



# Determinants of technology sourcing modes : the case of iranian hi-tech firms

Azita Karamipour

## ► To cite this version:

Azita Karamipour. Determinants of technology sourcing modes : the case of iranian hi-tech firms. Other. Institut National Polytechnique de Lorraine, 2011. English. NNT : 2011INPL072N . tel-01749514

**HAL Id: tel-01749514**

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# **INSTITUT NATIONAL POLYTECHNIQUE DE LORRAINE**

## **ECOLE DOCTORALE : RP2E**

Equipe de Recherche sur les Processus Innovatifs

### **THESE**

Présentée et soutenue publiquement le 7 novembre 2011

Pour l'obtention du grade de Docteur de l'INPL  
(Discipline : GENIE DES SYSTEMES INDUSTRIELS)

Par

**Azita KARAMIPOUR**

## **Determinants of Technology Sourcing Modes: The Case of Iranian Hi-tech Firms**

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*To my family*

## *Acknowledgement*

First and foremost I want to thank my advisor **Dominique Jolly** for his great knowledge and his helpful guidance throughout the development of this dissertation. I would like to thank him not only for his scientific support but also for his excellent human qualities. I was deeply impressed by his generosity, his kindness and understanding. I consider myself very fortunate to work with him.

I also would like to express my sincere gratitude to my advisor **Vincent Boly** for firstly accepting me as a student of “Equipe de Recherche sur les Processus Innovatifs”. His understanding, encouragement, and personal guidance have provided a good basis for the present thesis.

For this dissertation I would like to thank my reading committee members: **Vincent Sabourine** and **Jean-Michel Ruiz** for their time, interest, and helpful comments. I would also like to thank the president of jury of my oral defense committee, **Bernhard Katzy** for his time and insightful remarks.

Many thanks to **Veronique Dono** and **Sandrine Chef** for their kind administrative contribution and making the job much easier to do.

I wish to express my warm thanks to **Mona Shokry Pour** Ph.D. student in statistics, for her guidance in statistical analysis, and professor **Auguste Rakoto** for his essential assistance in reviewing the chapters of this study and his comments on statistical points.

My special thanks are due to my friend **Maryam Taghavi** for editing the English of this document.

This study drew upon the knowledge and experience of the **Iranian top managers** of technology intensive firms. Although numerous to name, they are appreciated for their contributions. This research benefited particularly from the receptivity of top managers who shared their knowledge and experiences with me.

Last but not the least; I would like to thank my family for all their love and encouragement, for my parents, **Mohammad Reza karamipour** and **Azar Zadnemat** who raised me with a love of science and supported me in all my pursuits for my children, **Pourya** and **Shayesteh** for their understanding and patience. And most of all for my loving, supportive, encouraging, and patient husband **Mohammad Reza Arasti** whose faithful support during all stages of this Ph.D. is so appreciated. Thank you.

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## 1.12. Varsity in External





# **General Introduction**

## **1. Description of Problem (Problematic)**

Intense competition in today's rivalry world, encourage Firms to acquire sustainable competitive advantages in order to survive. The role of technology is a major factor to achieve competitive advantages (Cho & Yu, 2000), consequently the acquisition, development and application of technology creating competitive advantages as speedily as possible is vital for the firms (Allred & Swan, 2004). Firms rely on their internal R&D activities to maintain their technological competitiveness (Narula, 2001), but they also develop strategies in term of cooperation. Dyer & Singh (2000) point out that the use of technology sourcing modes (e.g. alliances) may create several advantages for the firms and, at the opposite, lack of organization cooperation may generate obstacles for technological innovation (Dertouzos et al. 1989). This is especially true for technology- intensive industries in where technology becomes more multidisciplinary and dynamic (Steensma & Corley, 2000).

Companies must develop the ability to execute both acquisitions and alliances if they want to grow. Knowing when to use which strategy may, however, be a greater source of competitive advantage than knowing how to apply them.

As a consequence, one major concern for researchers and practitioners is 'how can the firms obtain the technology?' and 'what are the sources of technology which firms would like to obtain?' (Moenaert et al., 1990). In fact, numerous organizational modes of technology sourcing are defined in the literature and used by firms. Decisions about which new technology to develop internally and which ones to access through collaborative and contractual links with external sources may affect the firm's long term viability in the new technological environment (Pisano, 1990). For example, electronics firms that decided in the early 1960s to license-in the new integrated circuit technologies rather than to develop the requisite R&D capabilities in-house had difficulty competing for many years afterward (Malerba, 1985).

The decision on how to gaining access to a technology have to sub-decision; identifying the primary determinants of technology sourcing modes and establishing a clear understanding of differential impacts of each on firm performance (Jones et al., 2000). this research is investigated on the first one. The choice of different technology sourcing modes (TSMs) could be influenced by a set of factors in a systemic approach. Firms should select one or more modes which are considered appropriate according to these factors. It should be considered that the effect of these factors on the choice of TSMs is mostly contextual. In other words, the factors could have different effects for the firms situated in different

contexts<sup>1</sup> (industry and environment). Kiyota & Okazaki (2005) confirm this fact in their research which addresses the effect of different determinants of technology licensing in three periods. The difference between these three periods is the regulations and deregulations of licensing applied by Japanese government. According to this research, the effect of a certain determinant on a mode (specially licensing a technology) changes following the changes in regulations. Moreover, industry affects selection the modes. As acquisitions prevail in mature or declining industries (textile, food industry), alliances prevail in young, dynamic high-tech industries (Hoffman & Schaper-Rinkel, 2001).

Although technology sourcing research has started to advance (Allred & swan, 2004) in the world wide; such studies are in its threshold in Iran; as a developing country. No study determines the list of these factors for Iranian firms. On the one hand, Iranians firms- like many other firms situated in developing countries- don't move on the technological edge. On the other hand, special political and economic conditions in Iran differentiate it from other countries. Therefore, the effect of aforementioned factors could be different and it is important for the managers to recognize these effects.

This research investigates the factors which influence the choice of T.S.M. in Iranian technology intensive and high-technology firms while describing how those factors affect the choice of TSMs.

Our research makes the following contributions to the field including:

- Contrary to other studies, we propose a conceptual framework which classifies the modes and introduces the factors.
- None of the studies have concentrated on Iran as a developing country with special economic and politic conditions. This research, however, focuses on Iranian high-tech enterprises with a high rate of technological change and intense need of gaining access to the technology.

## 2. Thesis Structure

In this research we follow a 7-step approach to answer to research questions. These steps are described in figure 1.

This dissertation contains seven chapters which are:

**Chapter1: Preliminaries on Technology Sourcing Literature.** This chapter aims at introducing general expressions of Technology sourcing literature, definitions of modes of technology sourcing as well as their characteristics. In this chapter, reviewing previous models, we also propose a model which classifies different modes of technology sourcing in three categories: internal R&D, cooperation and acquisition.

---

<sup>1</sup> See chapter 2

**Chapter2: Determinants of TSMs: A Literature Review.** This chapter aims at introducing determinates affecting the choice of different modes of technology sourcing. In this chapter, based on the literature we propose a classification of factors and describe how these factors affect Technology Sourcing Modes (TSMs). Finally we propose a list of nine determinants of Technology sourcing modes; four technology-related and five firm-specific factors. Technology related determinants consist of a) technology life cycle, b) degree of commercial and technical uncertainty, c) strategic importance of technology, and d) technology urgency. Firm-specific determinants include e) strengths on internal resources, f) level of absorptive capacity, g) successful past experiences, h) strategic objective and i) firm size.

**Chapter3: Hypothesis.** This chapter is devoted to argue the hypothesis relying on determinants and their effects on three categories of technology sourcing modes (TSMs). Thirty one hypotheses are proposed which sixteen of them describe the relation between technology-related determinants and three categories of TSMs. The fifteen remaining hypotheses investigate on firm specific determinants.

**Chapter4: Research Methodology.** This chapter discusses practical elements of the research. It explores the research questions in more depth, and explains what methods are the most appropriate ways given the aims and nature of the research. Different methods of data collection are addressed while focusing on why particular methods have been chosen over others. This is followed by a discussion of the practicalities of how the data collection was conducted, and the approaches taken to data analysis.

**Chapter5: Results and Analyses.** This chapter deals with the statistical results of our research including testing the hypotheses. Employing statistical models such as factor analysis, regression, ANOVA, etc., factors affecting technology sourcing modes in the context of Iranian high-tech industries are identified. These statistical models are provided using SPSS software, version 15. Section 5.1 addresses descriptive statistics. Section 5.2 describes correlation analyses of research variables. Section 5.3 is devoted to hypotheses testing. The hypotheses of research are separately tested and the results are described. We use regression method in order to test how both technology related factors and firm-related ones predict a technology could be sourced internally, or gained by cooperation or through acquisition. The results of regression models are represented in section 5.4.

**Chapter 6: Discussion.** In this chapter the research results are discussed in detail.

**Chapter7: Conclusion.** In this chapter, a summary of research is presented. Moreover, we provide a general conclusion to this dissertation while pointing out the Limitations of present research as well as the fields for further studies. The last section of this chapter proposes implications for managers and researchers.

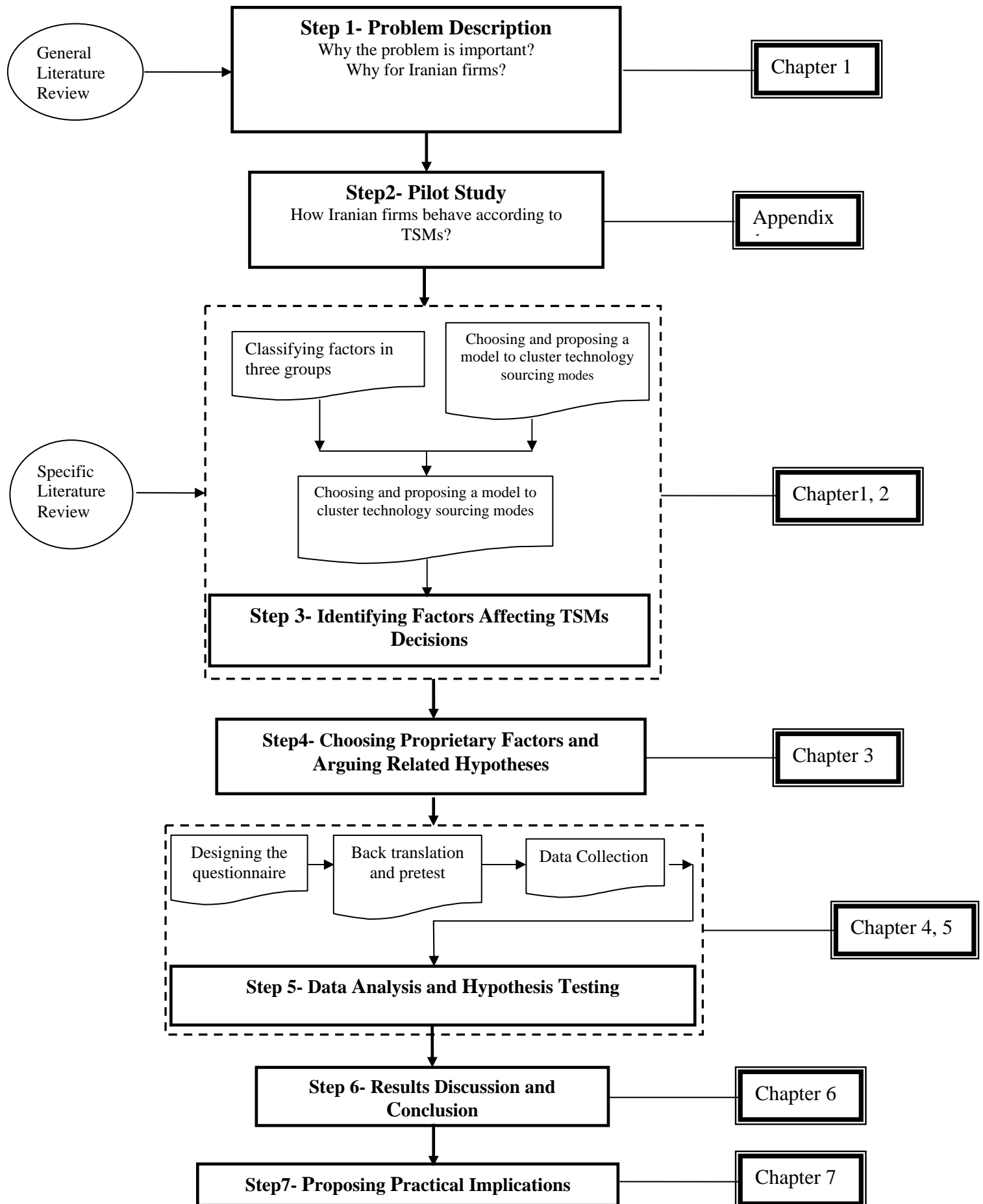


Figure1. Scientific Approach of Research

## **Chapter1**

### ***Preliminaries on Technology Sourcing Literature***

*This chapter aims at introducing general expressions of Technology sourcing literature, definitions of modes of technology sourcing as well as their characteristics. In this chapter, reviewing previous models, we also propose a model which classifies different modes of technology sourcing in three categories: internal R&D, cooperation and acquisition.*

## 1.1. Definition of Technology

In the literature, the concept of “technology” is defined as following:

- Abetti( 1989:37) proposes an R&D-based definition of technology as *“a body of knowledge, tools, and techniques (know how) derived from both science and practical experience that is used in the development, design, production, and application of products, processes, systems, and services”*.
- Khalil, 2000, defines technology as *“the practical implementation of knowledge which, according to (Zeleny, 1986), includes three components including; hardware, software and brain ware”*. **Hardware** deals with the physical structure and logical lay out of the equipment or machinery that is to be used to carry out the required task. **Software** addresses the knowledge of how to use the hardware in order to carry out the required task. And **brain ware** refers to the reasons for using the technology in a particular way. This may also be referred to know-why.

Khalil adds a fourth component, namely; know-how, which encompasses all levels of technology. **Know-how**: the learned or acquired knowledge or technical skills regarding how to do things well. Know-how may be resulted from experience, transfer of knowledge or hands-on practice.

According to (Khalil, 2000), technology is only the applied kind of knowledge which creates or improves a product, service or process.

- Burgelman et al. (2004) define technology as *“theoretical and practical knowledge, skills and artifacts that can be used to develop products and services as well as their production and delivery systems”*. It could be embodied in people, materials, cognitive and physical processes, plant, equipment and tools. In this point of view, the important part of technology may not be expressed or codified in manuals, routines and procedures. What is determining the success of a technology is technical rather than commercial.

- Boly, 2004 defines technology as *“a complex interrelation between technical and connected knowledge”*. Connected knowledge relates to the valorization of science and technique in order to manage an industrial activity and create value: this concern among other knowledge in the fields of finance, quality management, supply chain management, etc.

It is the complex aspect of technology; know-how and interrelation between its components that renders it difficult to obtain.

It should be laid a major distinction between technology and science. Science may be said to be universal. Within a given specialty scientists are working toward the same ends and operating within a

common social system. A scientist, therefore, is fully capable of understanding the nature of the problems and approaches employed by other scientists in his specialty anywhere in the world. The universal nature of the problems and the existence of shared language and methods allow effective communication across organizational and even national boundaries (Allen et al., 1979).

Technology, on the other hand, is not universal. Technology is highly localized as problems are defined in terms of the interests, goals, and local culture of the organization in which they are being attacked. Similar technological problems may be defined in very dissimilar ways by organizations working on them because these organizations often have different objectives and value systems (Allen et al., 1977).

