Chapter 17
Technology Transfer: A Literature Review

João Ricardo Lavoie and Tuğrul Daim

17.1 Introduction

With global economic dynamics and customers demanding better products and services, organizations regard innovation as a critical component of their businesses, regardless of the sector they compete on. Innovation, in turn, can be translated into more and better processes and products that minimize costs and that fulfill the ever-increasing and ever-more complex requirements and expectations of consumers. Having this scenario in mind, research and development (R&D) activities become more and more crucial since the innovation that organizations need spans largely from these activities. R&D, once seen as a purely creative and non-manageable process, has started to attract the attention of managers who see an opportunity to enhance innovation and the whole performance of an organization by means of managing research and development efforts. In that context, many managerial processes have been created and advanced, among which one can mention project management, program and portfolio management, new product development, and road mapping, among others.

Technology transfer (TT) is one of those processes, and although it has been subject of research for at least 45 years, it is still a very unclear process and presents several research opportunities. Technology transfer is a multi-faceted process [1]. It is a very complex problem that involves multiple perspectives and disciplines [2–4]. Notwithstanding being less mentioned than other managerial processes when it comes to enhancing R&D performance and overall organizational performance, technology transfer plays a critical role especially for high technology organizations. According to several authors, an organization with good technology transfer

J. R. Lavoie · T. Daim (✉)
Portland, OR, USA
e-mail: tugrul@etm.pdx.edu

T. Daim et al. (eds.), *R&D Management in the Knowledge Era*,
Innovation, Technology, and Knowledge Management,
https://doi.org/10.1007/978-3-030-15409-7_17

capabilities has a competitive advantage over rivals, bringing better products and solutions to the market, faster, and more easily [5–7]. Once regarded as a one-time event to be carried out after a technology is completely developed, technology transfer has evolved to be much more than simply deploying or transferring a technology after it is fully developed. It is a crucial process that runs in parallel with technology development and can affect its outcomes. In 1976, Robbins and Milliken were already regarding TT as part of the innovation process. The consensus now is that this process should be properly managed, if it is to result in benefits to the organization [8, 9]. The importance of technology transfer is easily identified in the literature, but more than only the transfer itself, the process, and how it is managed is also very important. To have a proper TT process in place is vital. Magnusson and Johansson [9] explain that, for any transfer to be successful, not only do organizations need to be aware of what is going to be transferred and when, but also how the process is being conducted [9].

The objective of this chapter is to provide information about the body of literature on technology transfer, thus helping researchers and practitioners in obtaining an understanding of the field. Basic concepts, ideas, and dimensions of technology transfer are presented and discussed, and the borders of the filed are stretched in order to provide insights on how technology transfer interacts with other areas.

17.2 The Technology Transfer Literature

17.2.1 Technology Transfer Definitions

Technology transfer is a multidisciplinary effort, not quite comprehensively understood and carried out by organizations in general. This apparent fuzzy description of TT is also (and not by occasion) seen in academia. The very definition of technology transfer can be confusing and emanate different interpretations. Several different definitions are observed across the literature, each with slightly different perspectives and nuances. Although these definitions have common points and do not seem (at least not for the most part) to be diametrically opposed to each other, this plurality of definitions can be troublesome and harm practitioners in their pursuit of effective, smoother, faster, and more efficient technology transfer. As academia is always at the forefront of knowledge creation, therefore, scholars still need to come to a consensus on what is the best definition for technology transfer, or what are the best definitions, depending on the type of transfer, type of organization, purpose, and other factors.

For Zhao and Reisman [10], the definition would change according to the discipline or knowledge field [10]:

- Economy: the focus would be on technology production and design.
- Sociology: the focus would be on social aspects.
- Anthropology: the focus would be on cultural change.

In the early days of TT research, Bar-Zakay stated that technology transfer happens when a technology generated on one context is used in another one [2]. More recently, it was defined as bringing technical expertise from one organizational reality to another [3]. Heinzl et al. [11] bring the concept of commercialization into scene when they state that TT is the "process of developing practical applications for the results of scientific research," and the "process of moving technology from an institution of science base to an industrial organization, which successfully commercializes the technology" [11]. Also focusing on commercialization aspects but including a technology diffusion element, Meseri and Maitai [12] state that "technology transfer is a complex process, involving the diffusion of basic research and its ultimate commercialization" [12]. Following the same line, Rogers et al. [13] argue that it is moving a technology from a research organization to a receiver. The process is complete when the transferred technology is commercialized and sold in the market as a product [13]. Focusing more on the geographical aspect, Liu [14] defines it as transferring technologies from one organization or location to another [14]. Bringing the terminology of mechanisms, Amesse and Cohendet [15] argue that TT happens when people or organizations, using different mechanisms, come together and interact to interchange technologies [15].

In summary, technology transfer will always involve the movement of knowledge (and sometimes physical items) to be used, further developed, or commercialized by another set of people, be it within the same firm, across different organizations, or even different countries. The specifics of the process will vary significantly depending on the type and purpose of transfer.

