

Technology Transfers from Public-funded Research Organizations: A Systematic Literature Review

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Public-funded Research Organizations (PROs) are a class of research organizations carrying out R&D for the growth of industrial economy. These are distinct from University Research Organizations (UROs), despite both being publicly funded. While UROs are populated with student-faculty teams focused on academic research, PROs are populated with full-time professional researchers focusing largely on post-academic research. Technology transfers from PROs are important for national economic development and hence are worth a study. The objective of this paper is to study literature to (a) explore tech-transfer characteristics such as mechanisms, actors, success factors, stages, and models, and b) to gather any relevant insights. The method of Systematic Literature Review (SLR) was adopted for this study. Compared to conventional narrative review, SLR offers a replicable, scientific, and transparent process that aims to minimize bias and provides an audit trail of the reviewer's decisions. Hence, SLR by itself is considered a research. Among the various methods for the literature-analysis such as bibliographic analysis, meta-analysis and thematic analysis, this paper adopts thematic analysis consistent with the objectives of research and the limited size of the literature on the topic. Focusing chiefly on recent literature on domestic technology transfers from PROs, this work provides useful insights.

Keywords: Literature-analysis, Management of technology, Public research organization, SLR, Tech-transfer characteristics

Introduction

Public-funded Research Organizations (PROs) are organizations set up by the government to carry out research and experimental development¹ to aid the technological development in specific sectors of the economy such as agriculture, health care, manufacturing, aerospace, nuclear power, etc. They differ from University Research Organizations (UROs), which carry out academic research and at times post-academic research at the early stages of Technology Readiness Level (TRL), and are not disposed to technology transfers (tech-transfers hereafter) as much as PROs, especially in developing countries.^{2,3} While UROs receive funding for research from both the government and the industry⁴, PROs are funded largely by the government. There are certain research organizations that have characteristics of both PRO and URO. Examples include Homi Bhabha National Institute (HBNI) in India and Paris-Saclay University in France.⁴

Since not all industrial firms can afford to carry out R&D, an uneven competition might be set in

the market.⁵ To alleviate this, governments do provide interventions through government research organizations to cost-effectively provide technological innovations.⁶ In the context of the USA, Link & Scott state that private firms do benefit from the adoption of technologies from the federal laboratories. They further clarify that if a federal laboratory can provide a technology more efficiently than the private sector, it implies a social gain from the federal laboratory.⁷

As a matter of policy, governments take up research not only to contribute to the technological requirements of the industry but also to provide socioeconomic return on investment by supporting the areas such as medicine and environment.⁸

Given the unique characteristics of UROs and PROs, the USA enacted in the year 1980, two separate legal instruments namely the Bayh Dole Act for tech-transfers from universities, and the Stevenson-Wydler Act for tech-transfers from federal laboratories.

The unique strengths of PROs in respect of meeting industrial requirements are as follows. Scientists of PROs generally have minimal teaching obligation enabling them to devote almost full time to R&D work. While universities are populated by student-

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faculty teams with students available for the limited duration of their academic programme, the PROs are populated with full-time researchers and permanent scientific assistants available for a long enough duration required for arriving at a solution for real-life problems. Departments in the universities are largely discipline-specific with rigid boundaries, while PROs have multidisciplinary teams under one umbrella. There are PROs such as BARC where every division is a multidisciplinary unit.^{2,3} PROs are equipped with specialized research and demonstration facilities for carrying out R&D at both academic and post-academic stages, giving rise to products or services at a higher TRL.^{2,3,9} In recent years, though some UROs have set up multidisciplinary units on topics such as energy research, nano-sciences, etc., these initiatives fall short of needs to develop new technologies. Recognizing this, clustering of research centers and higher education institutes has now been taken up as exemplified by HBNI and Paris-Saclay University.

From all these considerations, tech-transfers from PROs are worth exploring.¹⁰ However, this topic is under-studied in comparison with tech-transfers from universities.^{9,11–13}

The objective of this paper is to study recent literature (a) to explore the characteristics such as mechanisms, actors, success factors, stages, and models pertaining to tech-transfers from PROs, and (b) to gather any relevant insights.