In this research, we define technology, as “*practical and theoretical knowledge and skills that can be used to develop products and services as well as the process of production them. It consists of three components; Knowledge and information, skills and expertise and physical equipment*”.

## 1.2. Technology Sourcing Position in Technology Strategy

Strategic management of technology is now more and more deployed by firms at the corporate and business level; more than 80 percent of companies in the Trial countries take advantage of technology strategy planning (Elder et al., 2002). Determining a firm's technology strategy means answering at least two questions; first what are the appropriate technologies on which the firm should invest? And second, how can the firm gain access to these technologies?

Chiesa (2001) contributes to technology strategy by determining three interrelated factors, namely; appropriate technologies, modes and time of gaining access to them (figure1.1).

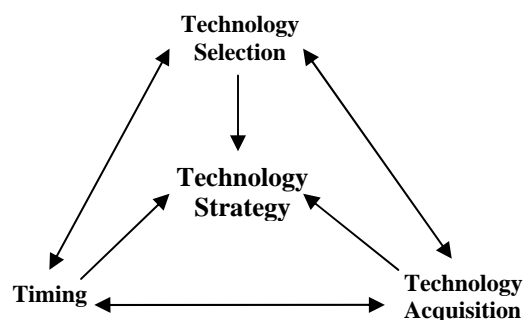


Figure1.1-Technology Strategy Components (source: Chiesa, 2001)

In this regard, a firm's appropriate technologies are determined considering the way and time the firm could obtain them. In other words, a technology is strategic for a firm if the firm could obtain it in a specific time. Therefore, the way a firm should obtain the technology is important. In the literature,



there are several terms that address this issue, namely; “technology sourcing, “technology acquisition” and “technology transfer”. The next section deals with definition of each term and the similarities and differences between them.

### **1.3. .Terminology: Technology Sourcing, Transfer and Acquisition**

**Technology Sourcing:** In order to introduce the concept of “technology sourcing, we should clarify the term “sourcing” at first. Sourcing generally refers to those decisions determining how different components of a product will be supplied for production (make versus buy) and what production units will serve which particular markets (e.g. domestic versus global) (Murray & Kotabe, 1999). *Sourcing* could be considered as a component of the global strategy of the firm. Based on this definition, “*technology sourcing*” is broadly defined as sourcing of technological knowledge for developing new products and processes either from inside or outside a firm (Hemmert, 2004a).

Some definitions of technology sourcing highlight the decision about the source of technology that the firm needs to obtain. These sources could be external, internal or a combination of these two (Driffield & Love 2005, Burgelman et al., 2004, vanhaverbeke et al., 2002). *Internal sources* of technology include any department or member within the firm which play an essential role in technology development; mostly R&D department (Schilling 2005, Burgelman et al.2004).

*External sources* of technology consist of firm’s competitors (Dogson, 1993 ;Hamel,1991), suppliers, clients (Shaw,1994 ; Von Hippel, 1988), research institutes and universities (Gerwin et al. 1992; Santoro, 2000; Tidd et al.,2002) and any other technology creator that is situated out of the firm boundaries and has the technology (source firm) which the firm is seeking to obtain (sourcing firm) (Schilling & Steensma 2002, Steensma & Corley 2000, Leonard-Barton 1995). Competitors and innovative companies which have a specialized knowledge in a certain technology or scientific field , are part of external sources of technology(Cagliano et al.2000).Universities and research centers which usually own leading-edge knowledge and guarantee adequate competencies in organizing and managing research projects (Cagliano et al., 2000).

Hung & Tang (2008) define it as a “process of planned, selective, focalized importation of advanced technology” which is either new for the firm or has new applications for the customers. The objective of a technology sourcing strategy is to guide the firm in acquiring, developing, and applying technology for competitive advantage (Allerd &Swan, 2004). Sourcing a technology internally or externally depend closely on, according to Cohen and Levinthal (1990), firms’ absorptive capacity which refers to the capacity of a firm to use external sources of technology.

Technological knowledge sourcing has become an important phenomenon as firms have come to realize that they can no longer solely rely on in house technological and knowledge capacity to generate new products, processes and services. Therefore, increasingly firms have to confront the problem of how to decide what elements of their technological knowledge requirements should be sourced externally and which ones should be generated in-house. Figure 1.2 shows how reliance of firms on external technology sourcing increased in the countries of the Triad; Western Europe, North America and Japan.

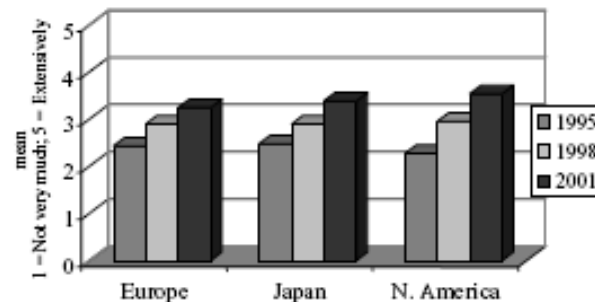


Figure1.2- Reliance on External Sources of Technology (source: Edler et al., 2002)

Technology sourcing decisions could be realized by applying different modes such as alliances, liscence purchase and etc. Section 1.4 deals with different modes of technology sourcing.

**Technology Transfer:** Traditional definition of technology transfer deals with diffusion of technology from one well-defined economic unit (firm or country), which is usually the place of its introduction and named transferor of technology, to another one which named transferee (Teece, 1977). Country –level of technology transfer sometimes is referred as “International technology transfer” (Davidson & Mcfetridge 1984, Grosse 1996 amongst others). Three main objectives of technology transfer are; introduction of new techniques by means of investment on new plants; improvement of existing techniques and generation of new knowledge or technology (Hoffman & Girvan, 1990). Technology transfer is viewed as a high-risk process (Guan et al., 2006), in which individuals are critical resources. Technology transfer may be categorized as *vertical* or *horizontal*. The vertical kind refers to the transfer within the various stages of a particular innovation process, e.g. from basic to applied research or to development. Horizontal kind refers to the transfer of technology from use of a technology in one place to its application in another place or from one project to another (Mansfield, 1975, Teece, 1977). In eighties, the most usual forms of transferring a technology consisted of “license purchase”, “turn -key contracts” or “foreign direct investment” (Davidson & Mcfetridge 1984, Contractor 1980). Later in nineties the concept has been revised as follows: “technology transfer may take place through market transactions, with one firm selling a product, process, or skill to another. Alternatively, it may be carried

out within a firm through its network of affiliates. Also, technology transfer may take place through strategic alliances between firms which agree to mutually use that technology, as in a joint venture or a cross-licensing agreement Grosse (1996, P: 782). Table 1.1 represents all modes of technology transfer.

Table1.1- Modes of technology Transfer (source: Grosse, 1996)

Modes of technology transfer	
Foreign Direct investment	Exporting
Licensing	Franchising
Technical Assistance Contract	Management Contract
Training Contract	R&D Contract
Turnkey Contract	Co-Production Agreement
Subcontracting	Representation Contract

Recently, the knowledge –based economy (KBE) view of the firm has changed the concept of technology transfer. In 2001, Amesse & Cohendet suggested a model of technology Transfer considering any transfer of knowledge and technology between two or more persons, groups or organizations. In this model, technology transfer includes all modes of technology sourcing, namely; in-house R&D, alliances/Joint ventures, license purchase, etc. This proposition has been also confirmed by Grosse (1996) and Cotractor (2001). We explain and analyze this model in section 1.5.2, where we argue technology transfer includes all of modes mostly known as “technology sourcing modes”. In this research, technology transfer is defined according to the definition of Amesse & Cohendet (2001).

**Technology Acquisition:** In the literature, the word “Acquisition” refers to two concepts. The first and the less usual is derived from the verb “to acquire” and denotes “gaining for oneself or come into possession of something”. Therefore, technology acquisition is used alternatively to address “gaining access to the technology” (see for example; Hung & Tang 2008, Bjorvatn & Eckel 2006, Hemmert 2004(a, b), Allerd & Swan 2004, Duysters et al.1999).

The second concept which is more common in the literature of technology sourcing concerns with the modes in which financial resources of firm are used in order to gain access to a technology. Technology acquisition is defined as the decision to buy the technology (Cassiman & Veugelers, 2007). Accordingly, the words “buy” and “acquisition” may be used interchangeably. Acquisition could be whole or partial possession of another firm (Blonigen & Taylor, 2000), licensing or outsourcing (Cassiman & Veguelers, 2007).

In this research, technology acquisition is used in its second sense and realized by modes such as; license purchase, outsourcing, and firm take over or partial firm take over, etc. All these modes will be discussed in section 1.4, in detail.

In this research By expression “gaining access to the technology” we mean have control over technology distribution, in other words a firm-said- has access to a technology if it can decide on how and when distribute the technology. In some cases gaining access to a technology consists of dominance of all dimensions of technology which is realized by internal development or technological collaborations and in other ones obtaining a technology consists of having control over its distribution without learning the know-how of it. The latter is realized by R&D outsourcing agreements as well as by firm take over.

#### **1.4. Technology Sourcing Modes**

Different modes of technology sourcing may be defined through the literature. In this section we propose different definitions of formal modes of technology sourcing. It is important to note that many informal modes of technology sourcing utilized by firms have not been addressed in this research. Formal modes are also known as “contractual governance modes” because they need to contract specifications which stipulate each party’s rights, duties and responsibilities as well as the specific mode’s goals, orientations and plans (Luo 2005, Oxely 1999). Such contractual governance mitigates opportunism. Each type of technology sourcing has some advantages and disadvantages, so none of them is ideal in all cases for a sourcing firm.

For this purpose, we use the Chiesa’s framework (2001). In order to define contractual modes of technology sourcing, Chiesa suggests a framework consisting of three issues (figure 1.3) to specify different modes. The first issue is kind of resources allocated by each part participating in a specific relationship. Different kind of resources could be defined.

However, it suffices the purpose of this research to separate the financial resources from non-financial one. The second Issue is ‘agreement on the activities performed during the relationship’, notably management of the activities, and property of resources allocated to this relationship. The third issue is the decision on the results obtained at the end of or during such a relationship; property and exploitation of these results. Different modes of technology sourcing are defined according to the following framework.

Decision on technology sourcing mode consists of internal R&D and a range of non-internal technology development methods (Narula, 2001), although theses modes are more complementary rather than substitutable (Tsai &Wang, 2007). Various technology sourcing modes discussed in the literature are briefly described below.

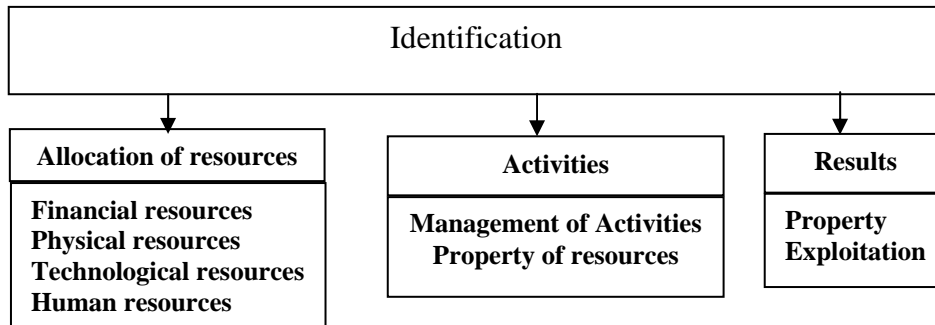


Figure1.3- General Framework for Definition of Technology Sourcing Modes (source: Chiesa, 2001)

**1.4.1. In-house R&D:** This is the most common sourcing mode. It could be defined as the creative use of the firm's own resources (existing knowledge embodied in R&D staff as well as laboratories, tools and other equipment) to realize a technological innovation. The main difference between “in-house” and other modes is that the former is intra-mural while the latter are extra-mural.

**1.4.2. Internal Transfers:** Such transfers occur when some technological knowledge is transferred from one SBU to another within a large company (a corporation). This means that the firm sees itself as a large reservoir of technology. The rationale behind this kind of transfer is that, if one technology was developed in a given SBU, it doesn't belong solely to that SBU but belongs to the entire group.

Consequently, other SBUs should be able to gain it (for a given internal transfer price).

The next three modes are positioned in cooperative agreements which first three modes mostly carried out in the area of technological innovation. However, innovation is costly and uncertain and its management requires special abilities being required in its management. Moreover, it is difficult to appropriate the results of innovation. Therefore, firms need to cooperate in R&D (Bayona et al., 2001).

**1.4.3. R&D Joint Venture:** This is a particular type of alliances in which an independent entity is created by a small number of sovereign firms (usually two or three). The partners pool technological resources of their own to establish a new business. JV might also be the result of a partial merger between two distinct companies that have decided, for example, to pool their respective R&D departments into one single body. Such entities are found in most Hi-Tech sectors. This form of joint venture is named equity joint venture (Figure 1.4).

Another kind of R&D joint venture exists in which any equity link is defined; i.e. without the creation of a common entity. It is called **Non-equity R&D joint venture**. This mode covers co-operative agreements between at least two independent firms where one specific R&D project is co-coordinated while workload shared and results are exchanged. Such definition is exactly similar to alliance.

JVs have been seen as achieving four main objectives; (1) taking advantage; of economies of scale and diversifying risk; (2) overcoming entry barriers into new markets; (3) pooling complementary bits of knowledge; (4) allaying xenophobic reactions when entering a foreign market reducing political risks(Hennart, 1988). Each of these four commonly described reasons provides a necessary, but not a sufficient, condition for the emergence of JVs.

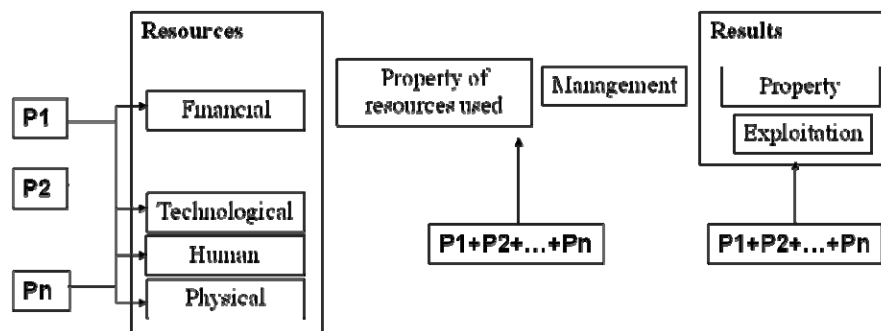


Figure 1.4- Joint-Venture (source: Chiesa, 2001)

Joint ventures could be local or international. In local JVs, the partners are the same nationality and activated in the same country. One example of this kind of JV is NEC Lamilion Energy- a joint venture of two Japanese firm; NEC Corporation and Fuji Heavy Industries. NEC Lamilion Energy is formed in order to develop and manufacture high-performance batteries for environmentally friendly automobiles. The project would combine NEC's expertise in manganese lithium-ion cell technology with Fuji's battery pack technology to create rechargeable batteries for the automobiles.

In international joint venture at least one partner is from a foreign country. This kind of JVs is formed to transfer a technology from a country (usually a developed country) to another (developing) one. Sino-foreign joint ventures are the example of international joint ventures in china. In this relationship, Chinese partners pool human resources, labours, land and some general equipment, distribution channels, local market knowledge while foreign partners pool technological resources, special equipment, brand and financial resources. In this relationship, as Chinese partners learn technological know-how and knowledge from foreign partner(s), foreign partners gain access to local market and learn about the local market and culture of China (Jolly, 2006).