17.2.2 TT General Characteristics

Technology transfer is a complex process. It requires an interdisciplinary approach [2, 16] and it is a multi-faceted process, not a simple one [1]. Instead of being passive in serving only as an auxiliary process for other managerial processes (e.g., project management), it has to give information that will help managers make decisions and take actions. The TT process involves "go/no-go" decision points [2].

According to Seaton and Cordey-Hayes [17], the requirements for an organization to conduct a technology transfer are:

- Technical functions should support the business priorities the organization has set and create new opportunities based on these priorities.
- All functions should be integrated in order for the organization to work as a network (with internal and external connections).
- Employees and managers should be educated on how the organization and the process work.

Bar-Zakay [2] has dealt with the questions of the skills required for technology transfer. The author argues that, for both sides (donor and receiver), these skills are essential: System analysis; technological forecasting; long-range planning; and project-related intelligence [2].

The question of success factors has also been dealt with in the literature. In order to be successful, TT requires the development of technology markets and the development of technology valuation methods [18]. Leonard-Barton and Sinha [19] highlighted two important factors for a successful technology transfer. The authors discuss how organizations have to undertake an adaptation process (either for the new technology to be adapted to the organizational environment, or the other way around), and how the communication and interaction between developers and users should be very clear from day one [19]. Franza and Grant [20] have listed success attributes by player types, namely the developer, the acquirer, and both, showing the traits and characteristics each group ought to have in order to thrive.

In a very comprehensive research work, Estep [21] identified technology transfer success attributes, perspectives, and factors that fall into four categories: research domain; technology recipient domain; technology characteristics; and interface strategy, as shown in Fig. 17.1 [6].

Previous studies have also tried to identify and define the stages contained in a technology transfer process. According to the framework developed by Bar-Zakay in 1971, technology transfer would contain four stages: Search—when one searches for technologies to be transferred; adaptation—when one adopts the technology and the organization for them to work together; implementation—when one does the actual transfer and deploys it in the new environment; maintenance—when one makes sure the technology is and will work properly in the long-run [2]. In a

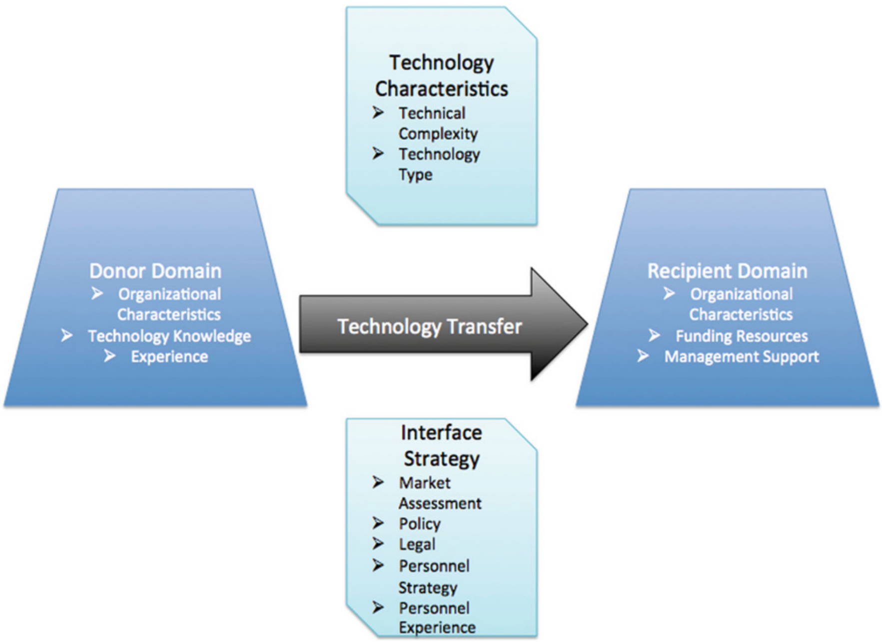

Fig. 17.1 TT success attributes perspectives, adapted from [6]

more simplistic fashion, Seaton and Cordey-Hayes have stated that the TT stages are ideas scanning, communication, and assimilation within the organization, and idea application with a purpose, which would be higher business effectiveness or competitive advantage [17].

Some studies were conducted with the aim of delineating the TT process and the elements or factors involved in the process. For Heinzl et al. [11], the important factors for technology transfer are: transfer object; transfer mechanism; intellectual property (IP) rights; absorptive capacity; and support structures [11]. Transfer object is the "what," it is the item or element to be transferred from the donor to the receiver. The mechanism is the "how" the way or the vehicle through which the transfer is conducted. IP rights comprise all legal considerations over patents, brand, trademarks, and other intellectual property aspects. Absorptive capacity refers to the skills of an entity of receiving, understanding, and properly using new information and knowledge [22]. The support structures are organizational arrangements and entities that provide aid and assist the transfer process. The Technology Transfer Office (TTO) at a university would be a good example [11]. Nobelius [1] lists three elements of the TT process: Strategic and operational synchronization; transfer scope; and transfer management [1]. The first part refers to the alignment between research and technology development efforts and the overall business strategy and application. The second part refers to the transfer object. The third and last part refers to the mechanism and the technology transfer process itself and how to manage it. Bozeman [3] also dealt with specific dimensions of effectiveness for TT. The author lists as important dimensions: transfer agent; transfer medium; transfer object; transfer recipient; and demand environment [3].