The study was carried out by the method of Systematic Literature Review (SLR) of the recent academic literature pertaining to tech-transfers from PROs. The SLR has its origin in the medical field and differs from traditional narrative reviews as it adopts a replicable, scientific, and transparent process that aims to minimize bias and provides an audit trail of the reviewer's decisions.¹⁴ Undertaking an SLR is regarded as a 'fundamental scientific activity' for producing a comprehensive synthesis in order to draw broad and robust conclusions rendering it an academic article in its own right.^{14,15}

Identifying the right corpus of publications is the central process of SLR. Further analysis of literature is done by methods such as a bibliographical analysis, meta-analysis and thematic analysis. Due to limited size of the corpus that resulted from our search and considering the nature of our research-objective, we carried out thematic analysis. The work provided useful insights.

Methodology

The following phases of SLR were followed.¹⁵

Planning Phase

The objective of the search was split into five Research Questions (RQs) -

- (i) By what mechanisms do the tech-transfers take place from PROs to industry?
- (ii) Who are the actors involved in tech-transfers from PROs to industry?
- (iii) What are the success factors for tech-transfers from PROs to industry?
- (iv) What are the stages of execution of tech-transfers from PROs to the industry?
- (v) What are the models depicting the tech-transfers from PROs to the industry?

Scoping phase

Following parameters were set up for scoping the search.

Period

2010 to 2023, since we are interested only in recent literature; considering a longer period is not desirable due to rapid evolution in techno-economic conditions seen in recent decades. Moreover, the intensification of tech-transfer activities in PROs is a relatively recent phenomenon, especially in developing countries.

Nature of the Articles

Journal publications in the area of technology transfer, of research and review type in English related to business & decision-making.

Inclusion Criterion

Technology-transfer from PROs and keywords corresponding to the research questions actors, factors, mechanisms, models, and stages.

Exclusion Criteria

Academic Entrepreneurship, Engineering Education, Education, University, University Sector, Universities, University Technology Transfer, University Spin-offs, Entrepreneurial University, University-industry Collaboration, University Industries, International Technology Transfers, International Trade, Higher Education, Students, University Research.

Searching Phase

The search logic built as per the said parameters was run on the Scopus web-based database, which is considered as the most suitable for the topic under study. Scopus returned 116 publications. After

removing duplicates and invalid records, a corpus of 113 valid publications were taken for screening.

Screening Phase

The steps of screening are depicted in Fig. 1. By the title, 56 numbers were shortlisted. By reading the abstracts, 42 publications were shortlisted for reading the text. Finally, 32 publications were selected for thematic analysis.

Analysis Phase

We initially made a descriptive analysis to get (a) the yearly trend of number of publications among the valid corpus returned by Scopus, (b) the list of journals that published those selected for thematic analysis, and (c) the list of ten highly cited publications. Then, the publications that answered the RQs were taken for thematic analysis. We found that some publications, though not answered the RQs, contain additional insights beyond RQs, but pertain to PRO tech-transfers. These are also perused in the discussion. The next section gives the descriptive analysis of the corpus of publications.

Descriptive Analysis of the Corpus of Publications

The number of publications on PROs published per year is shown in Fig. 2, which indicates non-uniformity in the trend. The non-uniformity cannot be easily explained since the number of papers is not large enough and the time-span considered is not long enough to figure out a statistical reasoning.

The journals that covered three or more publications pertaining to the topic of interest are listed in Table 1. These covered 61% of total corpus, implying a reasonable selectivity of journals for the topic studied. Over a quarter (27.5%) of the publications appeared in the Journal of Technology Transfer, consistent with the specialization of this journal. This along with the next four journals covered half the corpus of publications, indicating the importance of these journals for the subject of

interest. The next four important journals are Technovation, Research Policy, Technological Forecasting and Social Change and International Journal of Technology Management.

Journal wise numbers of publications selected for thematic analysis are listed in Table 2. In this list too, a quarter of the publications are from the Journal of Technology Transfer. Over half the publications came