**1.4.4. Equity R&D Consortia:** This is quite similar to equity R&D joint ventures – except that the consortia usually bring together a large number of firms (Ouchi & Bolton, 1988). A consortium may be focused on driving and co-coordinating the research conducted by in-house members or, on the contrary, on becoming a research centre distinct from its members (Evan & Olk, 1990). Several well-

known examples, such as the Microelectronics and Computer Technology Corporation (Werner, 1992) or Sematech (Spencer & Grindley, 1993) in the semiconductor industry, show that consortia usually target pre-competitive research.

**1.4.5. Sub-Contracted R&D (R&D outsourcing):** This is essentially funding another firm, under time and cost specifications, to conduct a specific R&D project whose results will be the property of the sponsoring firm(s). Unlike Roberts & Mizouchi (1989), we do not consider this approach to be a co-operative one, as there is no joint management, no common work and no reciprocity in the unilateral contract. Many organizations are increasingly considering outsourcing as a critical element of their organizational strategy (Holcomb & Hitt, 2007).

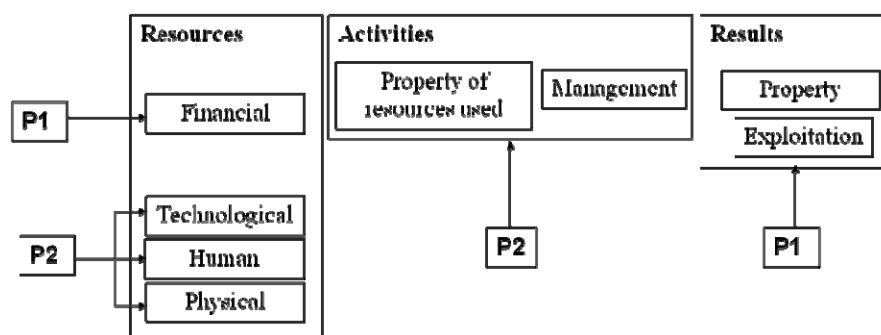


Figure1.5- Sub-contracted R&D (source: Chiesa, 2001)

A review of the relevant literature reveals that main reasons for firms to undertake R&D outsourcing include: reduce costs, minimize business risks, and hasten product market entry); focus on their core activities; bring in resource flexibility and build expertise by exposing the internal development staff to new knowledge, technology, and organizational development processes (Caudy, 2001; Ernst, 2000; Huang et al., 2009; Kumar and Snaveley, 2004; Piachaud, 2002; Teresko, 2003; Zhao and Calantone, 2003). For example, many Taiwan small and medium-sized enterprises (SMEs) have been successful in contracting out some of their R&D capabilities in order to combine the scale advantages of large firms with the speed and flexibility of smaller firms(Ernst, 2000).

**1.4.6. Licensing:** It is the most commonly observed in inter firm contractual agreements (Anand & Khanna, 2000). This simply involves paying royalties (or some other form of compensation) or a lump sum to an innovator for the right to use the proprietary technology he or she has developed. The license contract ends when the two parties (licensee and licensor) decide to cancel their agreement.

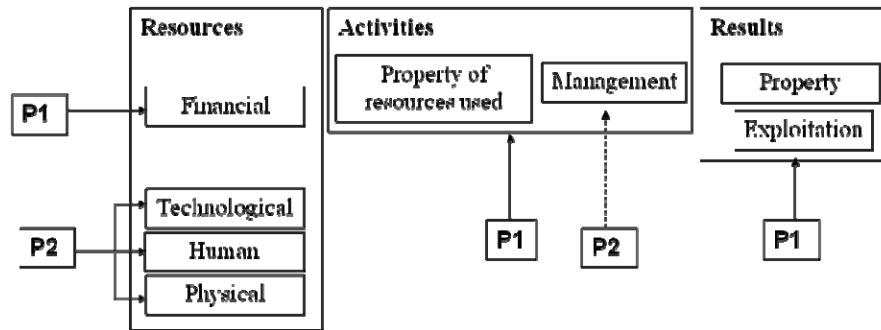


Figure1.6- License Purchase (source: Chiesa, 2001)

Licensing enables a firm to rapidly obtain a technology (or another resource or capability) it does not possess. For example, when Microsoft realized it had lost precious time to Netscape and needed to get a web browser to market fast, it licensed the necessary software from Spyglass Inc (Schilling, 2005).

For licensees, licensing a technology has the following advantages; firstly, licensee could gain access to a technology faster and less expensive than developing it in-house. Secondly, on the one hand, it is less risky since licensee usually obtains a technology that is already technically or commercially proven. On the other hand licensees may suffer some disadvantages. A technology that is available for license is typically available for many potential licensees; therefore gaining access to this technology may not create a sustainable competitive advantage for licensee.

It is important to know that licensing agreements typically impose many restrictions for licensees; for example high control of licensor over the use of technology. However, these restrictions may create an opportunity for licensees to gain valuable knowledge from working with licensor and enable them to later develop their own technology.

For licensor, licensing out a technology can enable firm to penetrate a wider range of market than it could on its own. Before a dominant design emerges and for the industries which have a strong pressure for adoption of a single dominant design, licensing out could enable the licensor to introduce its own technology as the dominant design. In the case that competitors are likely to be able to imitate the features of technology, licensing out the technology may prevent the potential competitors to develop their own technology. Thus the licensor may opt for a steady stream of royalties rather than gambling on the big gain or loss.

**1.4.7. Patent Purchase:** This mode involves much more commitment than license purchase because it is a definitive move. Ownership is transferred from the innovator to the acquiring firm. It is a way of internalizing knowledge that has been acquired outside the firm.



Both licensing and patent purchasing are usually far from being situations of co-operation as these unilateral commercial transactions take place between a seller and a buyer in the knowledge market (Hagedoorn, 1990).

**1.4.8. License Swap:** While some researches use this term (e.g. Zahra et al., 2005), others use the term “cross-licensing” (Anand & Khanna 2000; Telsio 1979) to describe an agreement where two firms agree to barter (without disbursement) their licenses. Such deals occur very frequently in industries with more intensive competition such as the semiconductor or the pharmaceutical industry (figure 1.7).

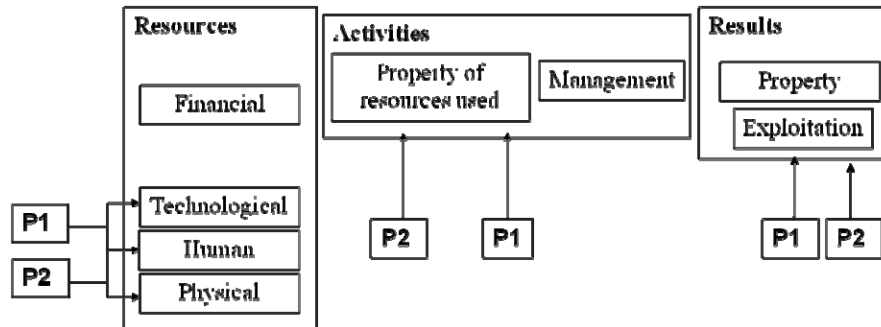


Figure1.7- License Swap (adapted from Chiesa, 2001)

Some forms of cross-licensing may be involved in joint development, but it differs from simple one-way transfers of know-how through licensing (Hagedoorn, 1990). The coupling between the partner firms is tighter because they mutually benefit from the successful development of products and processes. Teams of scientists and engineers from both partners may work side by side in their quest to jointly exploit the shared technology, or at the very least they maintain constant communication. Despite this higher level of interdependence, however, each partner firm maintains its own set of objectives and possibly competing goals. These competing goals can impede the flow of technological know-how between the partners as each partner takes precautions to limit its transparency and guards against transferring specific know-how (Steensma & Corley, 2000).

**1.4.9. Firm Take-over:** This might be a full take-over (100%), an acquisition (in order to gain financial control) or an absorption (where  $A+B=A$ ). Acquisition may be realized as either majority or minority equity investment; dependent on the percentage of the firm’s proprietary. In contrast to majority acquisition, the minority one does not guarantee management control of the company where the technology of interest is embedded. All these moves allow the company to gain access to an existing technological asset or take over those R&D capabilities of the firm that are otherwise not possible to efficiently redeploy (Anand & Delios, 2002). Acquisitions and take- overs may have other objectives apart from attaining the technology. For example, in 1998 United Healthcare, an HMO recently pursued

the acquisition of several small software firms in order to prevent its rivals from obtaining the best information technology (*Economist*, 1998). Figure 1.8 represents the case.

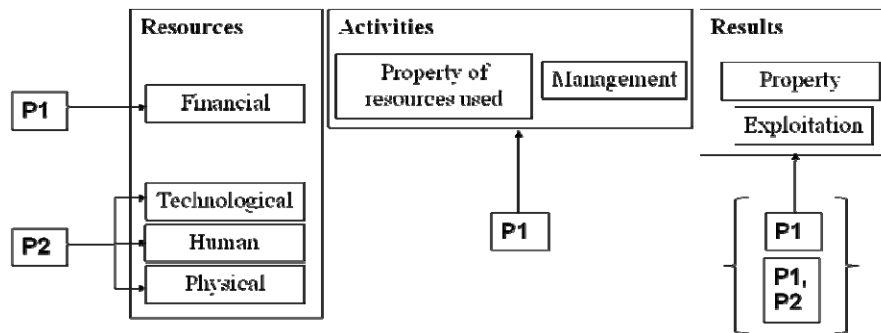


Figure1.8- Firm Take-over (source: Chiesa, 2001)

Sometimes two firms are agreeing to buy a third one to gain a technological base, **Joint take- over**. It is not a frequent mode. Most of the time, it ends in splitting the targeted entity between the two buyers.

**1.4.10. Complementary License Purchase:** This involves a two party agreement. The first one is a firm requiring technological knowledge and the second one is a research centre or university (rarely another firm). The buyer sends its qualified labour to learn a certain technological knowledge, and pays for this training to the second party. The responsibility of preparing the equipment belongs to the firm and the second party (research centre or university) acts as consultant (figure1.9).

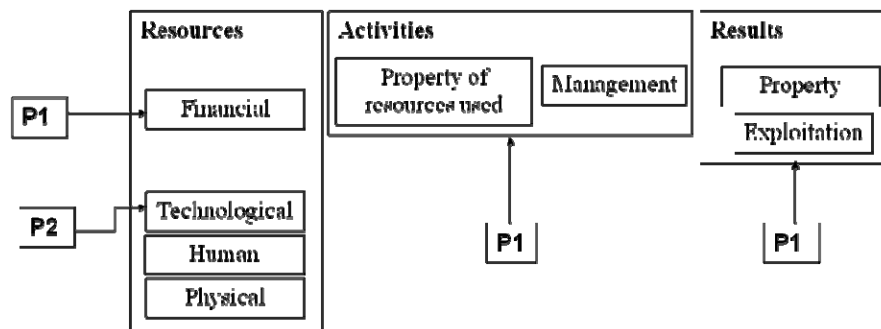


Figure1.9. Complementary license purchase (source: Chiesa, 2001)

**1.4.11. Alliance:** Alliance may be defined as a provisional relationship in which two (or more) allies or partners, pool their resources in order to achieve a predefined shared objective. The results of this relationship benefit all partners. Out of this relationship, allies stay independent (Jolly, 1995). As represented in figure 1.10, firms A and B cooperate to produce product R and in the meanwhile they produce their own products; X, Y, Z for firm A and Sand T for B, independently from each other.

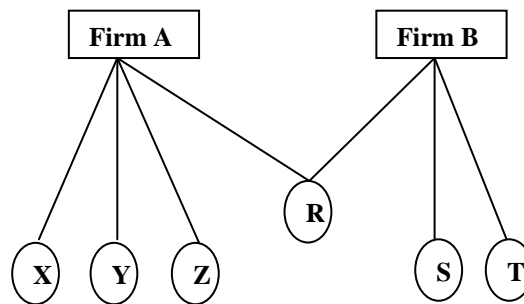


Figure 1.10- Alliance definition

Based on Chiesa's approach, alliance could be defined as represented in figure 1.11. During an alliance, activities could be managed in two manners; one of the partners manages the relationship or a team of all involved parties control the activities.

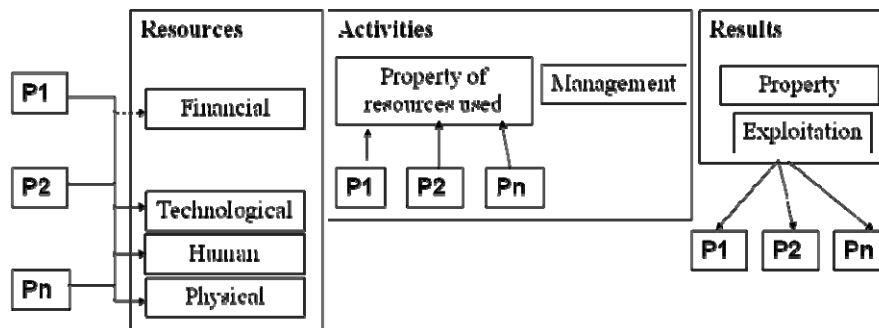


Figure 1.11- Alliance (adapted from Chiesa, 2001)

There are some differences between alliance and collaboration. Alliance is a contractual partnership involving close cooperation between two or more parties having specified and joint rights and responsibilities. Collaboration involves cooperation in which parties are not necessarily bound contractually. There is a relationship, but it is usually less formal than a binding, legal contract and responsibilities may not be shared equally. Collaboration exists when several people pool their common interests, assets and professional skills to promote broader interests for the community's benefit. The most important thing to remember is: Organizations don't collaborate – people collaborate.

Despite this definition, some authors use alliance and collaboration interchangeably; for example, Taylor and Steensma, 1995 define collaboration as follows:

*“Any activity where two or more partners contribute differential resources and technological know-how [knowledge and skill required to do something correctly] to agreed complementary aims. This definition does not include one-way transfers of know-how such as licensing, marketing agreements, or simple one-time only contracts. Rather, technological collaboration is an ongoing arrangement where partners*

*mutually share their expertise and output. It represents a range of alliances between organizations (Borys & Jemison, 1989; Hagedoorn, 1990, 1993; Oliver, 1990; Ring & Van de Ven, 1992)”.*

In this research the differences between alliance and collaboration are accepted. In such a relation, objectives consist of entering new markets (George et al., 2001), sharing the cost or risk of a transaction, gaining access to resources (George et al., 2001), acquiring complementary skills and capabilities (George et al., 2001), gaining access to a technology (technological alliance)<sup>2</sup>. Sometimes alliances are taken place in order to change the architecture of a specific industry (i.e. introduce a new standard to the market) such as the alliance between Motorola, Ericsson and Nokia; by establishing the WAP forum in order to establish a common wireless telecommunication format (Schilling, 2005) or cooperation of 400 well-known firms in order to develop a WiMAX to the market <sup>3</sup>(Pisano & Teece, 2007).

Three classifications of alliance are presented here, namely; vertical versus horizontal, complementary versus scale and exogamy versus endogamy.

**Horizontal versus Vertical alliances:** This classification focuses on the partners. If the partner of allied firm is its competitor; i.e. the other firms activated in the same industry, the alliance is called horizontal.

If the partners are selected from other stages of firm value chain; i.e. suppliers or customers and universities or other research institute, such an alliance is called vertical.

**Complementary versus Scale alliances:** This classification focuses on the kind of resources pooled by the partners. In scale alliance, the partners forming an alliance pool similar resources pertaining to the same stages of value-chain. Scale alliances will produce economies of scale for those activities that firms carry out in the collaboration.

