2013; Finardi & Breznitz, 2017; Singhai et al., 2021). Technological requirement of industries also increases when research organization discover new technology which have greater potential to meet the basic requirement of manufacturing firms (Araújo & Teixeira, 2014). For this, TT offices (TTOs) in the research organizations play a vital role to promote technology and knowledge transfer for manufacturing industries (Bigliardi et al., 2015; Singh, 2021; Singhai et al., 2021). As research organizations are the originated place of technology, thus, TT increases as collaboration of research organizations with existing industries increases (Feng et al., 2010). Communication, knowledge, quality of product and motivation have significant contribution to strengthen the association of research organizations with manufacturing industries. Thus, these are key determinants to increase TT from research organizations to manufacturing industries (Singhai et al., 2021). Learning, education system and cultural arrangement of a research organizations also have a positive and significant impact on TT and commercialization (Kim et al., 2015; Osabutery & Jin, 2016). Technology-business incubators (TBIs) in research organizations also have a greater contribution to increase the TT and commercialization (Özdemir & Şehitoğlu, 2013; Hillemane & Satyanarayana, 2019).

2.3. Transfer of Technology within Firms in Manufacturing Sector

TT can be in different firms within or across manufacturing industries. Therefore, firm level factors such as communications, human resources, technology management, technology absorption capabilities, prior TT experience, financial benefits, technological capabilities are the key drivers of TT and commercialization across firms in manufacturing industries (Jun & Ji, 2016). For instance, Zhao & Grier (1991) identified

that R&D intensity is useful to increase TT in China. Yin (1992) observed that indigenous technological capability associated factors have a positive impact on success rate of TT in China. Return on R&D investment also provides the motivation to the research organizations and manufacturing firms to be involved in TT and commercialization. Muthoni et al. (2013) also claimed that education and training have an effective contribution to increase TT, while, technological information, finances, technological infrastructure and government financial support have positive impact on TT in Kenya. Furthermore, TT depends upon absorptive capacity of technology, human capital, trust and social connectedness of manufacturing sector (Araújo & Teixeira, 2014). Kang et al. (2013) have noticed that innovation capabilities, investment in R&D sector have a significant impact on TT and commercialization in SME in Korea. Collaboration of firms in manufacturing industries also nurture a conducive path to increase the TT and commercialization (Araújo & Teixeira, 2014).

2.4. Transfer of Technology and Knowledge Across Countries

TT and commercialization can be between two or more than two countries through bi-lateral or multi-lateral agreements (Hou & Lim, 2021). Therefore, factors associated with R&D, science & technology, government policies, tariff, human resource development, communication, legal term and condition are highly effective to increase TT and commercialization at international level. Training, international experience, technological partnership agreements, strong IPRs regime and network are the key drivers to increase TT (Ray, 2012; Rath et al., 2014; Araújo & Teixeira, 2014). Past experience and relations among the partners are also a crucial determinant of TT and commercialization (Araújo & Teixeira, 2014). Research outcome is essential to increase human capital and skills, and TT and commercialization (Feng et al., 2010). Foreign direct investment (FDI) is also a crucial determinant of knowledge and TT across countries (Osabutery & Jin, 2016; Osano & Koine, 2016). For instance, Kumar et al. (2015) developed an input-output model for TT and commercialization which include three types of factors such as input (i.e., human resource, financial resource, management skills, raw material, machinery and equipment), process (i.e., recognition, conceptualization, design, suitable technology, manufacturing, controlling) and output (i.e., innovative products, process, activities and services). Singhai et al. (2021) claimed that communication, motivation, time frames, individual actors and team competency are micro-level factors; quality of product, innovativeness, technology licensing, proactive policies and acts, financial support, social impact and return on investment are the macro-level factors; and training, experience, knowledge, management support, TTO and incubator are the meso-level factors to enhance the TT and commercialization.

3. Methods and Materials

3.1. Source of Secondary Data

This study used secondary and primary data. Secondary data related to TT, technology commercialization, TTOs, technical staffs, IP strength, IPRs and other at research institutions level was taken from their website. Information on number of granted patents, registered design application, registered trademarks application, registered geographical indication and revenue generated through IP system in India during 2006 – 2019 was taken from the various publications of Department of Industrial Policy and Promotion (GoI) and respective ministry of GoI.

3.2. Source of Primary Data

Selection of Research Organizations: This study considers only public funded research organizations and universities which have significant contribution in patenting, R&D activities, TT and commercialization in India. Aforementioned information was identified based on online web survey of respective research organizations. This study considers only those research organizations which had the practices of TT and commercialization. Accordingly, only 40 research organizations and universities were considered in this study (Table A1 in Appendix A).

Selection of Respondents: The selection of respondents was based on their current involvements in TT and commercialization, and IPRs related activities in public funded research institutions and universities in India. Three respondents from each institution were included in the survey. Accordingly, total 120 respondents were interviewed personally in selected research organizations. These respondents had an effective and active involvement in TT and commercialization, and IPRs related activities in research organization. Brief summary of the selected respondents based on their designations is given in Table 1. Structural questionnaire was used to conduct the interview of respondents. The survey was conducted during 1st September 2017 to 31st December 2017.

Table 1: Summary of the selected respondents based on their designations

Designation of Respondents	Frequency	Percentage
Head of the technology transfer offices (TTOs)	30	25
Directors/Professor/Associate Professor/Assistant Professor	25	21
Scientists	20	17
Manager (Business Development Unit)/Technology Business Incubators	15	13
IPRs Experts	15	13
Dean R&D	15	13
Total	120	100

Source: Based on field survey.

Structure of Questionnaires: The questionnaire was included the institute level information on TT and commercialization, focus research area, academic structure, number of scientists, technical staff, professor, associate professor, assistant professor, research fellow, publications of scientific research articles, patents, industrial design, number of patents commercialized, current collaboration of institute with industries, applied model for TT and commercialization, purpose of technology commercialization, problems of technology commercialization and IPRs; suggestions to increase TT and commercialization, awareness of researchers towards IPRs, and TT and commercialization. Expert's opinions on TT and commercialization and implications of IPRs in manufacturing sector were also included in the questionnaire. Accordingly, policy implications were also identified to increase the TT and commercialization from research organizations to industries in India.