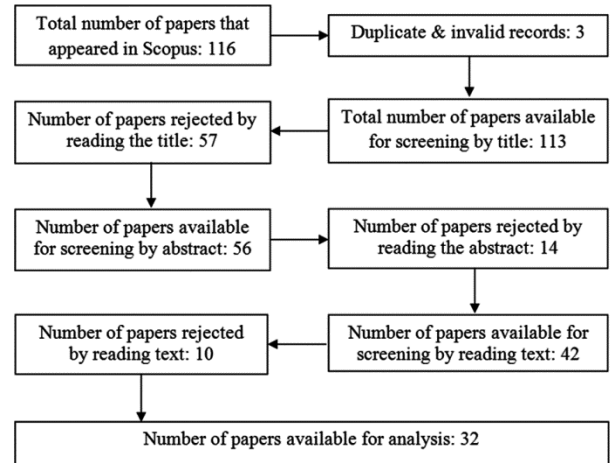


Fig. 1 — Steps in selecting the publications for analysis

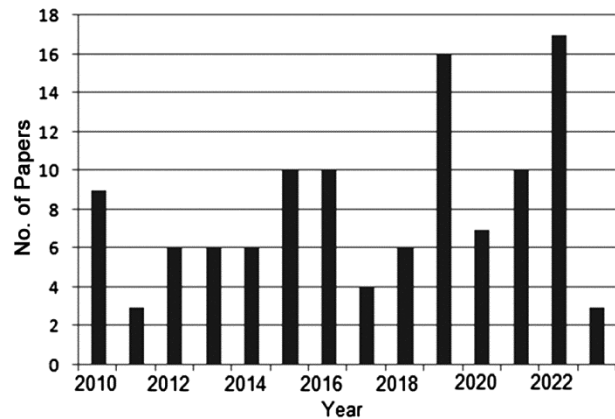


Fig. 2 — Yearly plot of the number of publications obtained by Scopus search

Table 1 — Journals that covered three or more publications in the full corpus

Sl. No.	Journal	No. of publications	Percentage in full corpus	Cumulative % in full corpus
1	Journal of Technology Transfer	31	27.5%	27.5%
2	Technovation	9	8%	35.5%
3	Research Policy	8	7%	42.5%
4	Technological Forecasting and Social Change	6	5%	47.5%
5	International Journal of Technology Management	3	2.7%	50.2%
6	International Journal of Innovation Management	3	2.7%	52.9
7	Journal of Technology Management and Innovation	3	2.7%	55.6
8	Knowledge Management Research and Practice	3	2.7%	58.3
9	Technology Analysis and Strategic Management	3	2.7%	61%

from six journals, four of which are among the five best found in the full corpus. This kind of consistency reveals that the screening of the publications is free from any selection bias. The two important journals

Table 2 — Journal and the number of publications selected for thematic analysis

Sl. No.	Journal	No. of publications
1	Journal of Technology Transfer	8
2	Research Policy	3
3	Technovation	2
4	International Journal of Technology Management	2
5	International Journal of Innovation Management	2
6	Technology in Society	2
7	Technological Forecasting and Social Change	1
8	Innovation: Organization and Management	1
9	International Journal of Business and Globalization	1
10	International Journal of Learning and Intellectual Capital	1
11	International Journal of Services, Technology, and Management	1
12	Journal of Evolutionary Economics	1
13	Journal of Knowledge Management	1
14	Journal of Public Budgeting, Accounting and Financial Management	1
15	Journal of Science and Technology Policy Management	1
16	Research Technology Management	1
17	Service Industries Journal	1
18	Industry and Higher Education	1
19	Technology Analysis and Strategic Management	1

other than those mentioned in the previous paragraph are International Journal of Innovation Management and Technology in Society.

The top 10 highly cited publications among those selected for analysis are listed in Table 3. Interestingly, the highest number of citations is for a relatively recent publication by Doblinger *et al.*¹⁶ about government research alliances with firms in clean technologies aimed at mitigating climate change and providing affordable energy. This reveals a high level of research interest in government research alliances for a technology that addresses a contemporary challenge. All other publications received about half or fewer citations as Doblinger *et al.*¹⁶ However, the next two highest numbers of citations came from the publications of Cunningham^{17,18} that focus on the need to motivate the research scientists to take up techno-managerial activities in addition to striving for technical excellence. This underlines the importance of human element in tech-transfers.

Thematic Analysis of Publications

The publications were examined for the findings against each RQ and segregated (Table 4). The highest number of publications corresponded to mechanisms. This is consistent with growing complexities of technologies and business models of industries.

The following paragraphs describe RQ wise insights obtained.