On the contrary, the complementary one -also called link alliance- aims at combining different skills and resources that each partner contributes.

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<sup>2</sup> In this research, we focus on the technological kind of alliance which is realized in order to learn about a particular new technology and reduce the uncertainty surrounding this new technology (Letterie et al., 2008).

<sup>3</sup> WiMAX (Worldwide Interoperability for Microwave Access) is a technology for high-speed (broadband) wireless web access. Unlike current Wi-Fi networks (found in airports, homes, or local coffee shops) whose ranges are typically limited to a hundred yards or so, WiMAX permits Internet access at a range up to 30 miles and at speeds 50 times faster. In essence, WiMAX is a substitute technology for current coaxial and fiber optic lines that deliver broadband Internet access to homes and offices. WiMAX is an excellent example of a technology embedded in a broader system of complementary technologies. Implementing WiMAX requires innovation in microprocessors, modems, wireless networks and web infrastructure, mobile handsets, data services, and other communications technologies. It is no wonder, then, that WiMAX is being developed as a cooperative alliance involving companies such as Intel (microprocessors), Samsung (handsets and network equipment), Motorola (handsets and network equipment), Sprint-Nextel (carrier), Clearwire (carrier and the largest holder of spectrum suitable for WiMAX), Vodafone, and over 400 other companies that form the “WiMAX Forum (Pisano & Teece, 2007).”

Sakakibara (1997) proposes a similar classification as cost-sharing and skill-sharing alliances. The first one tends to involve partners with homogenous capabilities while the latter tends to involve partners with heterogeneous one.

**Endogamy versus Exogamy:** proposed by Jolly(2006), this classification not only distinguishes the alliances in terms of the resources pooled by the partners, but also with respect to the resources the partners possessed and the socio-cultural environment that partners come from. In an endogamy alliance, not only the resources the partners possess and their environments are similar, but also they pool similar resources. On the contrary, in an exogamic alliance, each of the above three elements could be different. In endogamic alliances, usually the objective pursued by the partners is scale- related and at the same time few opportunities for learning exist. In an exogamic alliance more learning opportunities exist and the partners complement each other qualitatively.

According to this definition, vertical alliances are always exogamy while horizontal alliances could be classified as exogamy or endogamy.

Occasionally alliances are used as the intermediate modes to help one partner evaluate another partner in order to acquire it in the future (Lambe & Spekman, 1997). The alliance taken place between the pharmaceutical company; Amgen, and ABgenix was meant to serve this purpose. In 2003, the companies entered in an alliance and in 2006 Amgen acquired ABgenix (Schilling, 2005).

The above mentioned technology sourcing modes are not exclusive. Other modes like **Specialist recruitment**<sup>4</sup> could be added in the list. In addition, at a corporate or even at a SBU, one project may be based entirely on In-house R&D as another project may be run through a technology acquisition. Furthermore, a combination of different modes could be applied for a single project, for example the project may start with In-house R&D and continue with alliance or acquisition. External technology sourcing strategies may be seen as a means of complementing and leveraging internal capabilities (Granstrand et al. 1992, Roberts 1995, Jonash 1996, Chatterji 1996).

Figure 1.12, shows the ratio of number of each mode used in European Union on total number of external technology sourcing modes used before 1995.

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<sup>4</sup> This is a quick way to internalize some expertise into the firm's set of resources.

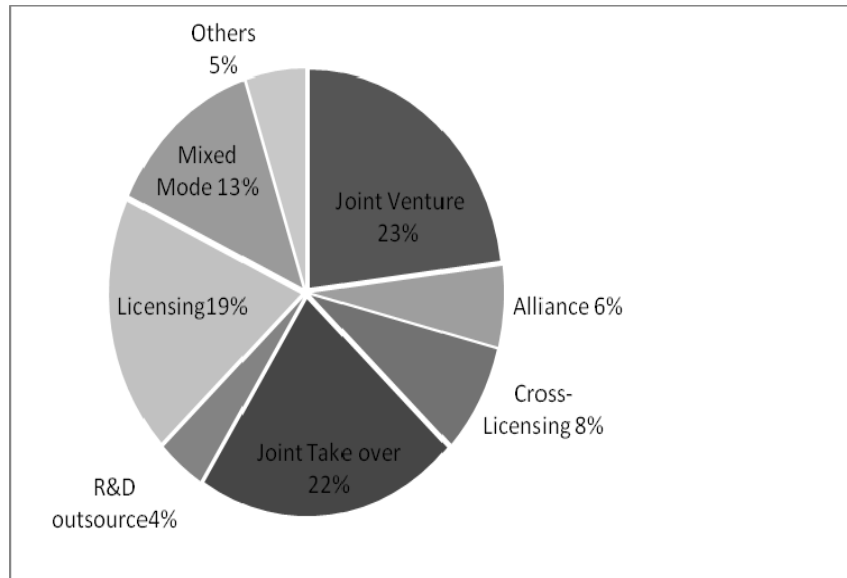


Figure 1.12- Variety in External Technology Sourcing Modes in the countries of European Union (Source: Mowery et al., 1996)

Different modes have their own characteristics; according to them choosing different modes bring different advantages and disadvantages. In sections 1.4.11 and 14.12 the characteristics and each modes advantages and disadvantages are discussed.

#### 1.4.12. Characteristics of Modes

In this section different characteristics of each mode are described. Table 1.2 summarizes some trade-offs between different modes of technology sourcing. In-house R&D is relatively slow and expensive way to gain access to a technology. Meanwhile the firm that engages in internal development maintains total control on technology development and distribution. Internal development also offers great potential for the firm to leverage its existing competencies as well as to develop the new one. Internal development may make sense for the firm that benefit from strong competencies related to new technology, access to financial resources and it is not under time pressure to gain access to the technology.

Speed, cost and degree of control of the firm in other external modes of technology vary. Some modes of technology sourcing, such as license purchase may enable a firm to gain access to a technology faster and cheaper than in-house development, but give the firm a low level of control over the technology. These modes provide opportunities for the firm to gain access to other firms' competencies, while permit to leverage own competencies poorly.

Table1.2- Characteristics of Technology Sourcing Modes (source: Schilling, 2005 and Ford,1988 )

Modes of Technology Sourcing	Speed	Cost	Control	Potential for leveraging existing Competencies	Potential for developing new competencies	Potential for accessing other firms' competencies	Commitment / investment involves
Internal R&D	Lowest	High	High	Yes	Yes	No	High
alliances	Varies	Varies	Low	Yes	Yes	Sometimes	Shared
Joint venture	Low	Shared	Shared	Yes	Yes	Yes	Shared
Licensing In	High	Medium	Low	Sometimes	Sometimes	Sometimes	Low
Outsourcing	Medium/ High	Medium	Medium	Sometimes	No	Yes	No Commitment

Developing technology internally ensures greater control over its distribution and serves to maintain a viable technical capability for the firm but may require greater resources than the firm is willing or able to commit. While gaining access to a technology through collaborative modes may facilitate rapid development and deployment of commercial technologies and products, but it can also undermine the need to maintain and upgrade internal capabilities.

Therefore firms must carefully weigh the advantages and disadvantages of each group of modes to ensure the ability to compete effectively in today's market.

Due to diversity of modes to obtain the technology, it is necessary to select an approach for classification of different modes. In section 1.5, we address different approaches already discussed in the literature while proposing a model for classification of different modes.

## 1.5. Models

Organizational modes of technology sourcing have been classified according to two approaches; namely, one dimension and two dimension models. This section is devoted to introduction of these two types of classification models.

### 1.5.1. One Dimension Models

In this approach, all modes of technology sourcing are classified in a spectrum between internal R&D and turn- key agreements or licensing (e.g. Chiesa 2001; Ford & Saren 1996; Schilling 2005).

In this regard, all modes are situated in a spectrum according to their characteristics such as the speed of gaining access to the technology, the cost and etc. (see below for details) (

Schilling (2005), classifies the modes in two groups, the solo approach and the cooperative one. Internal R&D is the only mode situated in solo approach and all other modes of technology sourcing are classified in the second group. However, according to definition of cooperation in this research, not all modes of technology acquisition (buy) are classified as cooperative one.

For example, a licensing agreement, especially with a lump sum contract, may be considered rather unilateral (Hagedoorn, 1993), while the same agreement with a loyalty payments on each products (with or without a pre- payment) could be considered a cooperative agreement. It is because in the second situation the licensor is more concerning to product process and the method of payment necessitates the presence of licensor in each stage of production, while in the first situation licensor has already gained its benefit.

### 1.5.2. Two Dimension Models

Another approach classifies the modes according to certain factors such as degree of firm independence (Hoffman & Schaper-Rinkel, 2001), mode of access and action (Jolly, 1995) and etc. These models are described immediately after.

**Hoffman and Schaper-Rinkel, 2001:** In their model, Hoffman & Schaper-Rinkel classify the modes according to the extent to which they keep the firm's legal and economic independence. In alliances, the firm's legal independence is preserved as well as economic independence outside of collaborative activities. But merging forfeits the firms' legal independence just as cooperation and acquisition retain the firm's legal independence (Figure 1.13).

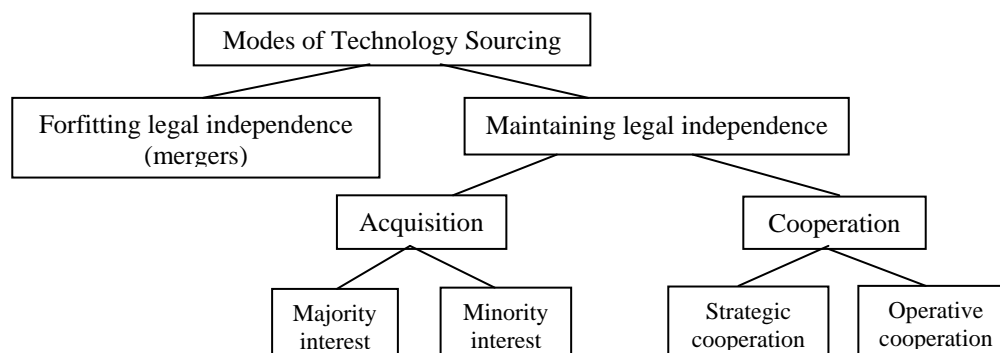


Figure1.13- Hoffman & Schaper-Rinkel's Model

**Amesse and Cohendet, 2001:** Amesse & Cohendet, 2001 define four broad contexts for technology transfer. The process of technology transfer could be realized within the organization or outside it (internal or external) and by creating the technology when the technology is new, i.e. technological innovation or by diffusing or reproducing an existing technology in another firm (figure1.14).



Reproducing and diffusing technology	Within Organization	Between Organization
	<b>I</b> <b>Managing Innovation</b>	<b>II</b> <b>Contracting Out R&amp;D and Outsourcing</b>
	<b>III</b> <b>Internal transfer</b>	<b>IV</b> <b>Buying or Selling Proven Technologies (Licensing, turnkey,..)</b>

Figure 1.14- Four Types of Technology Transfer Contexts (source: Amesse & Cohendet, 2001)

The four different situations, the third one concerns with certain form of companies, namely; multinationals and headquarters.

The first situation is related to R&D activities in the firm and the problems of managing innovation which the firms confront. In this situation, information should be shared between different firm's departments. Second situation is when the new technology is created by the interference of another firm. In this situation, other modes could be utilized in addition to contracting out and outsourcing R&D proposed in this study.

The Third and fourth situations take place when a technology is not new for the firm and its reproduction or diffusion along the firm is important, the latter situation could also be realized by acquisition.

We propose to consider two following remarks:

- Contracting out R&D and outsourcing are not the only modes of creating a new technology with others; other R&D collaborations (alliances and joint ventures) could be also utilized.
- Licensing out and turnkey agreements are the most usual modes to diffuse an existing technology, although in some circumstances firms rely on other collaboration modes.

**Jolly (1995):** This approach considers two basic questions that the managers face in choosing TSM, including; firstly, whether to develop the technology internally or externally, and secondly, if the firm should act solo or with collaboration (Jolly 1995). Consequently, the access mode (internal versus external development) is separated from the mode of action (collaborative versus autonomous). In other words, the two dimensions of the matrix are: **(a) the access mode**; internal development (make) versus external development of technology (buy), and **(b) the action mode**: autonomous action versus collaborative action (figure 1.15). As it is presented, the majority of modes could be classified in this matrix. Nevertheless, some modes- such as license swap- are situated in the matrix difficultly. On one hand, License swap could be classified as license purchase due to their similarity. On the other hand,

license swap (especially if it is a full bartering without any supplementary payments) involves the resources of the firm for a given technology. By developing the technology it is meant that firm's resources should be utilized and enhanced in order to gain access to the same technology and not another one. Therefore, in license swap firm resources for a given technology are supposed to be developed internally and dominated by the licensor while this is not the case for taken technology.

Action Mode Access Mode	Autonomous Approach	Collaborative Approach
Develop the technology internally (Make)	In-house R&D  (I)	<b>All kinds of Technological Alliance:</b> <ul style="list-style-type: none"> <li>• Equity R&amp;D Joint Venture</li> <li>• Non-Equity R&amp;D Joint-Venture</li> <li>• Equity R&amp;D Consortium</li> <li>• Joint-Venture</li> </ul> (II)
Develop the technology externally (Buy)	<ul style="list-style-type: none"> <li>• License Purchase</li> <li>• Complementary License Purchase</li> <li>• Patent Purchase</li> <li>• Firm Take-Over</li> <li>• Acquiring one part of an Innovative Firm</li> <li>• Sub-Contracted R&amp;D</li> </ul> (III)	<ul style="list-style-type: none"> <li>• Joint Take-Over</li> <li>• Cross Licensing</li> <li>• ...</li> </ul> (IV)

Figure 1.15- Classification of Technology Sourcing Modes (Jolly, 1995)

This classification distinguishes between technology sourcing modes and acquisition ones which is an important point (Jones et al., 2000; Nobelious, 2004, amongst others). The model classifies all modes in four categories, therefore studying the effects of determinants for the small sample is simpler than doing the same for large sample of modes. In other saying, using the model we can study the effect of different factors on each of the four groups and accordingly select one of them, then amongst different modes within a group; if numerous modes exist; one mode is selected.

The model entails also some ambiguities. One of the ambiguities is that a certain mode could be classified in more than one category. License purchase, as an example, is not always classified in part (III) of the matrix as represented in Figure 3. According to the contract, some license agreements with paying royalties could be a kind of alliance and be positioned in the second part. Certainly this will be clarified after deciding about the licensing mode and even after reaching an agreement with the licensor. Therefore, license purchase could be situated in either the second or third part of the matrix according to the contract with the licensor.

**Suggested Model:** In this research, we purpose a model similar to jolly’s one with three group of technology modes classification, including; internal development, alliances and acquisition. In this model, we do not distinguish between joint and solo acquisition. Because – as revealed in our pilot study (Jolly & Karamipour, 2006) - the case of joint acquisition is very rare (one case amongst 40 studied firms). Therefore, we need much more cases to embark on studying the determinants of such a relation. The decision on solo or joint acquisition may be made after deciding to buy a technology and may not be taken simultaneously with it. Figure1.16 represents the suggested framework. As explained before, this framework is proposed based on the contextual conditions and should be reviewed in other contexts.

Access Mode \ Action Mode	Autonomous Approach	Collaborative Approach
	Technology Make	Technology Buy
Technology Make	Internal Development	Cooperation
Technology Buy	Acquisition	

Figure 1.16- Proposed Model of Our Research

According to this framework, in chapter 3 we propose factors affecting three categories technology sourcing modes; Internal development, cooperation and acquisition.