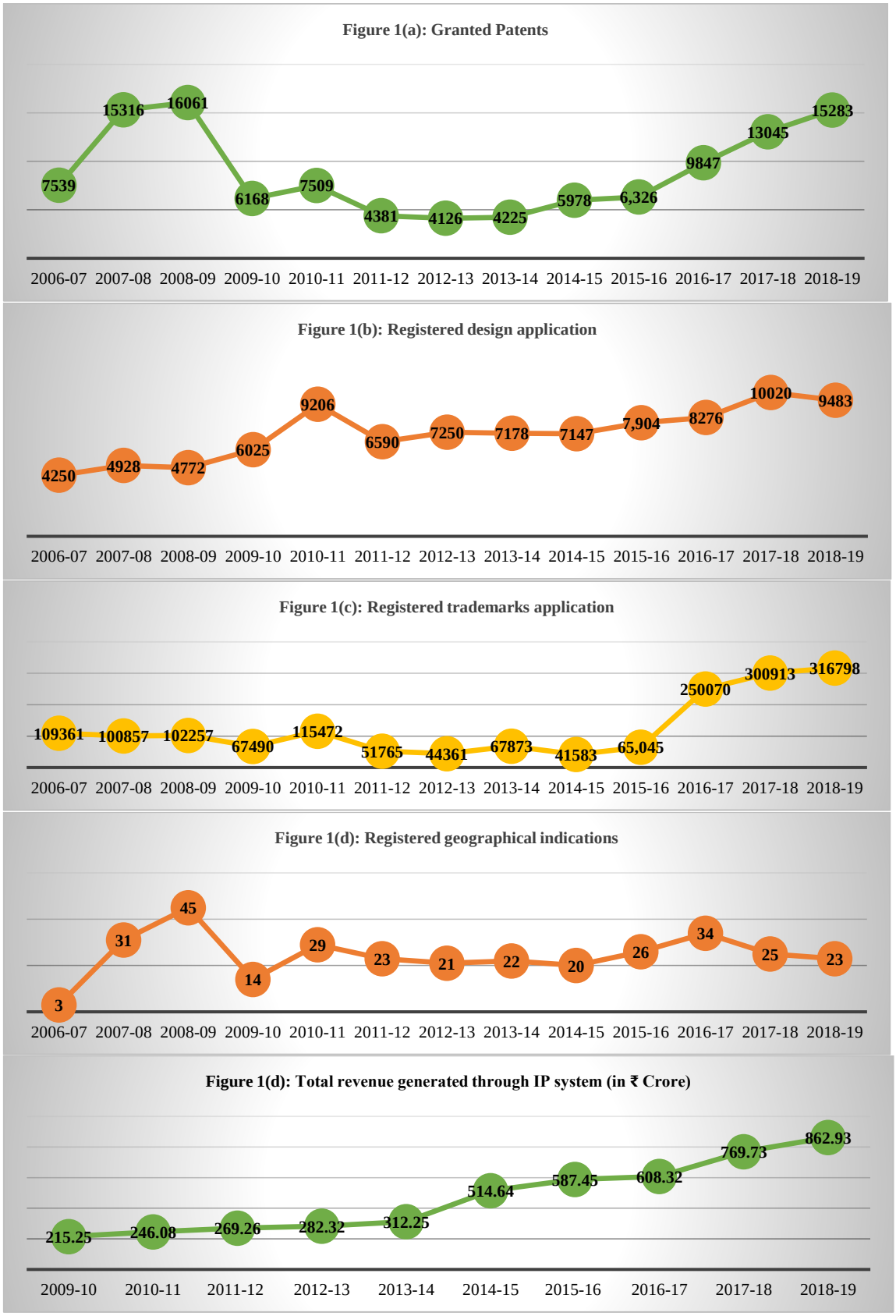
Analysis of Data: Simple descriptive and content-based analytical technique were used to analysis the collected qualitative data. SPSS statistical software and Microsoft Excel were used to analysis the collected information.

4. Discussion on Results

4.1. Recent Status of Intellectual Property Rights (IPRs) of India

Progress of IPRs cannot be observed through a single indicator or activity of a nation. Therefore, Singh & Ashraf (2019); Singh et al. (2019); Singh et al. (2020); Singh (2021) used number of patents application filed, registered trademark, registered industrial design, registered geographical indication and revenue generated through IP system to express the progress of IPRs of India and other countries. Hence, this study also provides the trend in aforesaid variables during 2006 – 2019 to explain the progress of IPRs of India. The Figure 1 show the progress of IPRs of India during the aforesaid period. It infers that number of granted patents, registered design application, registered trademark registered design application, and total revenue generated through IP system have increased during 2014 – 15 to 2018 – 19. Hence, India's progress in IPRs have been improved due to effective implementation of IPRs, S&T and other policies i.e., Science & Technology & Innovation (2013), Make in India, Start-up India (2015), Skill India (2015), Atal Innovation Mission (2016).

Figure 1: Progress of IPRs of India during 2006-07 to 2018-19

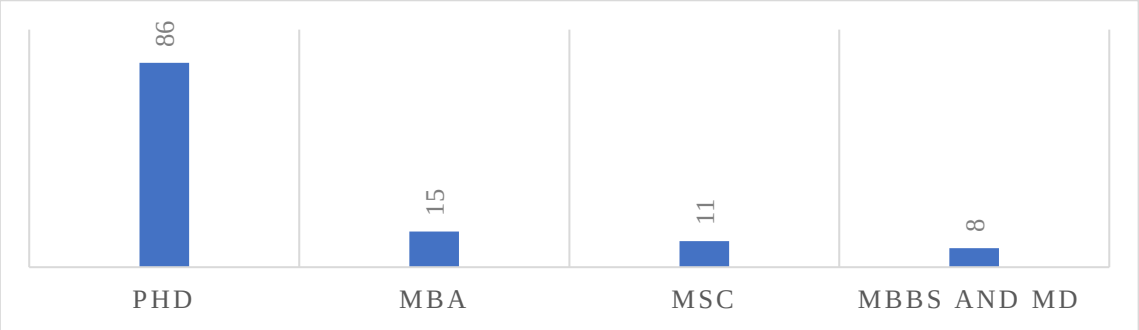


Source: Department of Industrial Policy and Promotion (GoI).

4.2. Academic Qualification and Work Profile of Respondents

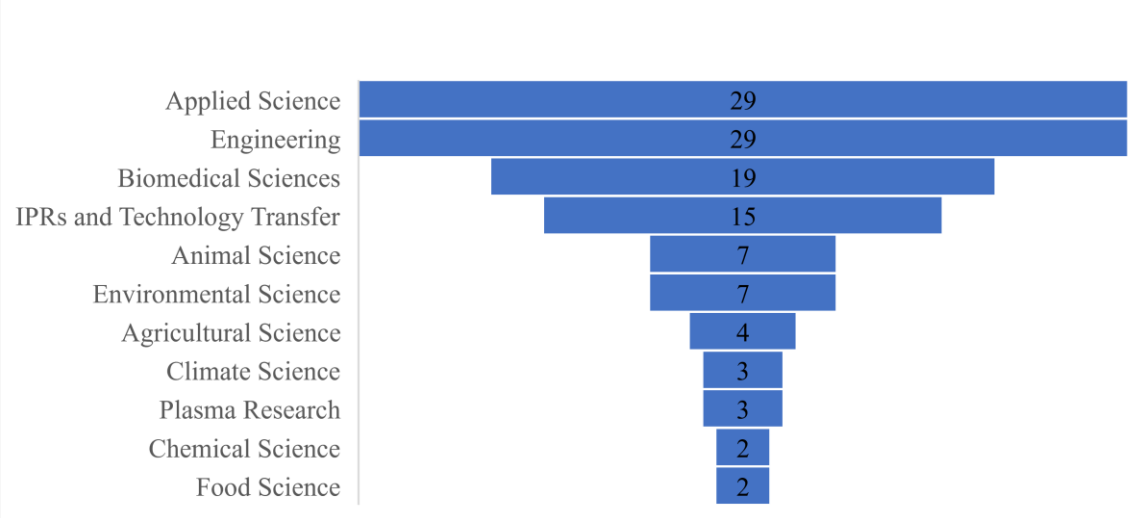
The academic qualification, research area and work profile of respondents is given in Figure 2, Figure 3 and Figure 4, respectively. The academic qualification of most respondents was PhD and their main research area was applied sciences. The respondents were also belonging from Engineering, Biomedical Sciences, IPRs and TT, Animal Sciences, Agricultural Sciences, Climate Science, Plasma Research, Chemical Research and Food Sciences. Furthermore, respondents were also working as consultants, incubates, business model formulators and key observers of IP in research organizations and industries. Therefore, they had crucial contribution in TT and commercialization related activities in selected research organizations in India.