Research Question: Mechanisms Involved in Technology Transfers from PROs

There are several channels of technology transfer, both planned and unplanned.²⁶ In this paper, the

Table 3 — Publications among selected ones with top 10 citation scores

Sl. No.	Title of the publication	No. of citations
1	Governments as partners: the role of alliances in U.S. Clean-tech Startup Innovation. ¹⁶	64
2	At the frontiers of scientific advancement: the factors that influence scientists to become or choose to become publicly funded principal investigators. ¹⁸	33
3	Managerial challenges of publicly funded principal investigators. ¹⁷	32
4	Not invented here: technology licensing, knowledge transfer and innovation based on public research. ¹⁹	28
5	Value generation from industry-science linkages in light of targeted open innovation. ²⁰	28
6	Do technology entrepreneurship and external relationships always promote technology transfer? Evidence from Korean public research organizations. ²¹	25
7	Facilitating public-to-private technology transfer through consortia: initial evidence from Korea. ²²	23
8	Exploring scientific productivity and transfer activities: Evidence from Argentinean ICT research groups. ²³	22
9	New entrepreneurial behavior of public research organizations: opportunities and threats of technological services supply. ²⁴	21
10	The emergence of new modes of R&D services in Germany. ²⁵	20

Table 4 — Classification of selected publications from Scopus search

Sl. No.	Classification of publications	No. of publications selected for analysis	
1	Research question answered	Mechanisms	12 [#]
		Factors	10 [#]
		Actors	5
		Models	0
		Stages	0
2	No specific RQ answered but gave additional insights (See Discussion)	Additional insights	6

One publication is in both mechanisms and factors

planned channels are called *mechanisms* of tech-transfers, and include - licensing, franchise, joint venture, turnkey project, FDI, collaboration, and technical consortium. Mechanisms such as franchises, joint ventures, and FDI did not appear in the literature studied.

The mechanisms that came out in this review were grouped into three categories - conventional, special mechanisms (implemented in China), and new paradigms (Table 5).

Conventional Mechanisms (Licensing, Research Contracts, Alliances and Spin-offs & Startups):

Buenstorf *et al.*¹⁹ conducted an empirical study to find mechanisms of tech-transfers from the Max Planck Society of Germany, a PRO meant for basic science. Though they largely focus on basic science, they substantially carry out patenting, licensing, and establishing and supporting spin-off firms, akin to an applied research PRO such as Fraunhofer Institute in the same country. They found that, licensing the technologies to spin-off firms is appropriate when IPR protection is weak and when the information asymmetry is expected to be higher with external firms. However, researchers are discouraged from taking management positions at spin-off firms while working at the Society.¹⁹

Helm *et al.*²⁹ too studied the mechanism of establishing spin-off firms. They viewed it from the firm’s perspective and found that the spin-off success depends on the degree of support from the parent PRO, the degree of innovativeness of the founding idea, and the stage of development of the technology at the time of the founding.

Sheth *et al.*³⁰ studied 12 Indian PROs and concluded that the startup firms need governmental support in improving the funding mechanisms.

Koschatzky and Stahlecker²⁵ analyzed emerging mechanisms of R&D services in Germany. For a long time in history, technologies were simple and standalone kind. The present-day technologies are

Table 5 — Mechanisms as mentioned in the publications reviewed

Sl. No	Mechanism
Conventional mechanisms	
1	Licensing ¹⁹
2	Spin-off and startup firms ^{19,29,30}
3	R&D Services ²⁵
4	Alliances ^{27,16}
Special mechanisms	
5	Regional cooperation ²⁸
6	Incubation ecosystem ²⁸
7	Cooperation platform ²⁸
New paradigms	
8	New mechanisms of tech-transfers to firms in the open innovation paradigm ²⁰
9	Technology spillovers from Big Science Centres ^{1,31–33}

complex and are an assemblage of multiple technologies sourced from multiple R&D laboratories. This situation has given rise to the idea of ‘R&D Services’ under public-private partnerships (PPPs). They further stated that there is no standardized model for PPPs.

Berbegal *et al.*²⁷ provided PRO’s perspective of alliances by R&D contracts that are considered the biggest revenue-generating mechanisms to PROs. They stated that the success of alliances is ensured when the IPR issues are clarified upfront and effective communication takes place across partners. They also found that rigid planning is not a prerequisite for success. This is due to dynamic changes in technology transfer activities and the intensity of human interaction and involvement. Alliances were classified by Doblinger *et al.*¹⁶ into five types: (a) technology development alliance, (b) startup-licensee (i.e. when the startup obtains the license), (c) procurement alliance, (d) startup-licensor (i.e., when the startup provides the license), and (e) project development alliance.