## 1.6. Conclusion

This chapter constituted an introduction to technology sourcing concept. We also present different other concepts which are in some ways used interchangeably; technology transfer and technology acquisition. Formal modes of technology sourcing as well as their characteristics are described, in section1.4. In section 1.5, reviewing different models of classification TSMs, we proposed a model consist of three categories; internal development, cooperation and acquisition. Next chapter is devoted to a more specific literature review to introduce factors affecting different technology sourcing modes.

## **Chapter2**

### ***Determinants of Technology Sourcing Modes:***

#### ***A Literature Review***

*This chapter aims at introducing determinates affecting the choice of different modes of technology sourcing. In this chapter, based on the literature we propose a classification of factors and describe how these factors affect Technology Sourcing Modes (TSMs). Finally we propose a list of nine determinants of Technology sourcing modes; four technology-related and five firm-specific factors. Technology related determinants consist of a) technology life cycle, b) degree of commercial and technical uncertainty, c) strategic importance of technology, and d) technology urgency. Firm-specific determinants include e) strengths on internal resources, f) level of absorptive capacity, g) successful past experiences, h) strategic objective and i) firm size.*

## 2.1. Classification of Factors

Many researchers have investigated factors affecting the choice of technology sourcing modes; these studies are different in terms of three points of view.

**Mode of technology sourcing:** some studies choose one special mode of technology sourcing and investigate factors affecting this mode (see for example Kiyota & Okazaki, 2005), others select two or three modes which substitute one for another (see for example Cho & Yu, 2000). In the first group of studies, factors are selected based on a particular mode and may not be considered as factors affecting other modes while the second type of studies is more general.

**Industrial Scope:** while some studies focus on one industry like telecommunication (Cho and Yu, 2000) or pharmaceutical industry (White, 2000), others select a wider range of industries like manufacturing enterprises in any industry (Allred and Swan, 2004) and a few studies consider no specification in industry (Hernan et al., 2003).

**Geographical Location:** the effect of determinants may not be similar in different areas or countries. Therefore, the findings of the previous studies about this effect is localized and relevant to a particular area/country, for example; China (White, 2000), Korea (Kiyota and Okazaki, 2005). Some studies are more general such as the study by Hernan et al. (2003) which focuses on international joint ventures situated in European Union countries.

Table 2.1 represents characteristics of previous studies according to the above three issues.

Table 2.1 Summary of Literature Review

Authors and year	Mode	Industry	Country
Davidson & Mcfetridge, 1985	licensing the technology from a parent or an affiliate in a country to another one and Foreign Direct Investment	Multinational companies in any industry	USA
Pisano, 1990	Internal and external R&D	Large pharmaceutical firms (who produce biotechnology –based products).	The largest firm in the world
Montalvo & Yafeh, 1994	licensing in agreements (especially those with foreign companies)	manufacturing firms	Japan
Tyler & Steensma, 1995	Technological collaboration	Manufacturing, utilities and software	USA
Folta, 1998	equity cooperation versus acquisition	Biotechnology	USA
Robertson & Gatignon, 1998	internal development versus alliances (excluding licensing and contractual R&D)	A wide range of industries, including automation, biotechnology, chemicals, computers, materials, medical equipment, pharmaceuticals, telecommunications, and transportation.	USA
Cagliano et al., 2000	Technological collaborations; JVs, consortia, ...	Different industries (pharmaceuticals, electronics, telecommunications, machinery, textile, and automotive).	different countries in European Union (Finland, France, Germany, Italy, Norway, and Sweden)
Cho & Yu, 2000	internal R&D, R&D cooperation and technology purchasing (consist of R&D contract, licensing and acquisition)	small and medium size enterprises in telecommunication industries	Korea
Jones et al., 2000	Internal development versus external technology sourcing	Subsidiaries of multinational companies	USA
White, 2000	internal R&D, R&D cooperation and technology acquisition	pharmaceutical enterprises and research institutes	China
Hoffman & Shaper-Rinkel, 2001	Acquisitions versus alliances	no specification	Germany
Hernan et al., 2003	Research Joint venture	no specification	Countries in EU
Allred & Swan, 2004	Internal development versus external technology sourcing	Subsidiaries of multinational companies in manufacturing	USA
Kale & Puranam, 2004	Equity ownership	no specification	USA
Kiyota & Okazaki, 2005	Licensing in agreements	no specification	Japan
Drejer & Lund Vinding, 2007	Collaboration	Manufacturing firms	Denmark

Globerman & Nielsen, 2007	Equity versus non-equity strategic alliances	no specification	Denmark
Huang et al., 2009	R&D outsourcing	Information technology Firms	Taiwan
Narayanan & Bhat, 2009	In-house R&D, license purchase and complementary license purchase	Basic chemical industry	India

As it is observed, diversity of factors and modes of technology sourcing as well as dissimilar effect of some factors in different contexts create a complex situation in which decision making is somehow difficult. In order to simplify the effect of such factors, some authors have classified them into different categories. For example, Davidson and Mcfertidge (1985) classify the factors affecting technology transfer decisions into three groups, namely: technology-related factors, transferor's characteristics (including all legal, economic and social environmental factors from which the technology is transferred) and receiving country specification (i.e. receiving country policies to gain access to the technology). The authors point out that environmental factors of transferor and transferee countries, i.e. their policies, legislations and economic conditions, have a crucial effect on selecting between obtain a technology by license purchase or direct investment in recipient country. In their classifications the authors don't consider the effect of firm-specific factors. It is due to the level of research that is mostly national rather than firm level.

Hernan et al., (2003) also categorize the factors into two groups including; internal and external factors. Internal factors address elements related to the firm such as firm size while external factors are related to the industry within which the firm is activated such as industrial R&D intensity and technology spillovers. The authors neglect technological factors in their classification; neither do they consider the effect of environmental factors such as legislations economic conditions, etc. Noting that the study is conducted in different countries situated in European Union, investigation on this kind of factors may change the results of study.

Lee et al., 2009 propose a classification of five categories; capability, strategy, technology, market and environment. As illustrated in the figure 2.1, category of capability consists of some firm specific factors; firm resources, firm size ,etc. some of technology related factors such as technology life cycle, development cost of technology, technology relatedness and easiness to imitate are classified in category of technology while others such as "importance of technology" and "acquisition urgency" are classified in Strategy. In category of strategy, factors related to firm's strategy are classified. In category of "market" and "environment" some external factors are classified. In this classification, market and

environment overlap with each other to some extent dynamism and competitive intensity. In addition some factors in category of “strategy” are mostly related to the technology rather to the firm strategy, for example. Relevant to two other factors in strategy category; “fit with business strategy” and “fit with technology strategy”; we suppose that all the technologies which firm intends to acquire are convergent with firm’s strategy and strategically important for the firm<sup>5</sup>. Amongst all of these strategically important technologies, there are technologies which create sustainable competitive advantage and those who are basic for the firm while some of these technologies are not even “core” to the firm.

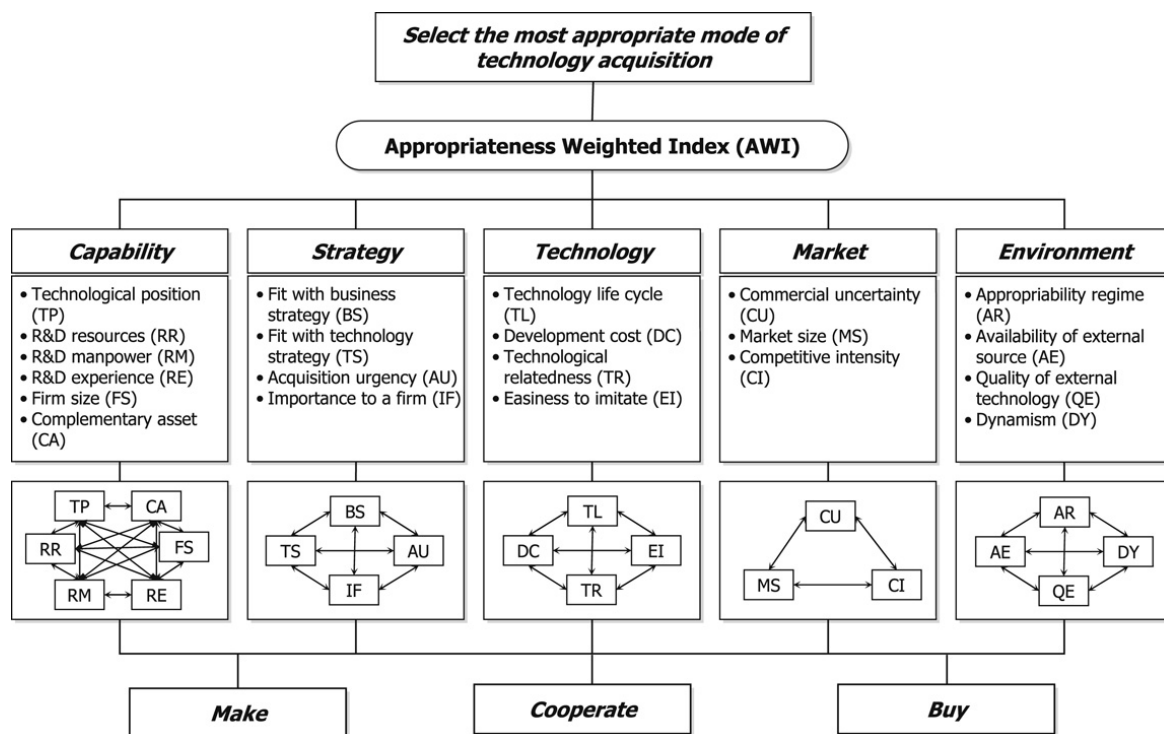


Figure 2.1- ANP model for selection the appropriate mode of technology sourcing (source: Lee et al., 2009)

Another classification is suggested by Yu and Cho (2000) who distinguish three groups of factors including; *technological, internal and external factors*.

Since the later classification contains all determinants without any overlap within the groups; we also propose to distinguish three groups of TSMs determinants including technology-related, firm-specific, external factors.

- **Technology-related factors** are related to the technology which the firm would like to gain access to.

<sup>5</sup> They have already been fitted with firm’s strategy in the “technology selection” phase of technology strategy.



- **Firm-specific factors** determine the firm's characteristics, amongst which some controllable factors changed by long-term decisions are studied.
- **External factors** are those on which the firm (except for some large companies) has no control. These factors are categorized into two subgroups of *Industry-specific* and *Environmental* factors. It is noteworthy that these factors are not independent of each other. In other words, some factors of one group could influence certain factors in the same or other groups. In addition, external factors have a duplicate effect; they not only affect decisions on technology sourcing modes but also they could influence the effect of other groups differently (figure 2.2). This research concentrates on the first two groups of determinants, i.e. technology-related and firm-specific factors.

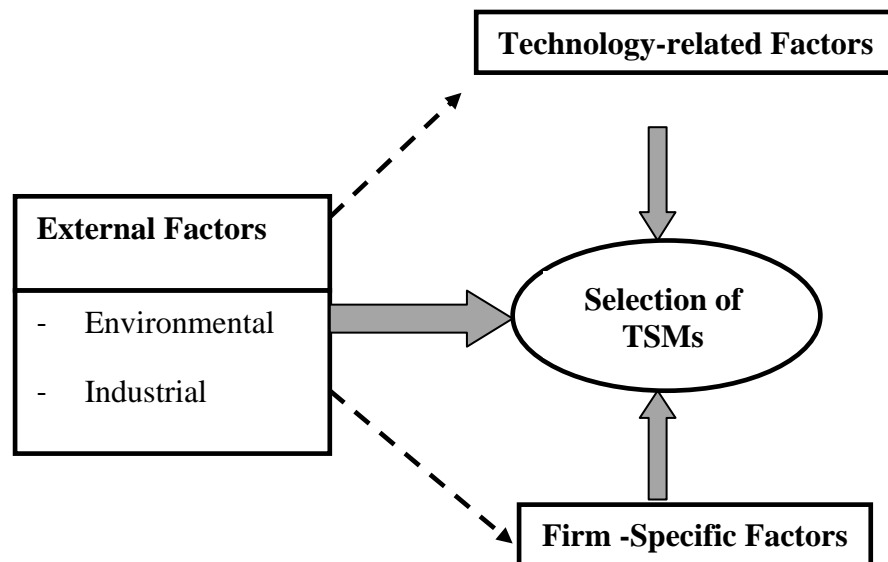


Figure 2.2-Classification of Factors Affecting TSMs

The next section deals with all the previous studies are according to our classification.

## 2.2. Literature Review

The following subsections address, studies about each group of the above-mentioned factors while pointing out concluding the results of our research.

### 2.2.1. Technology-related Factors

Technology life cycle: the stage in which a selected technology is situated may influence the mode used to obtain it. In the literature four stages of life cycle is proposed; birth, growth, maturity and laggard. While some authors; e.g. Khalil, 2000, consider technology life cycle after basic and applied scientific

research<sup>66</sup>, others add these two phase to technology life cycle (Burgelman et al., 2004). As we explain later in chapter 3 (section 3.2.1,) technology life cycle is considered after the phase of scientific research. Different phases of life cycle necessitate relying on different modes of technology sourcing. Davidson and Mcfertidge (1985) propose a direct relationship between propensity to license a technology and its age. Cagliano et al. (2000) propose different kinds of collaboration in different “stages of innovation process”. They distinguish between three phase of innovation, namely; research, development and manufacturing. Moreover, they propose different kinds of collaboration according to the content of collaborations, the motivations, and type of partners involved. Tyler and Steensma, 1995 suggest that the more advanced a technology in its life cycle phase, the less attractive technological collaboration for firms.

*Strategic Importance of the Technology:* (also known as “Growth Potential of technological subfield” Folta (1998)). This factor represents the potential value that a technology could create now or in the future for a firm. It is more desirable for the firm to create or develop its capabilities around the technology. The more valuable the technology is for the firm, the more likely it enters to cooperation rather than acquisition. Robertson and Gatignon (1998) measure the strategic importance of product (technology) by the degree of assets specificity to the product. Based on a transaction view on the firm, they propose a positive relationship between product’s asset specificity and the propensity to internal development. They argue that the risk of opportunistic behavior by the partner favors internal development. Tyler and Steensma, 1995 find an inverted U-shape relation between strategic importance of technology and the propensity to collaborate. They argue that the attractiveness of collaborative efforts to develop technology will increase with the significance of the technology to the firm’s strategy up to a point and then decrease as concerns over proprietary control build, i.e. when the firm's strategy is highly dependent on a given technology, executives may not collaborate for fear of losing control over vital resources (Harrigan, 1986).

*Demand Uncertainty:* Robertson and Gatignon, 1998, based on a transaction view of the firm, point out that the transaction costs to specify, monitor, and enforce a workable contract increases in the conditions of higher level of demand uncertainty. Consequently, as demand uncertainty increases, the efficiency of alliances decreases and internalization becomes the transaction-efficient governance

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<sup>66</sup> “Basic scientific Research refers to activities involved in generating new knowledge. Applied scientific research is geared toward solving particular technical problems” (Burgelman et al., 2004: page 4)

structure. Therefore they propose a positive effect of demand uncertainty on the propensity to internal development.

Technological Uncertainty: as the level of technological uncertainty increases, the propensity of firm to cooperate increases (Robertson and Gatignon, 1998). Tyler and Steensma, 1995 proposed a positive relationship between potential development risk of a technology and propensity to cooperate. White (2000) concluded that low level of technological uncertainty motivates firms to acquire the technology.