The literature also provides more specific criteria that should be assessed during a transfer, or questions that should be posed in order to measure the transferability of an item or to measure the potential for transfer. Both qualitative and quantitative criteria are mentioned as vital to assessing technology transfer aspects. In his 1977 article, Bar-Zakay lists two sets of criteria/questions to be checked on the donor and the recipient side. The questions relate to the number of people involved, training, interaction, planning aspects, and complexity of transfer, among others [16]. Bozeman [3] lists as important criteria: out-the-door; market impact; economic development; political reward; opportunity costs; and scientific and technical human capital [3]. Out-the-door would relate to the question whether technology has actually been received by another party. Market impact relates to the question of profitability and market-share changes caused by the transfer. Economic development relates to market impact questions on a regional or country level. Political reward relates to political gains derives from the transfer, such as more and better access to funding. Opportunity costs relate to other uses for resources or other agents and items. Scientific and technical human capital relates to the impact and advancements to technical skills and infrastructure caused by the transfer. Heinzl et al. [11] provide three categories each of which with associated factors and dimensions needs to be taken into account: providing agent; receiving agent; and environment [11]. Baek et al. [18] also list specific criteria. On the qualitative side, the author lists the analysis of technology's degree of contribution. On the quantitative side, the author lists the analysis of expected returns, cost structure estimation, and market estimation [18].

Technology transfer, although it can be strictly confined to the boundaries of one organization (when it is an internal TT), usually involves two or more entities. Moreover, even if it is an internal process, it will certainly involve several different groups and departments. The collection of these entities is commonly referred to as the technology transfer ecosystem. A TT ecosystem is a collection of stakeholders and entities (a system) that work together to promote a better transfer and to create value. Meseri and Maital [12] argue that a systems approach is essential for technology transfer [12]. Some of the entities mentioned are: science parks; research centers; incubators; TTO's; innovation and commercialization networks; and proof of concept centers (POC) [11]. The technology transfer offices (TTO) are also mentioned in other studies [23, 24].

17.2.3 TT Types

Several types of technology transfer are mentioned and studied in the literature. Table 17.1 shows the most recurrent ones.

The succinct definitions of each type are as follows:

- Internal—intra-firm transfer; the process occurs within the same organization.
- External—the transfer occurs between different organizations, regardless of their locations.
- Domestic—the transfer occurs within the same country.
- International—the transfer occurs between different countries.
- Military to civilian—military technologies to be transferred to civilian usage/ private companies.
- National labs to private sector—technologies developed within federal labs to be commercialized by private companies.
- Universities to private sector—technologies developed within Universities to be commercialized by private companies.

Table 17.1 Technology transfer types

Type	References
Internal	[14, 22, 25]
External	[2, 14, 16, 18, 25]
Domestic	[3]
International	[2, 25–32]
Military to civilian	[16]
National labs to private sector	[3, 13, 20, 33, 34]
Universities to private sector	[3, 11–13, 35, 36]
Research to development	[33]

- Research to development—the transfer from the technology development process into the product development process. Also involves the transfer of technologies in its early stages of development.

The above list brings the most recurrently mentioned TT types in the literature, but it is not exhaustive. Furthermore, these types are not mutually exclusive, as a transfer might fall into two or more types, for example, an American company may transfer a technology from a university in the UK to be used in one of its business units in America. In that case, the transfer would be external (different entities involved), from a university to the private sector and in the international realm. Within this list of TT types we provided, the University technology transfer is, perhaps, the type scholars investigate the most. The following section brings a more detailed discussion about university technology transfer.

17.2.3.1 University Technology Transfer

University technology transfer, especially from an economic and country development standpoint, is very important. According to Heinzl et al. [11], universities are vital to the national innovation system, because they provide diverse and high-quality knowledge while disseminating good practices, know-how, and competency [11]. The author further states that a more efficient technology transfer process from universities would mean more jobs and wealth for its region and country [11]. Previous studies have tried to identify the steps involved in the process of transferring technologies from universities [13, 36]. The models depict the disclosure of the invention made in academia, followed by the protection of the intellectual rights. Also, they include the reach out effort to interested parties and the negotiation to transfer, and the appropriate mechanism to do so.

Chen et al. [35] summarize the main themes in the literature when it comes to university TT: government policy and national innovation systems; university-operated enterprises; university science parks and spin-offs; university-industry linkages; TTO's; and university patenting and licensing [35]. In 1991, during the rise of technology transfer offices (TTOs), Mitchell noticed a change in how universities dealt with technology transfer [37]. In 1998, however, Mejia was arguing that the majority of transfers from universities were still done by publications, and a stronger linkage between universities and industry was needed [23]. In another comprehensive study on university technology transfer, Siegel et al. [36] create a series of propositions after analyzing the literature, pointing on characteristics and challenges, such as providing more rewards for researchers; providing more and better resources for TTO's; changing the mentality of university researchers; management and marketing efforts on TTO's; more flexibility on the university's side; and more formal and constant interactions between industries and universities [36].