Special Mechanisms (Regional Cooperation, Incubation Ecosystem and Cooperation Platform Implemented in China)

Chen *et al.*²⁸ state that the Chinese PROs in the form of the Chinese Academy of Sciences (CAS)

assigned heightened importance to tech-transfers to the industry after shifting from a planned economy to a market-oriented economy. This has prepared the firms in their country to partake in global competition. The three technology transfer mechanisms in the CAS are (a) Region Cooperation Mode, (b) Incubation Ecosystem mode, and (c) Cooperation platform-driven mode. In the region cooperation mode, research institutes transfer their technologies to promote regional economic development by implementing measures such as carrying out cooperative projects, establishing science centres, and building joint laboratories with the technical entities in the region. In the incubation ecosystem mode, the research institutes support the entrepreneurs in absorbing the technology and enabling interactions with investors. In 2007, Chinese scientific and technological legislation was improved by adding a new clause that encouraged public research institutes to open their infrastructures to entrepreneurs. Responding to this, CAS research institutes established cooperation platforms to advance industry-PRO interactions.

New Paradigms (Big Science Centres and Open Innovation)

Big Science Centres (BSCs) are a class of large PROs with participation of multiple nations to enable the pooling of funds as well as technologies. Objectives of BSCs are inter alia, exploring fundamental phenomena such as gravitational waves using a sophisticated facility LIGO (Laser Interferometer Gravitational-Wave Observatory), or addressing a contemporary challenge such as generation of carbon-free energy by harnessing fusion. BSCs are characterized by high technological content, long time range, and large funding. Tech-transfer activities from BSCs can be largely considered as technological spillovers driven by policies aimed more at maximizing the impact rather than revenue generation since the subsystems needed by BSCs are highly specialized and usually unavailable in the general industry. The fabricators of the subsystems are required to educate themselves about the special requirements.³¹

Taking another BSC (ITER nuclear fusion megaproject) as a case study Puliga *et al.*¹ worked on the idea that the technological levels of BSCs are too challenging for SMEs supplying the subsystems, that they need the support of PROs. The local PROs help in channelizing the high-tech requirements of ITER to the concerned SME, forming a tripartite collaboration.

Given the multiple complex technologies required for BSCs, knowledge transfer from them takes place through several mechanisms compared to traditional transfer modes. Nilsen & Anelli³² listed the mechanisms implemented in CERN as licensing, collaboration, consultancy, technical service, open-source software & hardware, spin-off firms, startup firms, training, and international collaborations. The firms involved with BSCs benefitted not only with advanced technical knowledge but also with improved reputation; enabling them to enter new markets.

Despite altruistic image of BSCs, they do have an interest in return on investment according to Scarra & Piccaluga.³³

Open Innovation (OI) is a firm-centric set of mechanisms enabling both the outgoing and incoming flow of technological innovations.³⁴ The open innovation paradigm has brought in new opportunities to PROs for responding to a spectrum of firms seeking technologies.²⁰ Concurrently, PROs face the challenge in being *chosen* by a firm. While conventional tech-transfers generally result from technology push, those under the OI paradigm result from the market pull.

Research Question on Actors Involved in Technology Transfers from PROs

The key sets of actors involved in technology transfers are the scientists, the TTO (Technology Transfer Officers), and the executives of tech-transferee firms, in university setting as per Mendoza & Sanchez.³⁵ Current study too brought out similar sets of actors in the cases of PROs (Table 6).

Following observations are made for different actors.

Scientists

Cunningham *et al.*^{17,18} observed that the scientists are generally content with the scientific-intellectual nature of their profession. They find it challenging to detour into the managerial functions demanded by tech-transfer activities. Though the trend has changed in recent times, they opine that, training in the areas such as team building, technology-development

Table 6 — Publications which mentioned about actors

Sl. No	Actors
1	Scientists ^{17,18}
2	TT Officers (TTOs) of various types of affiliations(In-house and outsourced) ³⁶
3	TT Offices of various organizations forming consortia ²²
4	Executives of transferee-firms ³⁷

management, and network management would favorably re-orient the scientists.

Tech-transfer Managers

Tech-transfer managers (Managers hereafter) in the Technology Transfer Offices (TTOs hereafter) commonly focus on such tasks as patent management, technology valuation, technology marketing, establishing formal agreements, and post-agreement coordination. Derrick³⁶ has identified two types of affiliations of TTOs - (a) one that are set up in-house and (b) the other where activities are outsourced to an external TTO. The In-house TTO ensures closer interactions with the scientists; but is fraught with challenges such as differences in the thinking styles of researchers and managers, and the reward systems across these two groups. Such differences may be eased out by suitable policy changes such as offering collective incentives. An external office might be appropriate if the number of tech-transfers per year is not substantial.