Developing Cost of Technology: Cho and Yu (2000) propose this factor as a determinant of TSM. They found out that as the estimation for developing cost of the technology increases, the propensity to internal development decreases while the propensity of technology acquisition increases and according to Tyler and Steensma, 1995 the propensity to cooperate also increases.

Need for establishing a standard based on the technology: Cho and Yu (2000) propose this factor as a determinant of TSM and conclude that as the need for establishing a standard increases the propensity of firm to cooperate increases while the propensity of firm to internal development and acquisition decreases simultaneously.

Technology codification: Huang et al., 2009 propose the more the technology can be codified the easier it is to be contracted out.

### **2.2.2. Firm-specific Factors**

In this group more than 14 determinants are known, while some determinants are close to others conceptually. We propose special terms under which the similar determinants could be defined. These terms consist of experiences, resources, knowledge, culture, dependence, size and strategy.

#### **Experiences:**

Past experience of sourcing firm in the same mode: Propensity of firms to select a mode positively depends on the firm's past experiences in the same mode (Davidson and Mcfertidge 1985, Pisano 1990). Robertson and Gatignon (1998) point out that the firms only tend to duplicate their experience of a successful mode selection in the future. Therefore, successful past experiences, and not just any experience, increase the propensity of the firm to select past modes. This hypothesis is confirmed by the findings of Cho and YU (2000), White (2000), Hernan et al., (2003), Kiyota and Okazaki (2005).

Past experiences of other firms: The more a specific technology is gained by a special mode in other firms; the firm is more likely to acquire the technology with same mode (Davidson and Mcfertidge, 1985).

## **Resources:**

Source firm's R&D intensity: Propensity to license out the technology decreases as R&D intensity of source firm (licensor) increases.

Internal resources: according to Jones et al., (2000) firm's internal resources consist of technical, personnel (Human) and R&D infrastructure. They find that as firms' access to internally technical resources increases; their propensity to source externally declines.

Human resources: Cho and Yu (2000) found a relation between level of human resources in the firm and its propensity to collaboration as well as its propensity to internal development and acquisition. They concluded that firms with a higher level of human resources are more motivated to cooperate and are less inclined to work towards internal development and acquisition. This statement is argued based on transaction cost economics; as strengths in human resources can decrease the transaction costs of cooperation agreements. However, according to Allred and Swan(2004) and with a resource-based view, there is a negative relationship between level of human resources and the propensity to rely on external sources of technology, either cooperation or acquisition.

Technical resources: Cho and Yu (2000) propose that as the level of a firm's technical resources increases, the propensity to internal development and cooperation increases and the propensity to acquire the technology decreases. Named also "R&D resources" by Allred and Swan, 2004, they argue a negative relationship between the degrees of firms' strengths in R&D resources and propensity to source technology externally. Tyler and Steensma, 1995 also suggest that the level of technological skills and capabilities effects firms' propensity to cooperate as well as internal development.

Financial Resources: Allred and Swan (2004) found that "as the level of **financial resources** increases, the reliance on external product technology decreases". Hoffman and Shaper-Rinkel (2001) also found a positive relationship between the level of financial resources and firms' propensity to acquire the technology.

Liquidity constraints: the issue is defined as "cash flow of firms with limited access to main bank loans". It is suggested that as liquidity constraints decrease, the number of licensing agreements increases (Montalvo and Yafeh 1994, Kiyota and Okazaki 2005).

## **Knowledge:**

Absorptive capacity: Tyler and Steensma, 1995 propose a direct effect between firms' learning capacity and propensity to cooperate. They argue that higher level of absorptive capacity help the firms to internalize better tacit knowledge of partners.

Relevant accumulated knowledge: propensity to internal development increases as the prior knowledge relevant to the R&D project increases (Pisano, 1990). Cho and Yu (2000) not only confirm the findings of Pisano (ibid.) but also state that if the prior knowledge is relevant to the new area, the firm's propensity to cooperate and work towards internal development increases. However, White's study (2000) doesn't offer any significant findings to support the same hypothesis.

Technological distance: it occurs when two or more firms suffer from lack of enough diverse knowledge to evaluate the technology base of each other. In other words, different areas of business and lack of diverse knowledge may increase the technological distance between the firms. In this case, Folta (1998) proposes that firms with more technological distance should enter in equity collaboration rather than acquisition.

#### **Culture:**

Cultural symmetry of source and sourcing firms: So far, studies have revealed three aspect of cultural symmetry, namely; distance, language and religion (Davidson and Mcfertidge, 1985, Mayrhofer,2004). Propensity to internal transfer increases as the cultural distance between the transferor and receiving firm decreases.

National origin of firm: Pisano, 1990, in its research shows that this factor influences the choice of internal or external R&D (Pisano, 1990). He points out "A firm's national-geographic origin may influence its R&D boundary choices by affecting its relative costs of undertaking R&D. When, as in the case of biotechnology, there are national-regional differences in technological expertise, firms from one country may find it more costly to pursue R&D themselves than to purchase R&D from firms in another country better endowed with the relevant personnel and scientific expertise" (p: 162).

#### **Dependence:**

Firm's dependence on its relative business: In the case of (corporate) firms with a higher percentage of their businesses in a specific area, the propensity to internal development of related projects increases (Pisano, 1990).

Being Part of a network Group: firms who are belonging to a Keiretsu group (a kind of Japanese network group), purchase more license (Montalvo and Yafeh, 1994).

#### **Size:**

Firm size: Pisano (1990) proposes two converse hypotheses regarding firm size, none of which are supported statistically. He argues that on the one hand when a firm grows; it would have more resources to invest in internal capabilities. Therefore the propensity of internal development increases. On the other hand size can have a negative effect on R&D performance due to the complexity of

administrative processes in larger firms. Robertson and Gatignon (1998) examine size as a control variable which could inhibit the firm's ability to choose between alliances and internal development. The results don't show any relationship between size and propensity to cooperate or internal development. Montalvo and Yafeh (1994) show that as firms grow, the number of licensing agreements increases. Hernan et al. (2003) found that firms with size symmetry are more likely to enter in RJVs with each other. Kiyota and Okazaki (2005) have also concluded that larger firms are more likely to acquire the technology.

### **Strategy:**

Strategic objectives of firm: Allred and Swan (2004) believe that this factor influences selection of technology sourcing mode. They classify these objectives into two categories (developed by Michael Porter); differentiation and low-cost. They show a negative relationship between the importance of these two objectives and firms' propensity to rely on external sources of technology.

### **2.2.3. External Factors**

Number of R&D suppliers: Pisano 1990 proposes that as propensity to internal development increases as the number of firms working on the related R&D project decreases. This proposition is argued based on small-numbers-bargaining hazards. In markets where R&D capabilities are specialized to a few suppliers, partner switching is difficult and a cost-consuming action; thus firms are more motivated to internalize R&D projects. White, 2000 argues that in the areas in which there are a large number of potential suppliers of research, the possibility of opportunism behaviors decreases, thus he suggest that "as the "number of potential suppliers" increases likelihood to joint development decreases.

Extent of competition: the propensity to internal development increases when the firm faces greater competition in the market (Pisano 1990). Folta (1998) calls this factor as "risk of preemption" and estimates it according to the number of rivals in the technology. He suggests that "fewer rivals in a technological domain lead firms to cooperate rather acquisition". Cho and Yu (2000) propose that more intense competition leads firms to internal development rather than cooperation. White (2000) has also found a positive relationship between "number of rivals" and firm's "propensity to ally or internal development".

Intellectual property rights: the factor refers to the degree to which intellectual properties are protected by legislations; i.e. the effectiveness of rules which facilitate for firms Legal protections of their intellectual properties (Williamson, 1991, Cohen & Levinthal, 1990). These rules and legislations are different amongst countries and affect decision on TSMs. Jones et al. (2000) found a relation between

this factor and propensity to internal development. They propose that “as subsidiaries’ perceive the level of intellectual property protection increases, their propensity to look outside the firm for (product) technology diminishes. Hernan et al. (2003) find a negative relationship between the degree of intellectual property protection and firms’ propensity to enter in a research JV.

Hoffman and Shaper-Rinkel (2001), also propose a relationship between level of intellectual property rights protection and the propensity to ally or acquire. They found out that as appropriability regime weakens, the propensity to acquire increases while the propensity to ally decreases, while Cassiman and Veugelers (1998) propose a positive relationship between strong legal protection and propensity to cooperate.

Technological innovation rate: this factor is measured according to the number of licensing agreements which close competitors have applied. If the rate of technological innovation increases, the number of licensing will increase (Montalvo and Yafeh, 1994). Allred and Swan (2004) call this factor as “product dynamism” while concluding that, within the industries with a high rate of product dynamism or technological innovation, firms are more likely to rely on external sources of technology. Hoffman and Shaper-Rinkel (2001) refer to a factor called “Dispersion of knowledge” which denotes a closer meaning to the concept of technological innovation. “Dispersion of knowledge” is defined as the industry with increasing knowledge creation rate that generate the conditions in which one firm is not able to assimilate and apply all aspects of knowledge and technology. In such circumstances, knowledge is dispersed in many firms and in order to gain access to a related technology firm have to cooperate with all of them. They (ibid.) conclude that there is a positive relationship between this factor and firms’ propensity to ally.

Technological spillover: defined as “the absorption of knowledge by competitors other than the originators” (Baskerville & Dulipovici, 2006), it occurs because knowledge is an inexhaustible, cumulative good that is difficult to control. According to Cohen & Levinthal, 1990 not all knowledge which spills out of the firm is important, only the “valuable knowledge” should be protected from dispersion. It is also part of factors affecting TSMs selection. Hernan et al., (2003) have found a positive relationship between the rate of technological spillover and firms’ propensity to enter in research JV agreements.

Industry R&D intensity: calculated as total R&D expenditures over total sales in each industry, Hernan et al. (2003) in their empirical research find a positive relationship between the rate of industrial R&D intensity and firms’ propensity to enter in research JV agreements.

Exogenous uncertainty: Folta (1998) defines this factor as a kind of uncertainty that is largely unaffected by firm actions as it depends mostly on the industry characteristics. It increases when the technological trajectory is not established, or the commercialization potential in the industry is unknown due to the newness of the industry, a lack of industry infrastructure, or when important legislation is pending. Conversely of two other uncertainties; technological and demand which relates to the technology itself, this kind of uncertainty depends on the industry and legislations. Folta (ibid.) proposes “the more the level of exogenous uncertainty, the firms are more likely to cooperate rather than acquisition” (S). Hoffman and Shaper-Rinkel (2001) point out another kind of environmental uncertainty called “strategic uncertainty” and define it as “fundamental environmental uncertainty, i.e. uncertainty about future attractiveness (lack of knowledge about further legal and technical constraints) and further development (constraints in the market and competition)”. Accordingly, they conclude a positive relationship between strategic uncertainty and firms’ propensity to ally.

Market growth: firms in high growth market are more likely to develop technology internally (Robertson and Gatignon, 1998).

Selection of the most appropriate mode of technology sourcing is a multi-criteria, complex and context - dependent decision. It is multi- criteria because in such a decision, managers deal with a list of diversified determinants which influence the decision. It is complex as managers have no control on certain environmental determinants; specially those who depends on governmental policies and legislations. It is context-dependent since the effect of determinants may change from one industry and/ or country to another one.

Additionally to above factors there are some factors which have been rarely pointed out in the previous studies and we have not addressed them in this study either. Some factors are related to partners’ behavior which is supposed to influence the choice of TSMs. For example, Hoffman and Shaper-Rinkel (2001) have found a relationship between a partner’s Behavioral uncertainty and the propensity of sourcing firms to ally. In this research, we don’t deal with the partner’s characteristics in the stage of selecting an appropriate mode. We propose to study the effect of these factors after choosing a mode or a group of modes in the stage of selecting partners. Moreover, we do not address the preference of the top managers for a specific mode.



## 2.3. Scope of Research

Considering the numerous factors affecting the choice of TSM, two following questions are posed “which factors are more appropriate amongst others in a particular group?” and “are there any priorities amongst three group of determinates?” We confirm that “the aim of present research is not the elaboration of a multi-criteria decision model, but our goal is a better understanding about TSMs decision and its determinants. We try to extract main determinants of TSMs and study their effect in Iranian context; meanwhile we introduce the study of Lee et al. (2009) who have found the response for two mentioned questions.

Based on an ANP (analytical network process), Lee et al.(2009) propose a list of 21 factors classified in five categories while attempting to select the appropriate mode of technology sourcing; make, Buy or cooperate (figure 2.3). Table 2.2 represents the relative importance of each category.

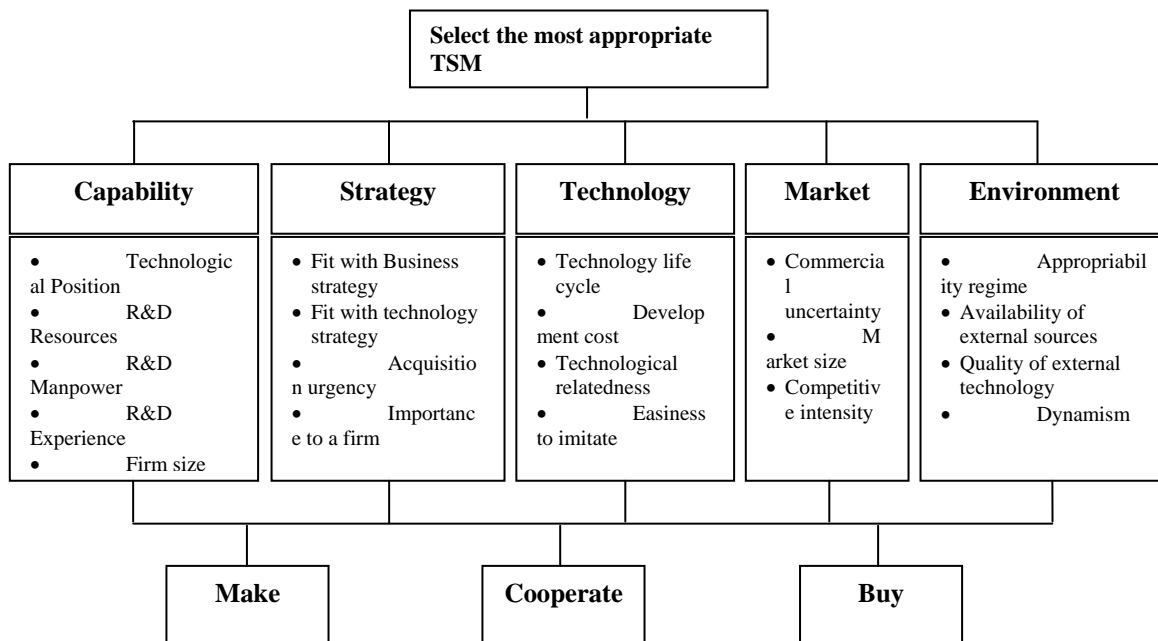


Figure2.3- Determinants of TS modes according to ANP Model (source: Lee et al., 2009)

Table 2.2-Relative importance of categories with respect to select the most appropriate TSMs (source: Lee et al., 2009)

Category	Capability	Technology	Environment	Market	Strategy
Relative Importance	0.445	0.237	0.165	0.082	0.071

In the above table, two categories capability and technology related factors are the most important factors while environmental factors (environment and market) are positioned later.

This model is context- based, i.e. although the model could be practiced in Korea or some other countries with similar conditions, it requires some changes depending on the country where it is practiced.