Figure 2: Academic qualification of respondents



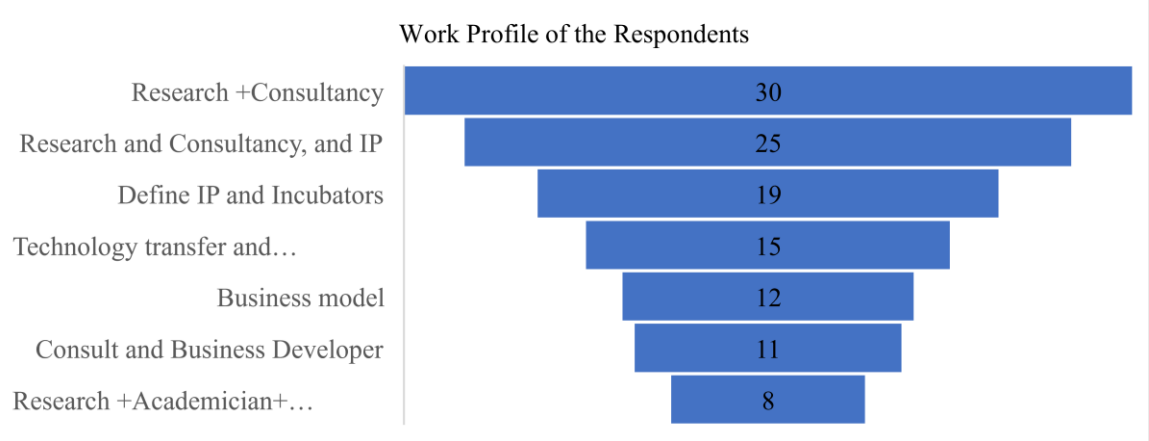
Source: Based on field survey.

Figure 3: Main research areas of the respondents



Source: Based on field survey.

Figure 4: Work profile of the experts



Source: Author's estimation based on field survey.

4.3. Expert's Opinion on TT and Commercialization, and IPRs in India

As per discussion of respondents, this study claimed that most Indian research organizations do not have a formal and uniform process for TT and commercialization. Contractual agreements, licensing for limited time periods, agreements with technology seekers and users, and mutual contract were the various process for TT and commercialization in Indian research organizations. Furthermore, estimation of economic value of intellectual property (IP), technology and innovation were very difficult in research organizations. Therefore, Indian research organizations could not develop a conducive ecosystem to increase TT and commercialization (Singh, 2021). In contrary, universities and research organizations have been developed better ecosystem to use of technology to produce goods and services in USA, China and South Korea. Subsequently, research organization could reduce their dependency on public R&D fund due to TT and commercialization in these countries (Singh & Ashraf, 2019). As TT and commercialization has a significant contribution to improve the production scale of manufacturing sector. Accordingly, manufacturing sector could buy technologies from research organizations in most developed countries. TT and commercialization may be useful to provide better financial return to the research organizations to produce and develop more technology as per the current need of manufacturing sector. Thus, this study includes the opinion of 120 experts from the 40 Indian research organization to identify the barriers and obstacles in TT and commercialization.

Barriers in TT and Commercialization: A technology has high possibility to be transferred and commercialized if it has quality and viability in the market (Singhai et al., 2021). Accordingly, most expert produced similar arguments on low rate of TT and commercialization in Indian research organizations (Table 2). As Indian research

organizations were unable to maintain the quality and viability of technology, therefore, manufacturing sector denied to buy technology from research organizations. Industries and research organizations have different aim to develop the technology, thus, there is low rate of TT from research organization to industries. Furthermore, research organization could not develop a systematic method to determine the economic value of technology. Therefore, estimation of economic value of technology was also a problem for research organizations to increase TT and commercialization. Research institutions cannot estimate the royalty fee of technology; thus, these were unable to increase TT and commercialization. Indian firms have low technological absorb capacity, thus, firms have low interest to buy technology from research organizations. Also, research organizations have low viability and usability of technology in industrial sector. Furthermore, research institutions cannot decide the time period of licensing of a technology and contractual agreements. TTOs and business development cell face several administrative issues and legal procedures which reduce TT and commercialization from research organizations to manufacturing firms.

Table 2: Barriers and obstacles in TT and commercialization in research organizations

Responses	Frequency	Percentage
Low quality and viability of technology and innovation discovered by research institutions	65	54.17
Research organizations and industries have different aim to develop technology	52	43.33
Unavailability of systematic method to determine the economic value of technology	45	37.50
Industries denied to buy technology from indigenous technology developers	43	35.83
Licensing process is complex for TT and commercialization	40	33.33
Research institutions are unable to estimate the royalty fee of technology	38	31.67
Research institutions cannot estimate the licensing fee and time period for a technology	32	26.67
Research institutions do not desire to be engaged in legal procedures of TT and commercialization	28	23.33
Research organizations cannot meet the current technological requirement of manufacturing industries	24	20.00
Low technology absorption capacity of manufacturing industries	21	17.50
Difficulty for research organizations to maintain the secrecy of technologies for long-term	20	16.67
Research organizations are unable to produce viable technology as per the needs of manufacturing industries	15	12.50
Research organizations cannot decide the licensing time of a technology	13	10.83
High risk for industries to buy technology from research organizations	11	9.17
Decision on contractual agreements by research organizations	9	7.50
TTOs and business development cells have several administrative issues	7	5.83
Total	N=120	

Source: Based on field survey. **Note:** Percentage may exceed 100 due to multiple responses.

TT in Indian Research Organizations: As per the perception of respondents, TT offices (TTOs) are useful to maintain the communication among the research organizations and industries (Table 3). Abhyankar (2014); Bigliardi et al. (2015); Singhai et al. (2021) also noticed positive impact of TTOs on TT and commercialization. Ravi & Janodia (2021) argued that TTOs should take effective action to increase the collaboration of research organizations with industries in India. Bigliardi et al. (2015) reviewed the importance of TTOs in TT from research organizations to industries in Italy. Hence, research organizations should introduce more TTOs to sustain the TT and commercialization. Feng et al. (2010); Muthoni et al. (2013); Mysore (2015) also provided aforesaid suggestions to increase association of industries with research organizations.

Table 3: Expert's suggestions to increase TT in research organizations

Suggestions	Frequency	Percentage
Founding of more TTOs in research organizations	85	70.83
Research organizations should work with manufacturing industries	75	62.50
Research organization should meet the technological requirement of manufacturing industries	69	57.50
Researchers and scientists should do research as per the need of industries	60	50.00
Research organizations should pursue strict IPRs regime	55	45.83
Research organizations should develop suitable methods to determine the economic value of technology or innovation	54	45.00
Research organizations should focus to discover advance technology	42	35.00
Research organizations should be more transparent to increase the trust of industries to buy their technology	37	30.83
Initiation of better market strategy by research organizations to increase TT and commercialization	28	23.33
Creation of demand of new products in the product market	27	22.50
Government should involve in TT related activities	25	20.83
Provision for proper incentive for innovators in research organizations	20	16.67
Freedom to maintain TT and commercialization in research organizations	18	15.00
Total	N=120	

Source: Based on field survey. **Note:** Percentage may exceed 100 due to multiple responses.