One challenge that PROs face is, whether the expenditure incurred on TTO is made up by the revenue from tech-transfers, as pointed out by Park *et al.*²² They propose that TTOs of several PROs when pooled as a consortium can draw strengths from one another and make tech-transfer activities cost-effective. They had identified four key drivers for this, namely, the experience of TTOs, the IP environment, the PROs being proactive, and the government support.

Executives of Transferee Firms

Hilkenmeier *et al.*³⁷ studied from the perspective of transferee firms, which are largely SMEs. They suggest that to the extent possible the technology being transferred be tailor-made to SME's business need. Along enough duration of the transfer project helps to build trust among stakeholders and is a desirable factor. Bringing together partners with complementary competencies results in a high interdependence between partners and enables the achievement of goals more easily. Temporary placement of scientists at transferee-firm leads to the success of tech-transfer.

Research Question: Success Factors for tech-transfers from PROs

Due to the higher practical importance of success factors, this topic appeared in a sizeable number of publications. The factors are listed in Table 7 and summarized in the following paragraphs:

Table 7 — List of success factors for tech-transfer

Sl. No.	Success-factors
1	Incentives for scientists ²³
2	Partnership with developmental teams
3	Technology Absorption Capacity of firms ¹⁹
4	Complementary assets in transferee firm ¹⁹
5	Marketing capacity of transferee-firms ¹⁹
6	Underplay of clause of conflict of interest ³⁸
7	R&D staff-strength in transferee-firm ^{39,43}
8	Presence of TT Office in the PRO ^{39,43}
9	Moderate tech-transfer fee ⁴⁰
10	Inter-communication ⁴¹
11	Short transaction times ⁴²
12	Technological entrepreneurship in PRO ^{21,39}
13	Market awareness ^{21,39}
14	Global design quality ¹³

Barletta *et al.*²³ studied the dichotomy between scientific publication productivity and tech-transfer performance. They found that research organizations in many developing countries stress more on scientific output and less on tech-transfer activities unless tech-transfer is well incentivized by the government. The nature of the partners is another factor. Linkages with developmental partners as opposed to research partners, lead to more tech-transfer activity.

Buenstorf *et al.*¹⁹ mentioned in the context of the Max Planck Society, that licensing is successful if licensees possess both the capabilities of technology absorption and marketing. The presence of complementary assets enhances the effectiveness of technology transfers. The patented technologies have a higher likelihood of getting transferred.

In any public organization, conflict of interest becomes an important factor when choosing a supplier or a client. Hernandez-Mondragon *et al.*³⁸ studied this in the context of tech-transfers from Mexican PROs. However, since technology transfers involve a higher level of technical knowledge than procurements, the stress on the aspect of conflict of interest might prove a deterrent. Interestingly enough, based on their work, the government of Mexico passed legislation to moderate the aspect of conflict of interest for tech-transfer activities.

Huian *et al.*³⁹ in the context of Romanian PROs found that the propensity to transfer technologies is correlated with the inclination to file patents. This in turn is driven by (a) the presence of a large number of qualified R&D staff (b) the experience of the scientists in publishing and (c) the availability of a TT office within the PRO. Kim *et al.*⁴⁰ stated that the number of patents in the contract, the fund spent on

R&D, and the exclusivity of the transfer-contract, positively influence the amount of the transfer fee. However, a moderate level of technology transfer fee might enhance the likelihood of tech-transfers.

Establishing smoother interactions and good communication across stakeholders are important factors for the success of tech-transfer activities, according to Nunez-Sanchez *et al.*⁴¹

Timely transfer of technology is an important factor since the technology market is time-sensitive. Ravillious *et al.*⁴² analyzed the timing efficiency of tech-transfer transactions in the context of US federal labs. They found that the transaction times are prolonged due to various reasons such as, a large number of stakeholders involved, frequent changes in the scope of work, the size of the entities involved, and the patenting being considered as a pre-requisite for tech-transfers.