In present research, we concentrate on two groups of factors; technology-related and firm-specific factors, for two following reasons:

- Our sample is selected amongst Iranian firms, thus external factors is mostly similar for them.
- According to Lee et al., 2009 these two group of factors are more important.

In each group, we have selected the factors which have been mentioned in the literature by most studies in order to verify their effect on TSMs.

Tables 2.3 and 2.4 demonstrate all Determinants which have been considered influential in the first two groups and their bibliographical references as well as the results of researches.

Table 2.3.Technology -related Determinants

Determinants	References	Which mode is affected by the determinant and How?
<b>Technology life cycle</b> (Phase of innovation process)	Davidson and Mcfetrige,1985 Lambe and Spekman, 1997 Cho and Yu,2000 Roberts and Liu, 2001 Cagliano et al., 2000	For Multinational firms, Propensity to license increases as the age of technology increases.
<b>Importance of technology</b>	Narula,2001, Ford,1988 Robertson & Gatignon, 1998 Folta, 1998	As the importance of technology increases the propensity to internal development increases. Folta, 1998 evaluates this factor with the potential value that the technology could create for firm. As the importance of technology increases the propensity to cooperation versus acquisition increases.
<b>Market uncertainty</b>	Robertson & Gatignon, 1998 (NS)	As the level of demand uncertainty increases, the propensity to internal development increases.
<b>Technological uncertainty</b>	Robertson & Gatignon, 1998 White, 2000	As the level of technological uncertainty increase the propensity of firm to cooperate increases.
<b>Developing cost of technology</b>	Cho and Yu,2000	As developing cost of technology increases the propensity to acquire the technology increases and reversely the propensity to internal development decreases.
<b>Need for establishing a standard</b>	Cho and Yu,2000	As need for establishing a standard become more importance the propensity to collaborate versus internal development and acquiring increases.
<b>Past experience of other firms in gaining access to the technology</b>	Davidson and Mcfetrige,1985	Propensity to select a mode to gaining access to a technology increases as Other firms' past experiences in selecting this mode for same technology.

Amongst determinants of TSMs, we have selected those which are:

- a) The more referenced in the literature. Since determinants in tables 2.3 and 2.4 are listed from the more referenced to the less, the first determinants are considered.
- b) More general amongst others; i.e. those which affect at least two different modes. A determinant such as “liquidity constraints” that affect only one specific mode; licensing, is not considered in our study.
- c) More important according to CEO’s view. The factors which were mentioned important by managers in our pilot study.

Accordingly four determinants are selected from the list of technology related factors; technology life cycle, degree of uncertainty, strategic importance of technology.

Table2. 4. Firm- Specific Determinants

Determinant	References	Which mode is affected by the determinant and How?
Successful Past experience	Davidson and Mcfetridge,1985 Robertson and Gatignon, 1998(NS) pisano, 1990 (NS) White,2000 Cho and Yu,2000 Hernan et al., 2003 Kiyota and Okazaki,2005	Propensity of firms to select a mode positively depends on firms past experiences in the mode. Pisano, 1990 could not find significant support for this hypothesis. The propensity of firm to cooperate increases as the number of successful past experiences of firm in alliances increases.
Human resources (Research manpower)	Cho and Yu,2000 Jones et al., 2001 Allred and Swan, 2004	As the level of human resources increases the propensity to collaborate versus internal development and acquiring increases.
Technical resources	Cho and Yu,2000 Jones et al., 2001 Allred and Swan, 2004(NS)	As the level technical resources increases the propensity to collaborate and internal development versus acquiring increases. As firms' access to internally technical resources increases; their propensity to source externally declines.
Financial ressources	Hoffman and Shaper Rinkel, 2001 Jones et al., 2001 Allred and Swan, 2004	As the level of financial resources increases the firms' propensity to acquire increases. As the level of financial resources increases, the reliance on external product technology decreases.
Past knowledge in related area	Cho and Yu,2000 Pisano, 1990 White, 2000(NS)	Propensity to internal development increases as the prior knowledge relevant to the R&D project increases.
Firm size	Montalvo and Yafeh,1994 Hernan et al., 2003 Kiyota and Okazaki,2005 Pisano, 1990 (NS) Robertson & Gatignon, 1998 (NS)	Number of licensing in agreements of a firm signed is positively related on its size. (Robertson & Gatignon, 1998) consider the size as a control variable.
Absorptive Capacity	Kiyota and Okazaki,2005 Hoffman and Shaper-Rinkel, 2001	
Strategic objectives (Low-cost versus differentiation)	Allred and Swan, 2004	As the importance of these two objectives increases firms' propensity to rely on external sources of technology decreases.
Past experiences of other firms	Davidson and Mcfetridge, 1985	the more a specific technology is gained by a special mode in other firms, the more the firm has propensity to gain access to the technology with same mode.
Liquidity constraints	Montalvo and Yafeh,1994 Kiyota and Okazaki,2005	as liquidity constraints decrease number of licensing agreements increases.
Belonging to a corporate business	Montalvo and Yafeh,1994	Belonging to a Kieretsu group increases the number of licensing purchase.
National Origin	Pisano, 1990	The factor influence the choice of internal versus external R&D.
Technological distance	Folta, 1998	Firms with more technological distance enter to equity collaboration rather than acquisition.
R&D Intensity	Davidson and Mcfetridge,1985	Propensity to license out the technology decreases as R&D intensity of Licensor increases.

We also added to other determinants to the list; degree of urgency of gaining access to technology, it refers to the degree that a firm is under time pressure to gain access to a technology. Amongst Firm-specific determinants a list of five are considered. They include successful past experiences in TSMs, strengths on internal resources, level of absorptive capacity, strategic objectives and size. In chapter 3, hypothesis regarding the effect of each determinants are argued.

## 2.4. Conclusion

This chapter was devoted to introduce determinants of TSMs. We began with proposing a classification of numerous factors affecting TSMs. We propose a classification of three categories; technology-related, firm-specific and external factors. Then browsing the literature we introduced determinants of TSMs in each category. Finally a list of technology related and firm specific determinates is proposed to study their effect on TSMs. Due to frequency of determinants in the literature and their generality, eleven determinants are proposed to investigate, amongst which six are technology related and five are firm specific. Technology related determinants consist of *technology life cycle*, *degree of commercial and technical uncertainty*, *strategic importance of technology*, and *technology urgency*. Firm-specific determinants include *strengths on internal resources*, *level of absorptive capacity*, *successful past experiences*, *strategic objective* and *firm size*. This classification is important because it constitutes the base of our research and personal contribution. This list of variables will be used to make our hypothesis of research, when we describe how they affect different technology sourcing modes in chapter3. Next chapter is devoted to define mentioned determinants and argue the hypotheses describing how these determinants affect three mode of technology sourcing; internal development, cooperation and acquisition.

## **Chapter3**

### **Hypothesis**

*This chapter is devoted to argue the hypothesis relying on determinants and their effects on three categories of technology sourcing modes (TSMs). Thirty one hypotheses are proposed which sixteen of them describe the relation between technology-related determinants and three categories of TSMs. The fifteen remaining hypothesis investigate on firm specific determinants.*

### 3.1. An Introduction to Propensity to internal development, ally, and acquire

We aim to investigate how these determinants affect a firm's propensity to internal development, ally and acquire. Accordingly, we suggest following definitions for three dependent variables.

*"Propensity to internal development"* is defined as the likelihood that a company invests in internal development of a technology.

*"Propensity to ally"* is defined as the likelihood that a company participates in joint ventures and alliances.

*"Propensity to acquire"* is defined as the likelihood that a company makes an acquisition, such as license purchase, R&D outsourcing, firm take over, etc.

In our definition, *Propensity is a general willingness or the "tendency" to internal development, ally or acquire.*

### 3.2. Technology –Related Determinants

In this section technology- related determinants of TSMs are defined and the hypotheses regarding each determinant are argued.

#### 3.2.1. Technology Life Cycle

Technology life cycle consists of four stages; embryonic or birth, growth, maturity and laggard (Utterback, 1994) (Figure 3.1). The question is "does technology life cycle affect mode of technology sourcing?" In other words, "does each stage of technology life cycle necessitate a certain mode of technology sourcing amongst internal development, cooperation or acquisition?" In order to answer this question, first we describe the characteristics of each stage of life cycle, also describe how each stage can influence the sourcing decision, and then based on these appearances address our propositions.

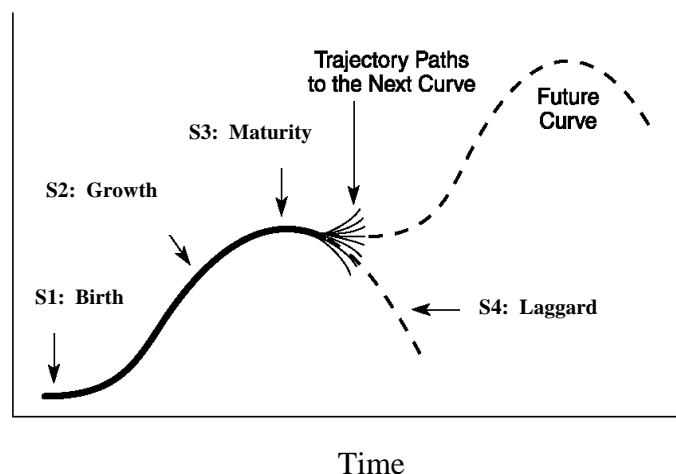


Figure 3.1- Four Stages of Technology Life Cycle

In the first stage, called **embryonic or birth**, most companies having invested in R&D programs, try to benefit from a quick return on investment. Consequently, becoming a leader or having a monopolistic temporary position may be an asset. So many companies hesitate to ally at this stage. But, the urgency of development of new technology is not definite for the firm and there is a high degree of uncertainty in technical terms and market demand. Even for a new technology that represents a high rate of demand, some firms hesitate to place all R&D bets on only one technology. For example, during the first stages of emergence of CDs technology Exxon Enterprises found eight other alternative technologies to increase data-storage capacity (Robert s and Liu, 2001). Although sharing risks and investment costs of developing new technology are the reasons which motivate innovating firms to seek cooperation with their rivals (Lambe & Spekman, 1997; Utterback 1994), external sourcing is less likely to occur at this stage of technology development (Abernatty and Utterback, 1975). On the other hand, high degree of uncertainty prevents many rivals entering such relationships. For example, PSA refused Renault's proposition on collaboration in Multi-Purpose Vehicles design and production at some point in its emerging stage due to market uncertainty. However, PSA decided to cooperate in MPV production with Fiat five years later when MPV market was successfully developed (Jolly, 1997).

Moreover, establishing alliances at this stage follows two other strategies; first in order to introduce the new product faster to the market and second to establish a standard. In the first case, alliance is established with key players in the supply chain while major competitors are involved in the second strategy.

In this stage, i.e. before the emergence of a dominant design, quick acceptance of technology helps the pioneers to introduce their product as a possible dominant design. Therefore, it may be in the best interest of the source firm to license its technology to as many firms as possible to ensure that the technology becomes the dominant design (according to Hill, 1999, Roberts & Liu, 2001). In this stage, managers pursue aggressive outward -licensing strategies to promote their technology, despite the low price of licensing compared with the price when dominant design emerges.

During this stage, well-established firms also acquire start-up companies which have the new technology under development or have just finished the development. In this stage, there are not many barriers to entry and brand loyalty is not important, the functionality and quality are more essential instead.

**In second stage**, basic designs, the concrete models for further development (Nelson & Winter, 1977); are appeared. In the early days of technology life cycle, it can be expected to find several versions of basic designs amongst which one or small numbers will survive (Anderson & Tushman, 1990). The basic design crowding out others is called dominant design that serves as a guidepost for further development



(Hagedoorn et al., 2001). Despite troubles which collaboration may create for partners in this stage (especially before presence of dominate design), firms are more likely to cooperate with their competitors because of advantages that could be produced along the cooperation. These advantages are as follows:

- Partners can pool incremental innovations of basic designs to increase the overall improvement in key attribute of the integrated design;
- Cooperation enables the partners supporting different basic designs to combine their customer bases;
- Partners can pool new technologies which individually extend existing designs, but in combination can constitute a new design.

Accordingly, with the emergence of dominant design in this phase the propensity to collaborate for innovating firms augments during this stage. Customers require quality products and timely delivery and thus companies must realign themselves with the new standards and pursue an aggressive growth strategy.

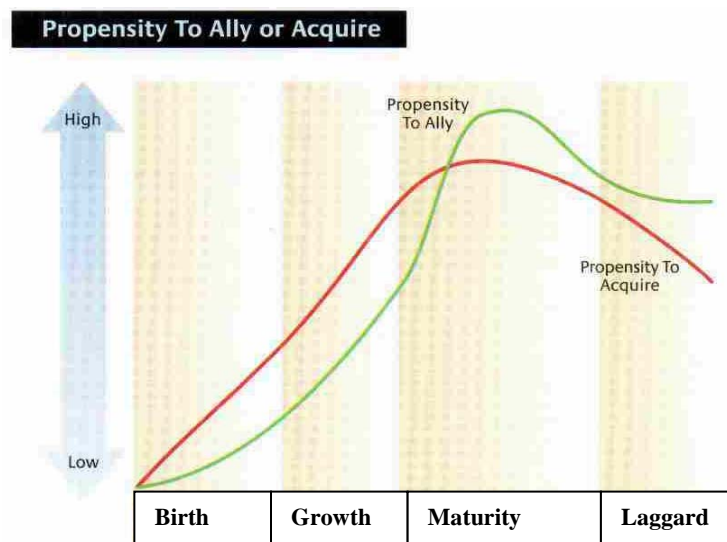


Figure 3.2- Firm's propensity to ally and acquire the technology (source: Roberts and Liu, 2001)

As shown in figure 3.2, propensity to ally reaches its peak in third phase of technology life cycle. During **maturity stage of life cycle**, companies often collaborate to improve the dominant design, to benefit from economical scale effects and develop new technological extensions features and

applications through joint R&D. Typically once they possess sufficient technological capabilities, companies of similar size join forces.

R&D efforts shift from product innovation to process innovation. Noting that process innovations are more time consuming and expensive, both alliances and acquisitions become more attractive. At this stage, firms are more likely to acquire the innovating firms which have access to new technology or licensing in the technologies (Lambe and Spekman, 1997).

In the last stage of technology life cycle; **laggard**, Reduction of the drives to ally in this stage leads firm to focus on internal technology development particularly process improvements to reduce product costs (Jones et al., 2000 and Lambe and Spekman, 1997). Wilson, 1997 points out that in a technology breakthrough; when a radical innovation is introduced to market; firms which are mostly followers are more likely to acquire the technology , mostly by licensing because they could save the cost of imitation. Figure 3.2 represents how firms' propensity to ally and acquire change during the four stage of technology life cycle.