17.2.4 TT Mechanisms

As already mentioned, a mechanism is the vehicle used to transfer the technology. Table 17.2 lists the most mentioned TT mechanisms in the literature:

Contract research is a contractual arrangement between the technology developer and the technology recipient. It sets the basics of the transfer, such as who is involved, what will be transferred, and how [11]. Foreign direct investments (FDI) are when an organization makes an investment through purchasing another organization in a foreign country. According to de la Tour [30], FDI in developing countries are "... carried out to benefit of cheap labor, they hire local work-force to which the know-how is then transferred" [30]. Further development happens when a technology is not completely ready yet, and follow-up research is needed. Also, further development is necessary when a technology is not significant enough for the industry to be willing to deploy it, or when the technology does not result in competitive advantage for the organization [38]. Transfer by internal start-ups happens when a technology generated within an existing organization is explored by a new company with relative independence from the original organization. According to Festel [38], internal start-ups would be fast and flexible enough to speed up the transfer process [38]. Joint venture R&D happens when two or more organizations share the costs, risks, and potential benefits of a technology development project. Seaton and Cordey-Hayes [17] argue that joint-venture R&D efforts have the ability to lower the risks of development and make the transfer less painful [17]. Licensing happens when an organization authorizes another to use and/or commercialize a technology, without transferring the ownership, which usually involves the payment of license fees. According to de la Tour [30], licensing is the most obvious mechanism of technology transfer [30]. Meetings can be used as a mechanism to pass information along to other parties. As Rogers et al. [13] put

Table 17.2 TT mechanisms

Mechanisms	Reference
Contract research	[11]
Foreign direct investment (FDI)	[30]
Further development	[38]
Internal start-ups	[38]
Joint-venture R&D	[11, 13, 17]
Licensing	[11, 13, 30]
Meetings	[13]
Mobility scheme	[11]
Monitoring of activities of the science base	[11]
Movement of personnel	[30]
Publications	[13]
Regional technology centers	[17]
Reverse engineering	[30]
Science parks	[17]
Spin-offs	[11, 13]

it, "meetings involve person-to-person interaction thought which technical information is exchanged" [13]. A mobility scheme is comprised of the movement of people and this movement can be temporary. Heinzl et al. [11] mention some of these movements, such as professors during sabbaticals; summer internships; and the temporary movement of personnel within and between organizations [11]. Monitoring science-based activities happens when an organization is attentive to the flow of knowledge in its field. Searches on academic article and patents databases, participation in conferences, and industry forums would be some of the activities involved [11]. Movement of personnel is very similar to the mobility scheme in that it involves sending workers along with the technology in order to ease the transfer, and these movements may not be temporary, as in the case of mobility schemes. De La tour [30] argues that these movements can be essential for a successful transfer [30]. Publications in journal and magazines are a way of transferring knowledge and technology and are intensely used in academia. However, although it is common in university transfers, Rogers et al. [13] caution that this is not the best mechanism for transfer, as usually articles are written in language following academic standards and not very easily understood by practitioners [13]. Regional technology centers are, according to Seaton and Cordey-Hayes [17] used in the UK as a mid-point between technology donors and recipients. These entities have a database of technologies available for transfer and help the involved in the process by aiming to improve the success of the transfer [17]. Reverse engineering consists in analyzing a product or technology in its final form and trying to understand its components and sub-systems. De la Tour [30] suggests reverse engineering as a transfer mechanism for companies that import products [30]. Science parks and incubators support and protect start-ups in their initial stages. Seaton and Cordey-Hayes [17] argue that by providing this support, science parks would help in the transfer of technologies [17]. Spin-offs are usually referred to as companies that are born out of universities. In this situation, professors and/or students decide to explore their inventions on their own, as a company [11].

17.2.5 TT Methods

Both quantitative and qualitative methods are found in the literature. Quantitative methods would include methods and tools focusing on mathematical and statistical models, plus multi-criteria decision-making models (MCDM) involve quantitative aspects, such as analytical hierarchy process (AHP) and hierarchical decision model (HDM). According to Khabiri et al. [31], qualitative methods define activities of those who are involved in the process and elicit factors and issues that may influence the success and effectiveness of a TT project. On the other hand, quantitative methods would quantify parameters and analyze them. Also, they try to minimize incompatibilities between donors and recipients [31].

Table 17.3 summarizes some of the sources found in the literature that use and/or mention methods for technology transfer.

Table 17.3 TT method types

Type	References
Quantitative	[6, 14, 18, 20, 29, 34, 39–42]
Qualitative	[2–4, 7, 11, 12, 16, 17, 22, 25, 32, 36]

Table 17.4 TT methods and tools

Method	Type	Reference
AHP	Quantitative	[42, 43]
Decision-model	Qualitative	[2, 11, 16]
Fuzzy-set theory	Quantitative	[42]
HDM	Quantitative	[6, 21]
Interviews	Qualitative	[36]
Mathematical models	Quantitative	[39, 41]
Other types of MCDM	Qualitative	[3, 4, 7, 17, 22, 25]
Nonlinear differential equation	Quantitative	[14]
Scenario analysis	Qualitative	[14]
Maturity scale	Qualitative	[43]
Social network analysis	Qualitative	[44]

Table 17.4 summarizes some of the sources found in the literature that use and/or mention specific methods and tools for technology transfer.