Technology transfer performance is affected by both institutional factors and individual factors, as studied by Hosung *et al.*²¹ Institutional factors include research capability, TTO's effectiveness, and pertinent policies. Key individual factors are motivation and market knowledge. PRO's use of the government's online platform to promote technologies positively influences the possibility of tech-transfers taking place. PRO's technology entrepreneurship at both organizational and individual levels positively influence the incidence of tech-transfers, but might not encourage the creation of spin-off firms, possibly due to professional satisfaction of the scientists in the PRO.

Thurner & Stanislav⁴³ from their empirical research, made a counterintuitive observation that the influence of basic research on radical innovation is more pronounced in *low-tech manufacturing*. They further found that, for the successful development of complex technologies, scientists with higher qualifications are needed, whereas, for ordinary technologies, industrial experience is more important. A good balance would do the job best. Another study found that higher revenues from tech-transfers may be possible by incorporating designs in line with or better than international standards.¹³

Research Question: Stages Involved in Tech-transfers from PROs

No publications among those shortlisted for analysis answered this RQ.

Research Question: Models Depicting Tech-transfers from PROs

No publications among those shortlisted for analysis answered this RQ.

Discussion

This literature review was conducted to understand the nuances of tech-transfer from PROs. The literature was examined through the lenses of three characteristics namely mechanisms, actors and success factors. The findings are summarized pictorially in Fig. 3 and further elaborated in this section.

Mechanisms

Licensing, the staple mechanism of tech-transfers, is often considered advantageous as it allows researchers to continue working on their research, without needing to commit time to commercial matters.²⁸ It also provides the transferor the convenience of obtaining from the licensee the system manufactured by using the transferred technology. This point is particularly applicable to mission-oriented PROs, since the product from the transferred technology might be required for repeated use in the mission. The technology document created in the process of licensing is immensely valuable in re-producing the product independent of developers. However, as brought out by this review, many mechanisms beyond conventional licensing have come into use, suiting the newer reality of technological complexities and business models in recent times. When two organizations are in a situation where multiple technologies need to be shared bi-directionally, then alliance seems an ideal mechanism. The research alliances involving PROs are on the increase, especially in societal technologies, as described by a highly cited publication of this review.¹⁸ The multilateral,

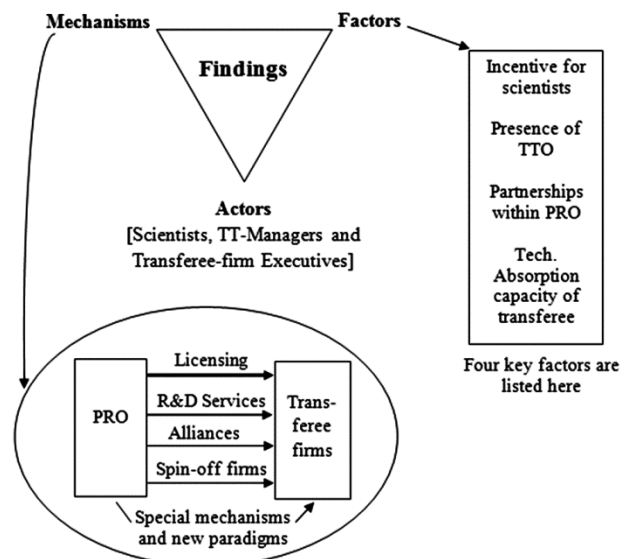


Fig. 3 — Pictorial summary of findings

multidirectional movement of technologies takes us into the paradigm of *open innovation* noted by Henry Chesbrough.³⁴

Technology spillover refers to informal transfer of technology that takes place in the contexts of the firms learning and supplying high technology components and equipment to the BSCs.

Considering the four key mechanisms (Fig. 3) that are relevant to PROs, licensing is the most dominant one, for multiple reasons mentioned earlier. Accordingly, the connecting line of licensing mechanism is shown thickest. Formation of spin-off firms is less common, especially from Indian PROs, given the risk in running a firm at the cost of leaving a lucrative job. Accordingly, the connecting line is shown thinnest. Prominence of other two mechanisms - R&D services and alliances lie in between.

Actors

Cunningham *et al.*^{17,18} opined that incentivizing PRO scientists to take up tech-transfer activities is a challenge. Through informal interactions with scientists from a mission-oriented PRO, it was noted that a large number of scientists are engaged in tech-transfers either to their internal/associated industrial units or to external firms in the case of spin-off technologies. Hence, there seems to be a difference between a mission-oriented PRO and a PRO. Observations by Cunningham *et al.* do not appear to be valid for a mission-oriented PRO.