Research organizations should work with manufacturing industries to reduce the technological gap between them. Accordingly, research organizations would be in position to meet the current technological requirement of manufacturing industries (Ravi & Janodia, 2021). Research organizations should compliance strict IPRs regime and develop systematic method to determine the economic value of innovation to improve the TT and commercialization. Falvey & Foster (2006); Yueh (2007); Abhyankar (2014);

Osano & Koine (2016); Singh (2021) also reported the IPRs protected technology have a high possibility to be transferred from research organizations to manufacturing sector. Researchers and scientists should develop advance technology as per the requirement of industries. They also should pursue better market strategy for TT and commercialization. The government should create demand of new products through implanting an appropriate fiscal policy (fair taxation, subsidy and public spending on social sector) and increase the involvement of research organizations in TT and commercialization. Provision for proper incentive for innovators and freedom of research organizations would be helpful to increase TT and commercialization.

Technology Commercialization in Research Organizations: Indian research organizations cannot increase the TT and commercialization due to several reasons. Experts suggested that research organizations should improve TT and commercialization through implementing effective policy action (Table 4). Collaborative research of research organization with industries may be a conducive policy action. Subsequently, industries would have greater trust to buy the technology and innovation from research organizations. Appropriate economic valuation of technology would increase the motivation of research organizations to sell their IP to the industries. Also, it would increase the association of industries with research organizations in long-term.

Table 4: Expert's opinion to increase TT and commercialization in research organizations

Responses	Frequency	Percentage
Research organizations should do collaborative research with industries	48	40
Increase trust for industries to buy indigenous technology	42	35
Formulate a scientific process for appropriate estimation of economic value of technology or innovation	39	32.5
Maintain association of industries with research organizations	36	30
Research organizations should develop technology as per the need of manufacturing industries	33	27.5
Government should adopt formal IP policy	24	20
Adoption of risk incentive policies by research organizations	21	17.5
Research organization should be involved in technology commercialization	18	15
TTOs should improve their ecosystem to increase the TT and commercialization	15	12.5
Total	N=120	

Source: Based on field survey. **Note:** Percentage may exceed 100 due to multiple responses.

Furthermore, national R&D labs should develop technology as per the current industrial requirement. The government needs to adopt formal IP policy to increase TT and

commercialization in research institutions. Adoption of risk incentive policies for research organizations will increase TT and commercialization. TTOs are required to improve their ecosystem to increase the TT and commercialization.

Government's initiatives for TT and Commercialization in Research Organizations: India has lower position in IPRs and science & technological development associated activities as compared to other competitive countries (Singh & Singh, 2020; Singh, Singh & Negi, 2020). Hence, India should focus on IPRs and science & technological development associated variables to increase the technological commercialization in research organizations. For this, India should increase research & development (R&D) expenditure and researchers in research organization. Indian research organizations should implement uniform policy to increase the TT and commercialization. The government should provide the financial support to the researchers to protect their technology through IPRs regime. Researchers should get research grant as per their previous performance in R&D. Innovation is fruit of structured and planned scheme of research in research organizations (Ravi & Janodia, 2021).

Table 5: Government's initiatives for TT and commercialization in research organizations

Suggestions	Frequency	Percentage
Research organizations should discover technology as per the requirement of industries	51	42.5
Financial support should be provided to organize seminar, conferences and workshop for industries	36	30
Research organizations should setup appropriate product discovery and testing research lab	33	27.5
Researchers and scientists should be aware for technology commercialization	27	22.5
Research organizations should introduce research quality evaluation committee	21	17.5
The government should provide financial support to the research organizations to increase technology commercialization	15	12.5
Researchers and scientists should get research grant as per their previous performance in R&D	12	10
Implementation of a well-designed, uniform and formal policy to maintain technology commercialization	9	7.5
The government should provide financial support to the scientists for advancement of exist of technology	6	5
Total	N=120	100

Source: Based on field survey. **Note:** Percentage may exceed 100 due to multiple responses.

Research organizations could not commercialize their innovation or technology due to several barriers which are given in Table 2. The government should take different policy actions to increase TT and commercialization (Table 5). For this, most respondents recommended that research organizations should discover technology as per the requirement of industries to increase TT and commercialization. Research organizations should organize seminar, conferences and workshops to showcase their technology and innovation to the manufacturing industries. The government should provide financial support to the research organizations for above-mentioned activities. Research organizations should setup appropriate product discovery and testing lab to attract the attention of manufacturing industries to buy technology from research organizations. There should be a provision to create more awareness among the researchers and scientists towards technology commercialization in research organizations. Research organizations should introduce research quality evaluation committee to examine the genuineness of research output. Research grant must be sanctioned as per the previous performance of scientists/researchers in R&D, TT and commercialization to maintain research quality in research organizations. The government should implement a well-designed, and formal policy to maintain TT and commercialization in research organizations. Furthermore, the government should provide financial support to the scientists for advancement of exist technology in research institutions.

Ineffective Relationship of Research Organizations with Manufacturing Industries: Indian research organizations do not have a fruitful relationship with manufacturing industries. Accordingly, research organization could not maintain the TT and commercialization with manufacturing industries. Therefore, Indian research organizations should create a conducive ecosystem to increase their collaboration with manufacturing industries (Table 6). As research institutions are using traditional instruments in research, thus, they are unable to produce new technology that cannot meet the technological requirement of industries. Subsequently, research organizations could not increase their association with manufacturing industries. Indian research organizations have low focus on TT and commercialization; therefore, they do not wish to be associated with manufacturing industries. Furthermore, researchers and scientists have other academic responsibilities; therefore, generally they avoid to be engaged in the paper work of TT and commercialization, and IPRs in research institutions. As research organizations and industries discover technology and innovation with different aims and targets. Therefore, most research organizations do not have effective mechanism to work with manufacturing industries. Most research organizations reluctant to share their technological ideas with manufacturing industries. Furthermore, research organizations face several administrative issues which hamper their association with manufacturing

industries. Also, research organization is unable to maintain collaboration with manufacturing industries due to administrative and legal issues.

Table 6: Expert's view on ineffective relation of research organizations with manufacturing industries

Responses	Frequency	Percentage
Research organizations are unable to maintain the quality of technology as per the need of manufacturing industries	65	54.17
Researchers have low interest on TT and commercialization	55	45.83
Researchers and scientists are unable to be engaged in the paper work of TT and commercialization due to their other academic responsibilities	51	42.50
Research organizations and manufacturing industries develop new technology with different aims	45	37.50
Research organizations are knowledge oriented and manufacturing industries are the profit makers organizations	40	33.33
Research organization could not create a favourable ecosystem for manufacturing industries	38	31.67
Research organizations feel worry to disclose and share their ideas with manufacturing industries	25	20.83
Research organizations cannot introduce their syllabus as per current needs of manufacturing industries	21	17.50
Research organizations face several administrative issues to be associated with manufacturing industries	18	15.00
Total	N=120	

Source: Based on field survey. **Note:** Percentage may exceed 100 due to multiple responses.

Proposed Initiatives to Increase Industrial Association with Research Organizations: Several policy initiatives can be introduced to fill existing gap among the research organizations and manufacturing sector in India. Indian research organizations should setup more TTOs to increase their collaboration with manufacturing industries (Table 7). Association of industries with research organizations would increase as adoption of syllabus as per the industrial requirement in research organizations. There must be a provision for manufacturing industries and research organizations to do collaborative research to maintain their relationship. Research organization should pursue a formal IP management policy to increase the trust of manufacturing sector towards indigenous technology.