As it can be seen in Table 17.4, subjective models are, by far, the most dominant way of dealing with technology transfer. Within the subjective models, multi-criteria decision-making (MCDM) methods are used. As aforementioned, technology transfer is a complex, multi-faceted, and multidisciplinary effort. As such, it seems that MCDM models are the most appropriate method since they can approach the problem from several different perspectives at the same time. AHP [42, 43] and HDM [6, 21] are not the only models used. There are also decision models based on donor/recipient criteria [2, 11, 16]; manufacturing strategy [25]; contingent effectiveness [3, 7]; broadcasting [22]; multi constituency [17]; and climate-friendly technology transfer [4].

17.2.6 TT Application Areas

Technology transfer models developed in the literature have been applied to a myriad of sectors, from nanotechnologies to aerospace. Table 17.5 brings a list of some of the application areas found in the literature.

Table 17.5 Technology transfer application areas

Area	References
Aerospace	[14]
Climate change	[40, 45]
Construction	[29]
Electric components	[22]
Energy	[4, 6, 30, 32, 46]
Information technology (IT)	[27, 39]
Nanotechnologies	[7]
Semiconductors	[28]
Steel production	[47]

17.2.7 TT Complexities, Challenges, and Gaps

Technology transfer, although having been subject of research for over 45 years, still presents a fair share of challenges to both practitioners and researchers due to its fuzziness and complexity. It is still unclear how to deal with the process and how to manage and conduct it in a proper way. Festel [38] mentions the research gap that exists in the transfer of research and development outcomes to the successful commercialization of those outcomes [38]. As it was discussed, the very definition of TT is not consensual as it varies significantly from discipline to discipline. According to Bozeman [3], TT involves a very large set of players, activities, and interests, making it burdensome [3]. Still, according to the same author, TT is a very complex and risky process. It is very time consuming and usually does not produce the expected results [3]. It is not clear where and when TT starts and ends and concepts like prototypes and proof of concept are not clear either. Most of the time, prototypes are developed without any concern for user requirements and yet they are used as a basis for the final product [33]. Literature suggests the technology transfer process and efforts are challenging and it also suggests that organizations should strongly support and care about the process should they want to obtain good results. Isaacs and Tang [33] say that TT is a contact sport. The transfer is done by people, not by materials or reports. There should be a high commitment and support for the TT process [33].

Concerning university technology transfer, Landry et al. [24] perceive a research gap to be filled. The authors argue that when it comes to TTOs, there is a need to conduct a demand-side perspective study to understand how TTOs' clients perceive those organizations [24]. Some of the questions would be: Do they appreciate the TTOs services? What do they like or dislike about it? How can TTOs be more helpful and effective?

As for the internal technology transfer type, some authors also identify a need for further investigation and research. Malik [22] states that more studies should be done on intra-firm TT to understand it since the majority of research is done on international and external transfer processes [22]. Magnusson and Johansson [9] also argue that more research on internal technology transfer is needed [9].

17.2.8 TT Relationship with Other Fields and Concepts

By analyzing the literature, one can clearly notice that technology transfer, as a field, overlaps with several other fields and concepts. The following sections shed a light on those overlaps and explain how these interactions happen.

17.2.8.1 Relationship with Commercialization

To the vast majority of scholars, technology transfer is intimately related to the concept of commercialization. In the context of TT, commercialization would mean to successfully bring to the market a product and/or service developed during an R&D project. A solid technology transfer process would enable the successful commercialization of new technologies [18]. Improving the technology transfer process and partnerships would improve the commercialization results [7]. Innovations commercialization would be helped by and could move beyond technology transfer [11]. Technology transfer would bridge the gap between R&D and commercialization [28]. If technology transfer is better thought of and understood, chances of successful technology commercialization increase [6]. In summary, scholars agree that technology transfer would enable, improve, or have commercialization efforts as part of the process. Table 17.6 brings a list of studies that mention the relationship.

17.2.8.2 Relationship with Policy-Making

A myriad of studies touch upon policy issues when dealing with technology transfer since the transfer from the public sector to the private is one of the biggest branches of the field. Furthermore, in understanding how crucial the technology transfer process is for the overall technological development of a region/country, public authorities venture to try to boost and promote the process. In 1977, Bar-Zakay published a study that had as primary objective to create policy recommendations to enhance and improve the technology transfer from the military sector to the civilian sector in Israel [16]. In analyzing international technology transfer, Bommer et al. [25] mention government policies as a critical factor to be taken into consideration [25]. In analyzing technology transfer in the solar photovoltaics (PV) industry, Zhang and Gallagher [46] state that government policies would be one of the main drivers [46]. Worrell et al. [5] argue that policies can heavily influence the technology transfer process [5]. Lai and Tsai [42] state "government's policy is always a crucial factor in influencing TT" [42]. Table 17.7 brings a list of studies that mention the relationship.