Many authors reiterated the importance of the TTO. This was underlined by the US' Stevenson Wydler Act of 1980, which mandates the federal labs to set up a TTO. As mentioned previously, TTOs could be integrated or external to a PRO.³⁶ Both happen to exist in an Indian PRO namely Defense Research & Development Organization (DRDO). The in-house TTO was set up for the mission technologies, and an external TTO for dual use technologies.⁴⁴ The third model is a consortium of TTOs.²² A variant of the consortium, in the form of an umbrella TTO for multiple PROs is exemplified by an Indian government TT organization called National Research & Development Corporation (NRDC)⁴⁵ that serves a cluster of PROs under the Council of Scientific & Industrial Research of India.

Success Factors

Success factors of tech-transfers were well covered in the literature of tech-transfer research. Recent literature brings out some new factors such as transaction times, entrepreneurial skills at the

organizational level and individual level, R&D staff strength, reasonableness of Tech-Transfer Fee. The need for higher staff strength of R&D scientists is interesting since research activity needs a certain minimum critical volume of staff to ensure synergy among creative thinkers.²⁴ This idea helps in the staffing policy of a research organization. While studying Russian PROs, Thurner & Stanislav⁴³ and others made an interesting observation that the influence of basic science is more pronounced in low-tech innovations, rather than in high-tech ones. The authors of this review conjecture the reason for this counterintuitive observation by the fact that the single innovations get unnoticed in high-tech systems since these are combinations of a number of individual innovations. In contrast, a phenomenon underlying a basic science research gets highlighted in a low-tech system using a small number of phenomena.

Stages & Models

The research questions pertaining to stages and models have not appeared among the publications screened for analysis. This may be due to the reason that PROs as opposed to URO are under-studied. Other reason might be the short length of the chosen time-period for this review. The classical work done by Thursby & Thursby⁴⁶ in defining the process of technology transfer is applicable in most of the situations. Some models that are reported in the literature during the time-period of our review are either the variation or extension of the Thursby & Thursby Model.

Additional Insights Found Beyond RQs

Around a quarter of reviewed publications gave some additional insights, discussed as follows.

A remarkable development as observed by Coccia and Rolfo²⁴ is that most UROs and PROs have been increasingly pursuing tech-transfer activities without compromising their scientific excellence. This resonates with the situation in the Department of Atomic Energy in India.

While most of the literature focuses on economic and political motivations in supporting public research, Feller⁴⁷ dealt with the third motivation namely societal impact keeping human welfare at the center of discourse. He dealt with the metrics thereof, in addition.

Choudhry & Ponzio⁴⁸, and Gardner *et al.*⁴⁹ discussed about metrics of the performance of technology transfers from PROs. The formers described two metrics - filing ratio (number of patent

applications filed, divided by the total number of disclosures in one year) and transfer rate (ratio of number of new patent licenses granted over the total number of patent applications filed). Gardner⁴⁹ made an eclectic coverage of metrics used in several countries.

Tran *et al.*⁵⁰ gave a comparison of PROs across developed and developing countries, taking the U.S.A. and Vietnam respectively as examples. They found that the research community in developing countries is relatively unfamiliar with IP legal system. They further found that in the U.S.A., the UROs are the largest performers of basic research, and private research is the largest for technology development; whereas in Vietnam and many other developing countries, PROs are the main research centres for both basic research and technology development.

Conclusions

This review brought to light, myriad mechanisms and success factors by which PROs can engage well with industry and society. One of the significant findings indicates that the license fee accrued by tech-transfers is not substantial even in advanced economies in comparison with the overall cost of R&D. However, it helps in generating entrepreneurship, employment, and availability of essential goods & services to the society at affordable cost. A variety of alliances and the idea of open innovation can be utilized by PROs to provide technologies and to buy several standalone subsystem technologies from other sources. Possibly, due to easier access to universities, PROs have often been the overlooked sources of technologies. Given the merits of PROs as spelt out in this review, the firms can avail benefits of higher TRL technologies and more sustainable technical support from PROs.

In several technologically aspiring countries, the PROs are increasingly succeeding in contributing to the industrial economy by myriad mechanisms and by leveraging the enabling factors. The insights described herein would prove useful for the stakeholders of PROs. An exclusive review on tech-transfers from PMROs may be considered for future.

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