Table 7: Policy initiatives to increase industry-research organizations relationship

Policy initiatives	Frequency	Percentage
Establishment of more TTOs in the research organizations	56	45.71
Research organizations should introduce academic syllabus as per the manufacturing sector	42	37.14
Manufacturing industries should do collaborative research with research academia	33	31.43
Research organization should pursue a formal IP management policy to increase the trust of manufacturing sector towards indigenous technology	39	28.57
All scientists should discover at least one technology from a R&D project	35	25.71
Research organizations should increase the members in research consulting team and business development cells	30	20
Researchers should take research project from manufacturing industries	25	17.14
Implementation of research evaluation committee to assess the research quality at national level	18	14.29
Research organizations should apply fair policy to maintain their association with manufacturing industries	11	5.71
Total	N=120	

Source: Based on field survey. **Note:** Percentage may exceed 100 due to multiple responses.

All scientists should create at least one technology during a research project and disseminate with industries for further utilization of it. Research organizations should increase number of workers in research consulting team and business development cells to maintain a fruitful communication with industries. Consistent involvement of researchers and scientists in industrial activities may be positive to increase their collaboration with industries. Introduced research examination committee to assess the research quality and its suitability for manufacturing sector. Furthermore, research organizations should follow fair policy to maintain their association with manufacturing industries. It would increase the trust of manufacturing firms in R&D activities of research organizations.

Use of Technology of Research Organizations in Manufacturing Industries: As existing technology of research organizations cannot meet the requirement of manufacturing industries. Hence, researchers and scientists should take the research projects from manufacturing industries and develop a technology or innovation as per their needs (Table 8). Accordingly, research organizations would maintain the quality of research as per the need of manufacturing industries. Research organization should maintain strict policy to reduce the imitation of technology and innovation. Furthermore, research organizations should also create academic and tech-based start-ups. Creation of more tech-stat-ups would be useful to increase TT and commercialization in the market. Further, it would be useful to create appropriate entrepreneurship ecosystem in India.

Research organization should focus on monetary-driven activities in R&D sector to get return through TT and commercialization.

Table 8: Expert's suggestions to increase the use of technology in industries

Suggestions	Frequency	Percentage
Research organizations should take research projects from industries	67	55.83
Research organizations should organize training and outreach programme for industries	54	45.00
Research organizations should develop and discover technology according to need of manufacturing sector	50	41.67
Researchers and scientists should develop technology to produce innovative goods and services	47	39.17
Research organization should maintain strict policy to reduce the imitation of technology and innovation	34	28.33
Research organizations should create academic and tech-start-ups	30	25.00
Research organizations should develop an ecosystem to increase monetary-driven activities in the market	27	22.50
Total	N=120	

Source: Based on field survey. **Note:** Percentage may exceed 100 due to multiple responses.

Involvement of Researchers and Scientists in IPRs Regime: Indian researchers and scientists have a low understating on IPRs regime and its implications in manufacturing sector. IPRs is complex process, time consuming and need more money to manage its. Thus, researchers and scientists do not wish to spend more time to protect their technology through IPRs regime. However, previous studies claimed that patented technology have a high possibility to be transferred and commercialized without any restrictions in the market (Ray, 2012). Therefore, foreign and domestic firms willing to buy patented technology from research institutions to increase their production scale. Indian researchers and scientists should bring their innovation and technology under IPRs regime. Thus, Indian researchers and scientists must be conscious towards IPRs and its practical implications in TT and commercialization in India (Table 9). The Government of India should charge minimum price on patenting and IPRs associated activities for an innovation and technology. Furthermore, the government should take a minimum time to decide on a specific technology whether it can be considered as an IP or not? IPRs regime related programme and syllabus should be introduced in higher academic organizations to increase the importance of IPRs in TT and commercialization. The Government of India should provide financial support to the research organizations to recover the high cost of IPRs related activities. Research organizations should establish technology business incubator centre to increase the TT for manufacturing industries.

Table 9: Expert's suggestions to increase involvement of researchers in IPRs

Suggestions	Frequency	Percentage
Research organizations should motivate to the scientists and researcher towards IPRs regime	78	65.00
The government should charge minimum price on IPRs activities	61	50.83
The government should take a minimum time to decide whether a technology can be considered as an IP or not?	54	45.00
Researchers and scientists should develop technology in emerging areas of manufacturing firms	44	36.67
IPRs regime related programme and syllabus should be introduced in higher academic organizations	37	30.83
The Government of India should provide financial support to the research organizations to recover the high cost of IPRs related activities	31	25.83
Research organizations should establish business incubator centre	25	20.83
Total	N=120	

Source: Based on field survey. **Note:** Percentage may exceed 100 due to multiple responses.

Role of IPRs Regime in Manufacturing Sector: This study also includes the expert's view on implications of IPRs regime in manufacturing industries. Most respondents accepted that IPRs is powerful tool to increases the associations of industries with research organizations. IPRs also provide legal security of technology and innovation, and it can be used for further development of technology (Singh, Arya, & Jyoti, 2019; Singh & Singh, 2020; Singh, 2021). IPRs protected technology and innovation are useful to increase the science & technological (S&T) strength of a research organization in manufacturing sector. Furthermore, IPRs protected technology and innovation have potential to be commercialized in manufacturing sector. Manufacturing industries have a high trust to buy IPRs protected technologies from research organizations. Research organizations are doing commercialization of technology without IP protection due to high cost of IPRs activities. Thus, it reduces the realization of researchers and scientists in IPRs regime due to its complexity. Therefore, the government should provide financial support to manage the IPRs related activities, and implement a simple and effective IPRs policy in research organization and manufacturing sector.

Table 10: Expert's opinion on implications IPRs regime in manufacturing industries

View	Frequency	Percentage
It increases collaboration of manufacturing industries with research organizations	85	70.83
It increases awareness among the researcher and scientists towards IPRs regime	72	60.00
It provides legal security of technology and innovation	65	54.17
It is essential for further development of technologies	60	50.00
It is useful to increase the S&T strength of research organizations	57	47.50
It is helpful to increase the commercialization of technology and innovation	55	45.83
Manufacturing industries have a high trust to buy IPRs protected technology	51	42.50
Research organizations are doing commercialization of technology without IP protection due to high cost of IPRs	47	39.17
Researchers and scientists have low trust on IPRs due to rapid change in technology	41	34.17
Research organizations do not wish to be involved in IPRs activities due to its complexity	35	29.17
High maintenance cost of IPRs	30	25.00
The government should provide the financial support to the research organizations to maintain the IPRs related activities	24	20.00
The government should introduce an effective policy on IPRs regime in research organizations and manufacturing sector	18	15.00
High imitation rate of technology reduces the possibility of TT and commercialization	15	12.50
Total	N=120	

Source: Based on field survey. **Note:** Percentage may exceed 100 due to multiple responses.