Table 17.6 Relationship between technology transfer and commercialization

Studies mentioning the relationship	[3, 6, 7, 11–13, 18, 20, 24, 28, 34–37, 44, 48]

Table 17.7 Relationship between technology transfer and policy-making

Studies mentioning the relationship	[2–7, 11–14, 16–18, 20, 24–27, 29, 30, 32, 35, 36, 39, 42, 44–48]

Table 17.8 Relationship between technology transfer and technology assessment

Studies mentioning the relationship	[2, 4, 5, 14, 18, 39, 47]

17.2.8.3 Relationship with Technology Assessment

Technology assessment is another concept/practice that has an intimate relation with technology transfer. It is critical to assess and understand the technology one wants to transfer irrespective of the type of transfer or entities involved. Assessing the technology under different perspectives is always a part of the TT process, whether it is a quantitative process or a qualitative process. Worrell et al. [5] name technology assessment one of the stages of TT, followed by agreement, implementation, evaluation, and adaptation and repetition [5]. Talaei et al. [4] used AHP to assess technologies before recommending policies to transfer energy technologies to developed countries [4]. Similarly, Liu [14] uses technology assessment as part of the transfer process when dealing with aircraft engine technologies [14]. Bar-Zakay [2] argues that technology assessment should be conducted before choosing technologies to be transferred, so as to anticipate the changes and problems a society may face after the new technology is transferred and deployed [2]. As part of their transfer process for the steel industry, Okazaki and Yamaguchi [47] assess the technology and its barriers [47]. Table 17.8 brings a list of studies that mention the relationship.

17.2.8.4 Relationship with Technology Development

There is still, to a degree, a debate in the literature about when technology transfer efforts should start or even if an organization should or not have a formal TT process in place. Some think that TT should start only after the technology development project is done. Others say the TT process should be conducted in parallel. This debate will be further discussed in later sections, but the overlap and interactions between technology development and technology transfer are obvious.

Some authors highlight the interrelationship between public policies promoting technology development and promoting technology transfer [3, 35, 47, 48]. Other authors argue that different TT models are needed for technologies that are at different development stages [18, 34]. Estep [6] links the TT process to the very early stages of technology development, bringing it to the assessment and selection of research proposals [6]. For university TT, Bozeman et al. [3] argue that royalties are greater when more developed technologies are transferred [7]. From an economic standpoint, Siegel et al. [36] stated that when industry partners with academia for TT purposes, the whole sector experiences a greater technological development [36]. Table 17.9 brings a list of studies that mention the relationship,.

Table 17.9 Relationship between technology transfer and technology development

Studies mentioning the relationship	[3, 6, 7, 18, 21, 34–36, 47, 48]

Table 17.10 Relationship between technology transfer and product development

Studies mentioning the relationship	[1, 5, 7, 19, 25, 34, 36, 49]

17.2.8.5 Relationship with Product Development

As already mentioned, there are advantages in filling the gap between technology development and product development by increasing an organization's technology transfer capabilities because the new product development process is likely to go smoother if the technology transfer was adequately done. There are, however, other relationships between the technology transfer process and the actual product development process. Jugend and Silva [49] state that the technology transfer process, among other factors, is vital in having effective new product development projects [49]. As Spann et al. [34] put it, there is a technology transfer component within the product development process [34]. Bommer et al. [25] argue that, for long and costly product development projects, strategic alliances, and transfer skills are highly necessary [25]. In a research on transfer of energy-efficient technologies, Worrell et al. [5] state that better technology transfer skills can lead to better and more environmentally sound products [5]. Nobelius [1] suggests that the transfer to the market should be thought of before the new product development project is over. According to the author, usually, organizations only think about the transfer after the NPD project is done, and that would be a cause of delays [1]. Table 17.10 brings a list of studies that mention the relationship.

17.2.8.6 Relationship with Technology Forecasting

In the literature, the relationship between technology transfer and technology forecasting is not as strong and clear as in other cases, but some authors dwell on the subject. The reasoning is similar to that of the technology assessment concept in that the more information on the technology, the better for planning the transfer. Thus, if a technology forecasting assessment provides an organization with valuable insights on what directions the technology is taking or on what changes are going to be there as a result of the technology application, the better the transfer can be planned and conducted. For the most part, it is said that technology-forecasting assessments are, to some extent, encompassed within the technology transfer efforts [2, 14, 18, 48]. Bar-Zakay [2] is more straightforward, and argues that forecasting skills are necessary for an organization to be successful at transferring technologies [16]. Table 17.11 brings a list of studies that mention the relationship.

Table 17.11 Relationship between technology transfer and technology forecasting

Studies mentioning the relationship	[2, 14, 16, 18, 48]

Table 17.12 Relationship between technology transfer and technology maturity

Studies mentioning the relationship	[4, 12, 18, 38, 39, 48]

17.2.8.7 Relationship with Technology Maturity

As in the case of technology forecasting, scholars do not highlight a strong relationship between technology transfer and technology maturity. However, some interesting insights can be retrieved from the literature. As a general rule, scholars say that technology maturity/readiness would serve as one of the criteria to be considered during the transfer process because technologies that are more ready are easier to transfer [38, 48]. During the transfer assessment of technologies, maturity is an input [4, 12, 18, 39]. In describing the technology platforms implemented in Russia (policy instruments to boost technology development and transfer), Proskuryakova [48] states that technology readiness was one of the criteria considered [48]. Table 17.12 brings a list of studies that mention the relationship.

17.3 Summary

This chapter has brought an overview of the technology transfer literature. Rather than exhausting the whole body of literature on the topic—which goes back more than 40 years—the intention was to give the reader a high-level overview of what has been done so far. Readers can use this chapter as a resource to have a basic understanding of technology transfer and regard it as a starting point for deeper inquiries and investigations. The topics and discussions presented are central to the comprehension and further investigation of technology transfer—the definitions and scope, technology transfer types, mechanisms and methods of analysis, application areas of recent studies and the relationships with other fields.

All of the discussions presented in this chapter can be taken to a deeper level if one chooses to, most importantly concerning the points of contact and relationships between technology transfer and other fields of research. For instance, there are vast amounts of information and research being done in the knowledge management and innovation management fields that can be intimately related to technology transfer concepts and ideas, for example, collaborative research and development, strategic alliances, and open innovation. In that sense, the content presented in this chapter can also be useful to researchers from other fields that are looking for ways to understand how technology transfer relates or affects their research, or to understand how technology transfer concepts can be integrated into their models, propositions, and hypotheses.

References

1. Nobelius, D. (2004). Linking product development to applied research: Transfer experiences from an automotive company. *Technovation, 24*(4), 321–334.
2. Bar-Zakay, S. N. (1971). Technology transfer model. *Technological Forecasting and Social Change, 2*(3–4), 321–337.
3. Bozeman, B. (2000). Technology transfer and public policy: A review of research and theory. *Research Policy, 29*(4–5), 627–655.
4. Talaei, A., Ahadi, M. S., & Maghsoudy, S. (2014). Climate friendly technology transfer in the energy sector: A case study of Iran. *Energy Policy, 64*, 349–363.
5. Worrell, E., van Berkel, R., Fengqi, Z., Menke, C., Schaeffer, R., & O. Williams, R. (2001). Technology transfer of energy efficient technologies in industry: A review of trends and policy issues. *Energy Policy, 29*(1), 29–43.
6. Estep, J. (2015). Development of a technology transfer score to inform the selection of a research proposal. In *Portland international conference on management of engineering and technology* (Vol. 2015, pp. 1754–1768). IEEE.
7. Bozeman, B., Rimes, H., & Youtie, J. (2015). The evolving state-of-the-art in technology transfer research: Revisiting the contingent effectiveness model. *Research Policy, 44*(1), 34–49.
8. Robbins, M., & Milliken, J. (1976). Technology-transfer and process of technological innovation—New concepts, new models. *R&D Management, 6*, 165–170.
9. Magnusson, T., & Johansson, G. (2008). Managing internal technology transfer in complex product development. *European Journal of Innovation Management, 11*(3), 349–365.
10. Zhao, L., & Reisman, A. (1992). Toward meta research on technology transfer. *IEEE Transactions on Engineering Management, 39*(1), 13–21.
11. Heinzl, J., Kor, A.-L., Orange, G., & Kaufmann, H. R. (2013). Technology transfer model for Austrian higher education institutions. *The Journal of Technology Transfer, 38*(5), 607–640.
12. Meseri, O., & Maital, S. (2001). A survey analysis of university-technology transfer in Israel: Evaluation of projects and determinants of success. *The Journal of Technology Transfer, 26*(1), 115–125.
13. Rogers, E. M., Takegami, S., & Yin, J. (2001). Lessons learned about technology transfer. *Technovation, 21*(4), 253–261.
14. Liu, W. (1993). A quantitative technology-transfer model and its application to aircraft engines. *Technological Forecasting and Social Change, 44*(2), 179–186.
15. Amesse, F., & Cohendet, P. (2001). Technology transfer revisited from the perspective of the knowledge-based economy. *Research Policy, 30*(9), 1459–1478.
16. Barzakay, S. (1977). Technology-transfer from defence to civilian sector in Israel—Methodology and findings. *Technological Forecasting and Social Change, 10*(2), 143–158.
17. Seaton, R., & Cordeyhayes, M. (1993). The development and application of interactive models of industrial-technology transfer. *Technovation, 13*(1), 45–53.
18. Baek, D.-H., Sul, W., Hong, K.-P., & Kim, H. (2007). A technology valuation model to support technology transfer negotiations. *R&D Management, 37*(2), 123–138.
19. Leonardbarton, D., & Sinha, D. (1993). Developer-user interaction and user satisfaction in internal technology-transfer. *Academy of Management Journal, 36*(5), 1125–1139.
20. Franza, R. M., & Grant, K. P. (2006). Improving federal to private sector technology transfer. *Research-Technology Management, 49*(3), 36–40.
21. Estep, J. (2017). Development of a technology transfer score for evaluating research proposals: Case study of demand response technologies in the Pacific Northwest. Diss. Thesis.
22. Malik, K. (2002). Aiding the technology manager: A conceptual model for intra-firm technology transfer. *Technovation, 22*(7), 427–436.
23. Mejia, L. R. (1998). A brief look at a market-driven approach to university technology transfer: One model for a rapidly changing global economy. *Technological Forecasting and Social Change, 57*(3), 233–235.