5. Conclusion, Policy Suggestions and Further Research Direction

This study provided the progress of intellectual property rights (IPRs) of India during 2006 – 2007 to 2018 – 2019. Thereupon, it assessed the expert's opinion on TT and commercialization, and IPRs in selected 40 public funded research organizations and universities. For this, it conducted the survey of 120 stakeholders (i.e., Head of TT offices, director/professor, associate professor, assistant professor, scientists, managers, IPRs experts and dean R&D) who had active involvement in TT and commercialization, and IPRs associated activities in research organizations. The results based on secondary data demonstrate that number of granted patents, registered design application, registered trademark, and total revenue generated through IP system have increased consistently during aforementioned period. Hence, India's progress in IPRs related activities has improved during the aforesaid periods. In contrary, the share of manufacturing sector in India's GDP has decreased from 16.14% in 2011 to 13.65% in 2019 (World Bank, World Development Indicators, 2021). Thus, India needs to increase the share of manufacturing sector through TT and commercialization, and implementing strong IPRs regime and

science & technological development related policies in research organizations and manufacturing sector.

The descriptive results based on qualitative information given by experts, showed that there is no uniform process for TT and commercialization in Indian research organization. Most research organizations follow contractual agreements, licensing for limited time periods, mutual contract and agreements among the technology developers and seekers in TT and commercialization. Also, Indian research organizations do not have a scientific and uniform method to estimate the economic value of IP. Therefore, Indian research organization could not develop a conducive ecosystem to increase TT and commercialization due to several other barriers and obstacles which were identified as: low quality of technology and innovation developed by research organizations, presence of significant gap between R&D activities of research organizations and industries, researchers and scientists could not estimate the economic value of technology and innovation, industries are denied to buy technology from research organizations, licensing process is complex for TT and commercialization, difficulty in estimation of royalty fee, low technology absorption capacity of manufacturing industries, research organizations cannot maintain the privacy and time period of licensing of a technology, and managerial issues in TTOs and business development units. Thus, TT and commercialization are a challenge for individual researcher/scientist and research organization due to aforementioned barriers. Therefore, following recommendations can be considered in policy formulation to increase TT and commercialization in Indian research organization:

Research organizations should establish more TTOs, initiate collaborative research with manufacturing industries, meet the technological requirement of manufacturing sector, implement strict IPRs regime to increase the trust of manufacturing sector, develop an appropriate method to estimate economic value of technology and innovation, attract the attention of manufacturing sector towards their technology in various field, pursue better market strategy, setup product generation and advance laboratory for manufacturing sector, formulate research advisory committee to examine the viability of ongoing research, and adopt exclusive rights to maintain TT and commercialization. Researchers and scientists should try to understand the prime technological requirement of manufacturing industries, develop advance technology which have high viability in the market, take research projects from manufacturing industries, and be aware to increase the transfer of technology for industrial usages.

The government should create demand of new products in product market through implementing effective fiscal policy, adopt formal IP policy in research organizations and manufacturing firms, provide financial support to the research organizations to conduct

seminar and workshop for manufacturing sector, develop a favourable ecosystem in TTOs to increase TT and commercialization. Also, the research grant should be sanctioned as per the pervious performance of researchers and scientists in R&D and contribution in TT and commercialization. In India, research organizations have a low association with manufacturing sector due to following reasons: Research organizations produce low quality of technology and innovation which cannot meet the needs of manufacturing sector. Research organizations and manufacturing industries have different aim to develop technology and innovation. Therefore, research organizations have low scope to meet the technological requirements of manufacturing industries. Furthermore, researchers and scientists have several academic, research and administrative responsibilities, thus, they avoid to be involved in legal procedure of IPRs, TT and commercialization. Therefore, following actions can be introduced to increase the collaboration of industries with research organizations: Research organizations should setup more TTOs, develop academic syllabus as per the basic requirement of manufacturing sector, follow an effective uniform IPRs policy, increase number of members in consulting team to increase the better communication with manufacturing industries, and be transparent to increase their research collaboration with manufacturing industries. Provision for all scientists to develop at least one technology or innovation from one R&D project will be useful to TT and commercialization in research institutions.

Research organizations should take research projects from manufacturing industries, organize training and outreach programme to the manufacturing industries, maintain the research quality as per industry's requirements, implement strict law to reduce imitation rate of technology, and develop academic and technology-based start-ups to increase use of technology and innovation of research organizations for manufacturing industries. Also, researchers and scientists should be aware towards IPRs regime and its benefits to reduce imitation rate of technology and innovation. The Government should decide minimum time to grant a patent or other forms of IPRs on a technology. Research organizations should introduce IPRs related programme in higher academic institutions. The government should provide the financial support to increase the attention of researchers and scientists for IPRs which be effective to: Increase associations of manufacturing industries with research organizations, maintain the legal security of technology and innovation in research organizations, increase more technology and innovation in research organizations, increase science & technological strength of research organizations and increase the confidence of manufacturing industries to buy IPRs protected technology from research organizations.

This study detected the barriers and obstacles of TT and commercialization in research organizations, and implications of TT and commercialization, and IPRs regime in Indian

manufacturing sector. For this, it used qualitative data which was collected from the 120 subject experts in 40 reputed research institutions and universities in India. Accordingly, it provided several policy suggestions to solve existing issues in TT and commercialization, and IPRs regime in Indian research organizations. Therefore, this study makes a significant contribution towards the theoretical literature. However, this study could not examine the factors affecting TT and commercialization, and IPRs regime in research institutions using concreate empirical model. Hence, existing researchers can assess the impact of TT and commercialization, and IPRs regime in Indian manufacturing sector using robust empirical model. Furthermore, existing researchers can develop the scientific method to examine the economic values of technology and innovation to increase the TT and commercialization in Indian research institutions in future studies.

Acknowledgements

This article is one of crucial part of post-Doctorate research of first author. The prime author is grateful to Entrepreneurship Development Institute of India (EDII), Ahmedabad for providing financial support and resources to writing this article.

Conflicts of Interest

The authors do not have conflict of interest.

References

Abhyankar, R. (2014). The Government of India's role in promoting innovation. *Technology Innovation Management Review*, 4(8), 11–17. https://doi.org/10.22215/timreview/818

Alina, I., & Diana, D. (2016). Technology commercialization: Experience of the U.S. and possibilities for oil and gas industry in Russia. *International Journal of Applied Engineering Research*, 11(7), 4990-4994. http://wrecon.ru/system_dynamics/article/scopus/Ing_Scopus_0.260_Ilinova_Dmitrieva_Technology%20commercialization.pdf

Araújo, C., & Teixeira, A. (2014). Determinants of international technology transfer: An empirical analysis of the enterprise Europe network. *Journal of Technology Management & Innovation*, 9(3), 1-23. https://doi.org/10.4067/S0718-27242014000300009

Ashraf, S. N., & Singh, A. K. (2021). Impact of technological change on growth and agricultural sector in Gujarat state of India: A time series data study. *Asian Development Policy Review*, 9(3):144-160. https://doi.org/10.18488/journal.107.2021.93.144.160

Bigliardi, B., Galati, F., Marolla, G., & Verbano, C. (2015). Factors affecting technology transfer officies' performance in the Italian food context. *Technology Analysis & Strategic Management*, 27(4), 361-384. https://doi.org/10.1080/09537325.2014.1002464

Falvey, R., & Foster, N. (2006). *The role of intellectual property rights in technology transfer and economic growth theory and evidence*. United Nations Industrial Development Organization (UNIDO), Vienna. https://www.unido.org/sites/default/files/2009-04/Role_of_intellectual_property_rights_in_technology_transfer_and_economic_growth_0.pdf

Feng, H. I., Chen, C. S., Wang, C. H., & Chiang, H. C. (2010). The role of intellectual capital and university technology transfer offices in university-based technology transfer. *The Service Industries Journal*, 32(6), 899-917. https://doi.org/10.1080/02642069.2010.545883

Finardi, U., & Breznitz, S. M. (2017). Factors affecting university commercialization: Evidence from Italy. *Revista Vasca de Economia*, 92(2), 222-245. https://ideas.repec.org/a/ekz/ekonoz/2017210.html

Franco-Giraldo, L., & Gentilin, M. (2021). Factors affecting the commercialisation of new knowledge: a roadmap proposal. *International Journal of Business Innovation and Research*, 25(1), 19-34. https://doi.org/10.1504/IJBIR.2021.115045

Ganzer, P. P., Chais, C., & Olea P.M. (2017). Product, process, marketing and organizational innovation in industries of the flat knitting sector. *RAI Revista de Administração e Inovação*, 14(4), 321-332. https://doi.org/10.1016/j.rai.2017.07.002

Hillemane, B. S. M., & Satyanarayana, K. (2019). Technology business incubation for start-up generation: A literature review a conceptual framework. *International Journal of Entrepreneurial Behavior & Research*, 25(7), 1471-1493. https://doi.org/10.1108/IJEBR-02-2019-0087

Hou, P. & Lim, B. (2021). Commercialization of traditional performing arts in Mainland China. A case study of Deyunshe. *Journal of Management, Economics, and Industrial Organization*, 5(1), 86-99. http://doi.org/10.31039/jomeino.2021.5.1.5

Jun, Y., & Ji, I. (2016). Demand-pull technology transfer and needs-articulation of users: A preliminary study. *Procedia Computer Science*, 91(2016), 287-295. https://doi.org/10.1016/j.procs.2016.07.079

Jyoti, B., & Singh A. K. (2020). Characteristics and determinants of new start-ups in Gujarat (India). *Entrepreneurship Review*, 1(2), 1-25. https://doi.org/10.38157/entrepreneurship-review.v1i2.154

Kang, J., Gwon, S. H., Kim, S., & Cho, K. (2013). Determinants of successful technology commercialization: implication for Korean Government-sponsored SMEs. *Asian Journal of Technology Innovation*, 21(1), 72-85. https://doi.org/10.1080/19761597.2013.810947

Kim, M. S., Shin, D. H., Kim, J. S., & Lee B. H. (2015). An empirical analysis of technology transfer of national R&D projects in South Korea. *Advances in Multimedia*, 2015(498408), 1-9. https://doi.org/10.1155/2015/498408

Kim, B., Kim, H., & Jeon, Y. (2018). Critical success factors of a design startup business. *Sustainability*, 10(2981), 1-15. https://doi.org/10.3390/su10092981

Kumar, S., Luthra, S., Haleem, A., Mangla, S. K., & Garg, D. (2015). Identification and evaluation of critical factors to technology transfer using AHP approach. *International Strategical Management Review*, 3(1), 24-42. https://doi.org/10.1016/j.ism.2015.09.001

Laik, K. (2015). Role of intellectual property in economic growth. *Journal of Intellectual Property Rights*, 10(1), 456-473. http://nopr.niscair.res.in/handle/123456789/3698

Lov, J. H., & Roper S. (1999). The determinants of innovation: R&D, technology transfer and networking effects. *Review of Industrial Organization*, 15(1), 43-64. https://www.jstor.org/stable/41791239

Manral, M. S., Prashar, B., & Sheikh, Y. (2012). Technology transfer in pharmaceutical industry: facts and steps involved. *American Journal of PharmTech Research.*, 2(4), 73-82. http://docshare03.docshare.tips/files/29753/297535627.pdf

Kirchberger, M. A., & Pohl, L. (2016). Technology commercialization: A literature review of success factors and antecedents across different contexts. *The Journal of Technology Transfer*, 41(5), 1077-1112. https://doi.org/10.1007/s10961-016-9486-3

Muthoni, M. P., Omato, G. P., & Kithinji, M. A. (2013). Analysis of factor influencing transfer of technology among micro and small enterprises in Kenya. *International Journal of Business and Social Science*, 4(17), 71-179. https://ijbssnet.com/journals/Vol_4_No_17_Special_Issue_December_2013/21.pdf

Mysore, S. (2015). Technology commercialization through licensing: Experiences and lessons-A case study from Indian horticulture sector. *Journal of Intellectual Property Rights*, 20(1), 363-374. http://nopr.niscair.res.in/bitstream/123456789/33582/1/JIPR%2020%286%29%2036 3-374.pdf.

Odilpova, S. (2016). Patent protection, intelligence and economic growth: A cross-country empirical investigation. *MPRA Paper No.70842*. https://mpra.ub.uni-muenchen.de/70842/1/MPRA_paper_70842.pdf.

OECD (2000). *Science, technology and innovation in the new economy*. Policy Brief, 9, OECD Headquarters, Paris. https://www.oecd.org/science/sci-tech/1918259.pdf

Osabutery, E. L. C., & Jin, Z. (2016). Factors influencing technology and knowledge transfer: Configurational recipes for Sub-Saharan Africa. *Journal of Business Research*, 69(2016), 5390-5395. https://doi.org/10.1016/j.jbusres.2016.04.143

Osano, H. M., & Koine P. W. (2016). Role of foreign direct investment on technology transfer and economic growth in Kenya: A case of the energy sector. *Journal of Innovation and Entrepreneurship*, 5(31), 1-25. https://doi.org/10.1186/s13731-016-0059-3

Özdemir, Ö. Ç., & Şehitoğlu, Y. (2013). Assessing the impacts of technology business incubators: A framework for technology development center. *Procedia-Social and Behavioral Sciences*, 75(1), 282-291. https://doi.org/10.1016/j.sbspro.2013.04.032

Rath, S., Nathani, A., Patel, D., Kulkarni, P., & Gota, V. (2014). Status of technology transfer in India-the mucg needed Magic Remedy. *Current Science*, 106(8), 1058-1060. https://www.jstor.org/stable/24102297

Ravi, R., & Janodia, M. D. (2021). Factors affecting technology transfer and commercialization of university research in India: a cross-sectional study. *Journal of the Knowledge Economy*, 1-17. https://doi.org/10.1007/s13132-021-00747-4

Ray, S. (2012). Technological transfer and technology policy in a developing country. *The Journal of Developing Areas*, 46(2), 371-396. https://www.jstor.org/stable/23215378

Sattar, A., & Mahmood, T. (2011). Intellectual property rights and economic growth: Evidence from high, middle and low income countries. Pakistan Economic and Social Review, 49(2), 163-186. http://pu.edu.pk/images/journal/pesr/PDF-FILES/2%20SATTAR%20Intellectual%20Property%20Rights%20and%20Economic%20Growth.pdf

Sengupta, A., & Ray, A. S. (2015). University research, commercialization and knowledge exchange in the UK: An econometric analysis of the determinants and inter-linkages. ESRC Business and Local Government Data Research Centre, University of Essex Colchester Campus, United Kingdom. http://www.blgdataresearch.org/wp-content/uploads/2015/07/WPS2015-02-Abhijit-Sengupta-Amit-S-Ray.pdf

Shugurov, M. V. (2015). TRIPS agreement, international technology transfer and least developed countries. *Journal of Advocacy, Research and Education*, 2(1), 74-85. http://oaji.net/articles/2015/1704-1437910422.pdf