24. Landry, R., Amara, N., Cloutier, J.-S., & Halilem, N. (2013). Technology transfer organizations: Services and business models. *Technovation, 33*(12), 431–449.
25. Bommer, M., Janaro, R., & Luper, D. (1991). A manufacturing strategy model for international technology-transfer. *Technological Forecasting and Social Change, 39*(4), 377–390.
26. Reddy, N., & Zhao, L. (1990). International technology-transfer—A review. *Research Policy, 19*(4), 285–307.
27. Seror, A. C. (1996). Action research for international information technology transfer: A methodology and a network model. *Technovation, 16*(8), 421–429.
28. Chang, P., Shih, C., & Hsu, C. (1994). The formation process of Taiwan ic industry—Method of technology-transfer. *Technovation, 14*(3), 161–171.
29. Waroonkun, T., & Stewart, R. A. (2008). Modeling the international technology transfer process in construction projects: Evidence from Thailand. *The Journal of Technology Transfer, 33*(6), 667–687.
30. de la Tour, A., Glachant, M., & Ménière, Y. (2011). Innovation and international technology transfer: The case of the Chinese photovoltaic industry. *Energy Policy, 39*(2), 761–770.
31. Khabiri, N., Rast, S., & Senin, A. A. (2012). Identifying main influential elements in technology transfer process: A conceptual model. *Procedia-Social and Behavioral Sciences, 40*, 417–423.
32. Pueyo, A., García, R., Mendiluce, M., & Morales, D. (2011). The role of technology transfer for the development of a local wind component industry in Chile. *Energy Policy, 39*(7), 4274–4283.
33. Isaacs, E. A., & Tang, J. C. (1996). Technology transfer: So much research, so few good products. *Communications of the ACM, 39*(9), 23–25.
34. Spann, M. S., Adams, M., & Souder, W. E. (1995). Measures of technology transfer effectiveness: Key dimensions and differences in their use by sponsors, developers and adopters. *IEEE Transactions on Engineering Management, 42*(1), 19–29.
35. Chen, A., Patton, D., & Kenney, M. (2016). University technology transfer in China: A literature review and taxonomy. *The Journal of Technology Transfer, 41*(5), 891–929.
36. Siegel, D. S., Waldman, D. A., Atwater, L. E., & Link, A. N. (2004). Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: Qualitative evidence from the commercialization of university technologies. *Journal of Engineering and Technology Management, 21*(1–2), 115–142.
37. Mitchell, W. (1991). Using Academic Technology—Transfer methods and licensing incidence in the commercialization of American diagnostic-imaging equipment research, 1954–1988. *Research Policy, 20*(3), 203–216.
38. Festel, G. (2013). Academic spin-offs, corporate spin-outs and company internal start-ups as technology transfer approach. *The Journal of Technology Transfer, 38*(4), 454–470.
39. Raz, B., Steinberg, G., & Ruina, A. (1983). A quantitative model of technology-transfer and technological catch-up - the case of developed-countries. *Technological Forecasting and Social Change, 24*(1), 31–44.
40. Seres, S., Haites, E., & Murphy, K. (2009). Analysis of technology transfer in CDM projects: An update. *Energy Policy, 37*(11), 4919–4926.
41. Raz, B., & Assa, I. (1988). A model of coupled technology-transfer—A logistic curve approach. *Technological Forecasting and Social Change, 33*(3), 251–265.
42. Lai, W.-H., & Tsai, C.-T. (2010). Analyzing influence factors of technology transfer using fuzzy set theory. *International Journal of Innovation and Technology Management, 7*(1), 71–87.
43. Secundo, G., Secundo, G., de Beer, C., de Beer, C., Passiante, G., & Passiante, G. (2016). Measuring university technology transfer efficiency: A maturity level approach. *Measuring Business Excellence, 20*(3), 42–54.
44. Genet, C., Errabi, K., & Gauthier, C. (2012). Which model of technology transfer for nanotechnology? A comparison with biotech and microelectronics. *Technovation, 32*(3–4), 205–215.

45. Kypreos, S., & Turton, H. (2011). Climate change scenarios and technology transfer protocols. *Energy Policy, 39*(2), 844–853.
46. Zhang, F., & Gallagher, K. S. (2016). Innovation and technology transfer through global value chains: Evidence from China's PV industry. *Energy Policy, 94*, 191–203.
47. Okazaki, T., & Yamaguchi, M. (2011). Accelerating the transfer and diffusion of energy saving technologies steel sector experience—Lessons learned. *Energy Policy, 39*(3), 1296–1304.
48. Proskuryakova, L., Meissner, D., & Rudnik, P. (2017). The use of technology platforms as a policy tool to address research challenges and technology transfer. *The Journal of Technology Transfer, 42*(1), 206–227.
49. Jugend, D., & da Silva, S. L. (2014). Integration of R&D and new product development: Case studies of Brazilian high-tech firms. *International Journal of Business Innovation and Research, 8*(4), 422–439.