Singh, A. K. (2021). Technology transfer and commercialization models and policies in India, USA, China and Malaysia: A conceptual review. *Asian Journal of Sociological Research*, 3(1), 19-45. https://globalpresshub.com/index.php/AJSR/article/view/916

Singh, A. K., Arya, A., & Jyoti B. (2019). A conceptual review on economic, business, intellectual property rights and science & technology related activities in Asian economies. *JNNCE Journal of Engineering & Management*, 3(2), 1-22. http://jjem.jnnce.ac.in/article/JJEM030201.pdf

Singh, A. K., & Ashraf S. N. (2019). Viability of Bayh-Dole Act of USA in context of India: critical evidence from review of literature. *JNNCE Journal of Engineering & Management*, 3(1), 7-22. http://jjem.jnnce.ac.in/article/JJEM030102.pdf

Singh, A. K., Ashraf, S. N. and Arya, A. (2019). Estimating factors affecting technical efficiency in Indian manufacturing sector. *Eurasian Journal of Business and Economics*, 12(24), 65-86. https://doi.org/10.17015/ejbe.2019.024.04

Singh, A. K., & Jyoti B. (2020). Factors affecting firm's annual turnover in selected manufacturing industries of Indian: An empirical study. *Business Perspective Review*, 2(3), 33-59. https://doi.org/10.38157/business-perspective-review.v2i3.206

Singh, A. K., & Ashraf S. N. (2020). Association of entrepreneurship ecosystem with economic growth in selected countries: An empirical exploration. *Journal of Entrepreneurship, Business and Economics*, 8(2), 36-92. http://scientificia.com/index.php/JEBE/article/view/138

Singh, A. K., & Singh, B. J. (2020). Implications of intellectual property protection, and science and technological development in the manufacturing sector in selected economies. *Journal of Advocacy, Research and Education*, 7(1), 16-35. http://oaji.net/articles/2021/1704-1615668997.pdf

Singh, A. K., Singh, B. J. & Negi, V. (2020). Does sustainable development have a causal relationship with environmental development? Evidence from a country-wise panel data analysis. *International Journal of Technology Management & Sustainable Development*, 19(2), 147-171. https://doi.org/10.1386/tmsd_00020_1

Singh, A. K., & Kumar, S. (2021). Assessing the performance and factors affecting industrial development in Indian states: An empirical analysis. *Journal of Social Economics Research*, 8(2), 135-154. https://doi.org/10.18488/journal.35.2021.82.135.154

Singh, A. K., Jyoti, B., Kumar, S., & Lenka, S. K. (2021). Assessment of global sustainable development, environmental sustainability, economic development and social development index in selected economies. *International Journal of Sustainable Development and Planning*, 16(1), 123-138. https://doi.org/10.18280/ijsdp.160113

Singhai, S., Singh, R., Sardana, H. K., & Madhukar (2021). Analysis of factors influencing technology transfer: A structural equation modelling based approach. Sustainability, 13(5600), 1-15. https://doi.org/10.3390/su13105600

Sultana, F. & Akter, A. (2021). Women E-commerce: Perspective in Bangladesh. *Journal of Management, Economics, and Industrial Organization*, 5(3), 1-13. http://doi.org/10.31039/jomeino.2021.5.3.1

World Bank (2021) World Development Indicators 2021. https://databank.worldbank.org/source/world-development-indicators.

Yin, J. Z. (1992). Technological capabilities as determinants of the success of technology transfer projects. *Technological Forecasting and Social Change*, 42(1), 17-29. https://doi.org/10.1016/0040-1625(92)90070-A

Yueh, L.Y. (2007). Global intellectual property rights and economic growth. *Northwestern Journal of Technology and Intellectual Property*, 5(3), 434-448. https://scholarlycommons.law.northwestern.edu/cgi/viewcontent.cgi?article=1133&context=njtip

Zhao, H., & Grier D. (1991). Factors influencing technology transfer: The case of China. *The Journal of Technology Transfer*, 16(1), 50-56. https://doi.org/10.1007/BF02371492

Zuniga, P. (2011). The state of patenting at research organizations in developing countries: Policy approaches and practices. *WIPO Economic Research Working Paper, No. 4*, https://www.wipo.int/publications/en/details.jsp?id=3948

Appendix A

Table A1: Name of research organizations included in this study

Research Organizations	City	State	Funding Agency
PGP Polytechnic College	Namakkal	Tamil Nadu	All India Council for Technical Education
Central Food Technological Research Institute India	Mysore	Karnataka	Council of Scientific and Industrial Research
Central Salt & Marine Chemicals Research Institute	Bhavnagar	Gujarat	
Indian Institute of Chemical Biology	Kolkata	West Bengal	
Indian Institute of Toxicology Research	Lucknow	Uttar Pradesh	
National Chemical Laboratory Pune	Pune	Maharashtra	
National Geophysical Research Institute India	Hyderabad	Telangana	
National Institute of Science Technology and Development Studies	New Delhi	NCT Delhi	
Institute for Plasma Research	Gandhinagar	Gujarat	Department of Atomic Energy (DAE), (GoI)
National Innovation Foundation of India	Ahmedabad	Gujarat	
Tiruchirappalli Regional Engineering College Science and Technology Entrepreneurs Park	Tiruchirappalli	Tamil Nadu	
Indian Institute of Science	Bangalore	Karnataka	Government of India
National Institute of Design	Gandhinagar	Gujarat	
National Research Development Corporation	Bangalore	Karnataka	
Indian Agricultural Research Institute	New Delhi	NCT Delhi	Indian Council of Agriculture Research, New Delhi
Anand Agricultural University	Anand	Gujarat	
Central Institute for Research on Cattle	Meerut	Uttar Pradesh	
Indian Veterinary Research Institute	Bareilly	Uttar Pradesh	
All India Institute of Medical Sciences	New Delhi	NCT Delhi	ICMR (GoI)
Banaras Hindu University Institute of Medical Sciences	Varanasi	Uttar Pradesh	
Indian Space Research Organization	Ahmedabad	Gujarat	
Indian Institute of Science Education and Research	Pune	Maharashtra	Ministry of Human Resource Development (GoI)
Indian Institute of Technology Kharagpur	Kharagpur	West Bengal	
Indian Institute of Technology Madras	Chennai	Tamil Nadu	
Indian Institute of Technology	Mumbai	Maharashtra	
Indian Institute of Technology	New Delhi	NCT Delhi	
Indian Institute of Technology	Guwahati	Assam	
Indian Institute of Technology	Kanpur	Uttar Pradesh	
National Institute of Technology	Tiruchirappalli	Tamil Nadu	
National Institute of Technology	New Delhi	NCT Delhi	

IP Facilitation Center for MSMEs	Pune	Maharashtra	Ministry of Micro, Small and Medium Enterprises (GoI) and CSIR, New Delhi
B.V. Patel Pharmaceutical Education and Research Development Centre	Ahmedabad	Gujarat	Public Funded States Institute
Gujarat Energy Research and Management Institute	Gandhinagar	Gujarat	
Bangalore University	Bangalore	Karnataka	Public State University
Guru Nanak Dev University India	Amritsar	Punjab	
Jadavpur University	Kolkata	West Bengal	
Panjab University	Chandigarh	Chandigarh	
Punjab Agricultural University India	Ludhiana	Punjab	
University of Hyderabad	Hyderabad	Telangana	
University of Madras	Chennai	Tamil Nadu	