Relying on above arguments, we propose the following hypotheses:

***Hypothesis 1a:*** *The propensity of a firm to acquire technology increases from technology birth to technology Growth.*

***Hypothesis 1b:*** *The propensity of a firm to acquire technology increases from technology birth to technology Maturity.*

***Hypothesis 1c:*** *The propensity of a firm to acquire technology decreases from technology maturity to technology laggard.*

***Hypothesis 2a:*** *The propensity of a firm to cooperate increases from technology birth to technology maturity.*

***Hypothesis 2b:*** *The propensity of a firm to cooperate decreases from technology maturity to technology laggard.*

***Hypothesis 3a:*** *The propensity of a firm to internal development decreases from technology growth to technology maturity.*

***Hypothesis 3b:*** *The propensity of a firm to internal development decreases from technology growth to technology laggard.*

### **3.2.2. Uncertainty**

Although some kind of uncertainty is determined in different stages of technology life cycle, degree of uncertainty may independently influence the decision of choosing the mode of gaining

access to a technology (Amesse and Cohendet, 2001). In order to study the effect of uncertainty on the different modes, we need to define uncertainty and its difference with risk. While in many researches, the two words “risk” and uncertainty” are applied interchangeably (Bayona et al., 2001), in this research we use the words differently. According to Dyer et al., 2004, “Risk exists when companies can assess the probability distribution of future payoffs; the wider the distribution, the higher the risk. Uncertainty exists when it isn't possible to assess probability distribution and future payoffs. Therefore uncertainty could be neither estimated nor predicted while risk could be. For example, in the electronic industry the risk of failure of research projects has been estimated around 1 to 10- i.e., only 1 out of 10 research projects is expected to be successful (Kodama, 1992) , while the degree of uncertainty in the same industry is not predictable. This research addresses uncertainty related to a technology. Accordingly, two kinds of uncertainty are defined including *commercial and technical*. Commercial uncertainty- or as Robertson and Gatignon, 1998 point out- demand uncertainty refers to the uncertainty associated with the commercial success of a technology in the market (Chakravarthy, 1985, Cagliano et al, 2000). This uncertainty arises from the ambiguity as to whether the marketplace will favor associated products and processes, or in other words if the technology satisfies customer needs and requirements. Even when the products from a given technology perform as designed, superior technological knowhow does not always translate into market success (McGrath et al., 1992). Consider, for instance, the competition between Intel's complex instruction set computing (CISC) chip and the alternative reduced instruction set computing (RISC) chip. Despite the RISC chip's twofold increase in computing speed compared with CISC chip, it has only attracted a small market. Because of the incompatibility of CISC-designated software with RISC chip technology, few computer buyers have been willing to forego their software investments to adopt the new technology (Steensma and Corley, 2000). In order to estimate such uncertainty, the company should assess if consumers will use the technology, product, or service and how much time it will take to gain widespread acceptance (Dyer et al., 2004).

Another kind of uncertainty is technical. Technical uncertainty deals with technical success of a technology, whether the technology will work as it is designed to work. In order to estimate this kind of uncertainty, managers must evaluate the uncertainty associated with the technology or product when having discussions with the potential partner. They should ask questions such as ‘can we develop the technology technically as it is designed? Can we tell if the widget will work?’

Technology intensive industries are characterized by high rate of technological change and as a consequence high changes in customer demand, so firms are confronted with more uncertain technologies (technically as well as commercially). Entering in collaboration agreements helps firms to share the uncertainties and introduce the product more rapidly to market. Harrigan, 1988, counts commercial uncertainty as one of key factors which encourage firms to enter in a joint venture agreements. At the same time, in a highly or moderately uncertain situation, cooperation is preferable

to acquisition (Dyer et al., 2004). Considering this fact that alliances are less cost and time consuming than acquisition, Folta, 1994 proposes equity collaboration as an “option to defer” internal development or acquisition for high level of technical uncertainty. By deferring internal development, the firm will have adequate time to estimate the real value of the technology and at the same time evaluates the opportunistic partner and those who represents real self-value. In such a case, when the project of gaining access to the technology progresses and the level of uncertainty decreases, the firm may switch on internal development or acquisition of a firm with valuable assets. Hamel et al. (1989) and Dodgson (1992) argue that under the conditions of substantial uncertainty, R&D cooperation is the preferred mode while In-house R&D and Technology purchasing are suitable modes in the medium case and the low case respectively. Therefore:

***Hypothesis 4a: the propensity of firm to cooperate increases as the level of commercial uncertainty increases.***

***Hypothesis 4b: the propensity of firm to cooperate increases as the level of technical uncertainty increases.***

Conversely of above arguments, while the uncertainties of R&D in general can only be resolved sequentially as the project progresses (Nelson and Winter, 1977), in progressive stages the firms who enter in collaboration should renegotiate and rearrange another contract. Transaction cost of the contract and risk of opportunistic behavior (Williamson, 1975, 1986) may encourage firms to internal development rather than cooperation. This fact is supported by the studies of Walker and Weber, 1987. Accordingly, we propose following propositions:

***Hypothesis 5a: the propensity of firm to internal development increases as the level of commercial uncertainty increases.***

***Hypothesis 5b: the propensity of firm to internal development increases as the level of technical uncertainty increases.***

### **3.2.3. Strategic Importance of Technology**

Decisions about ‘which new technologies to develop internally’ and ‘which ones to access through collaborative and contractual links with external sources’ may affect the firm's long term viability in the new technological environment. For example, according to Malerba, 1985, electronics firms that decided in the early 1960s to license-in the new integrated circuit technologies rather than to develop the requisite R&D capabilities in-house had difficulty competing for many years afterward. In this regard, the relation between strategic importance of technology and its effect on the choice of technology

sourcing modes is recognized by a number of authors (Khalil, 2000; Ford, 1988; Narula, 2001). *“The decision to outsource must be based on how critical the technology is to the company. If it is within the company’s portfolio of core competencies, either ownership or stronger control over the supplier is warranted”* (Khalil, 2000). However, the strategic importance of these technologies determines to what extent their development can be externalized.

In order to evaluate how strategic a technology is for a firm, two classifications exist in the literature; the first of which was proposed by Ford, 1988 and the other one was suggested by Patel & Pavit (1997). In the present section, we describe these two classifications and then explain why the second classification is selected in this research.

Ford (1988), in his model, introduces *type of technology*, which itself falls into three categories: Distinctive, Basic and External. Distinctive technologies are those technologies which give a firm its unique competitive advantage in the market place. Firms must protect these technologies and nourish them. Basic technologies are those survival technologies on which the company’s operations depend and without which it would be excluded from its market, but do not give the company a distinctive advantage. External technologies are those technologies which are not crucial to the company’s survival and they are usually more supplied by an outside vendor.

Patel & Pavit (1997) classify four types of technology corresponding to the distribution of competence in a firm (figure 3.3) based on the works of Granstrand et al. (1997). These types of technology include:

- **Distinctive competence**, which commands a high share of technical resources of a company. These form the ‘core’ of the firm, which defines the technological profile of the firm and its competitiveness. Most firms’ resources should be concentrated in distinctive technologies. For a company which produces special drugs with a well-known brand, production of drugs are part of its distinctive competences. A firm who manufactures automobiles the know-how of vehicle designing or engines is distinctive competences.
- **Niche competence**, which are technologies for which the firm possesses some level of expertise, but these areas are intrinsically small in terms of their profile and in terms of the resources they command. These technological fields are generally complementary to their distinctive competencies. As an example the automobile manufacturer may design engines of aircraft or the pharmaceutical firm may produces bleaching and dyeing productions; theses competences are mostly known as niche competence.

➤ **Marginal/peripheral competence**, are sectors that were important to the firm in the past, or are expected to become important in the future (e.g. computing in Ericsson in the 1960s), in which limited resources are invested, and where the firm has no distinct technological advantages. For both automobile manufacturer and pharmaceutical firm, their technological know-how in inorganic chemistry or materials science is examples of marginal competences.

➤ **Background competences**, which enable firms to co-ordinate and benefit from technical change in the supply chain, are essential to the competitiveness of the firm and its ability to efficiently utilize its other, more 'crucial' competences. Although, these are equally crucial and significantly determine the competitiveness of a firm, they only utilize a small percentage of the firm's technology resources. They are, however, an important part of the firm's technological assets. Production technologies and chemical processes in automobile manufacturing firm, chemical processes in a pharmaceutical company are the examples of background technologies.

This classification determines two criteria in order to classify a technology. The first criterion is the relative importance of technology for the firm. The second criterion is relative importance of the firm in the field of technology, i.e. degree of competitiveness that the technology creates for the firm. Patel and Pavitt's classification prepares two dimensions in order to determine strategic importance of a technology while Ford's classification does not suggest any dimension for classification.

Ford suggests that firms rely on their own resources and use internal R&D to gain access to the most distinctive or critical technologies. The less competitive advantage the technology could create for the firm, the more it may rely on external development (Ford, 1988).

Davidson & McFetridge, 1985 use the term "peripheral technologies" against "mainstream technologies" and propose that peripheral technologies are more likely to be licensing.

Narula, 2001, suggests selection of the appropriate TSMs for firms according to the above classification.

For distinctive competences, the firm should solely rely on its internal R&D, whereas for niche competences a firm could select between internal R&D and alliances, while internal R&D is still preferred. The firm could either choose to make or buy the technology when dealing with marginal competences. Finally, for background competences, any kind of outsourcing (acquiring) may well be considered.

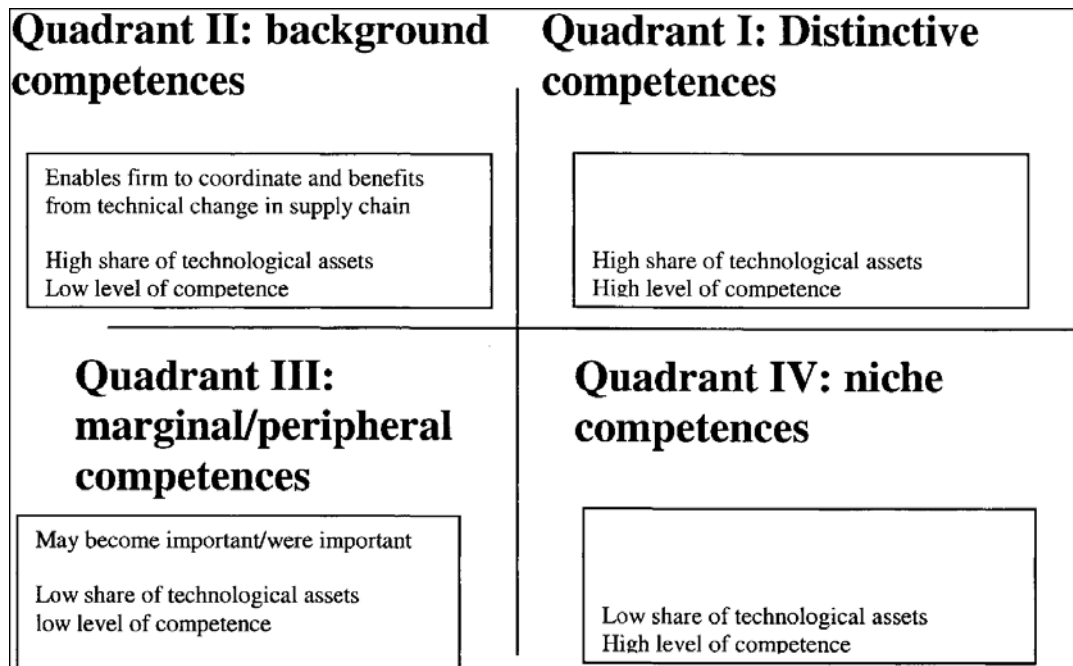


Figure3.3- classification of technological competence in a firm (source: Patel and Pavit, 1997)

Modes of technology sourcing which may be used for each category are proposed by Narula, 2001 in a static view (figure 3.4).

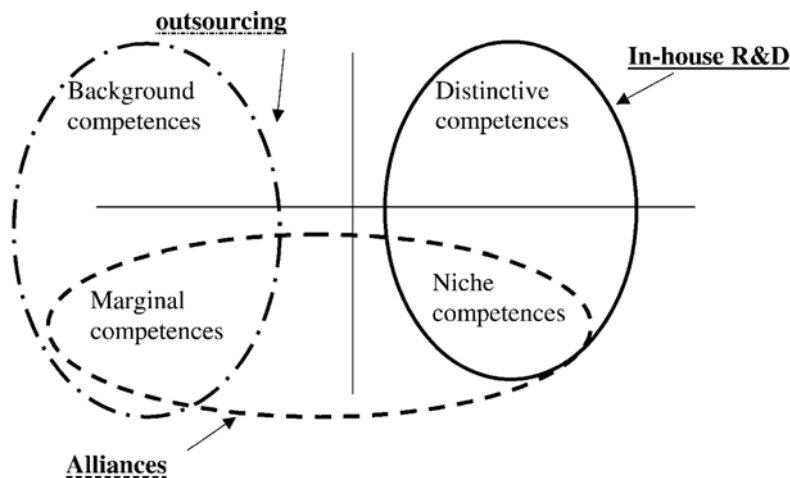


Figure 3.4-relationship between technology categories and modes of technology sourcing (Narula,2001)

Moenaert *et al.* (1990) have proposed that relevant technologies are more likely to be internalized. This is because when the knowledge generated by an R&D project is of strategic importance to the firm, the difficulties with regulating the transaction with incomplete contracts and the costs of protecting against opportunistic behavior favor internal modes of technology development (Robertson& Gatignon, 1998). Considering these arguments as well as works of Narula (2001), we make the following propositions:

**Hypothesis 6:** the propensity of firm to internal development increases when strategic importance of technology moves from niche to distinctive.

**Hypothesis 7a:** the propensity of firm to cooperate increases when strategic importance of technology moves from distinctive to niche.

**Hypothesis 7b:** the propensity of firm to cooperate increases, when strategic importance of technology moves from background to marginal.

**Hypothesis 8:** the propensity of firm to acquire increases, when strategic importance of technology moves from marginal to background.

It is important to note that the concept of strategic importance of a technology is mostly dynamic; i.e. it is changed for a firm during the periods of time. This temporal dimension is not taken into account in present research, because we investigate on the strategic importance of the technology only when the firm decides to obtain it.

#### 3.2.4. Urgency

Lambe and Spekman, 1997, argue that, to some extent, two specifications of different stages including urgency of gaining access to technology and uncertainty in the industry motivate the firms to enter in an alliance. As it is presented in figure 3.5, each stage is characterized by high and low level of these two factors. A firm's alliance motivation is a sagittal curve.

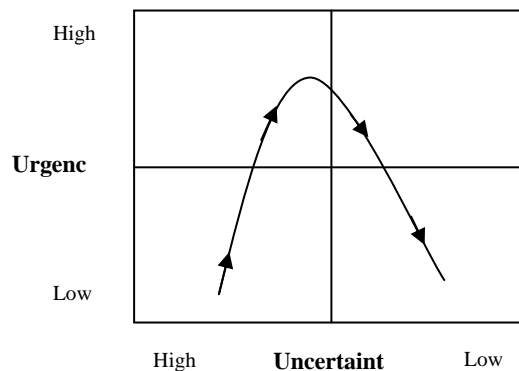


Figure 3.5- Technology alliance motivation curve (Lambe & Spekman, 1997)

Although different stages of technology life cycle may be characterized by urgency, in some cases it could be independent from the stage of technology life cycle. In other saying, it is not only the technologies that is situated in a specific stage of life cycle; i.e. growth stage which are supposed urgency to obtain. Sometimes gaining access to a technology in its maturity stage may be considered urgent. This case is true for some basic technologies in Nano fields. Noting that the speed of gaining



access to a technology is at its lowest degree in internal R&D and in cooperating is less than in acquiring technology, therefore:

***Hypothesis 9: The more gaining access to a technology is urgent, the propensity to internal development decreases.***

### **3.3. Firm-Specific Determinants**

In this section technology- related determinants of TSMs are defined and the hypotheses regarding each determinant are argued.

#### **3.3.1. Resources Endowments**

Two groups of definition are proposed to clarify what we mean by addressing 'resources of a firm'.

Although these two groups of definition are not very different in this section we explain the similarities and differences of these two groups while addressing the definition we adopt in this research.

The first definition is mainly proposed by Penrose, 1959 and Grants, 1991. Grants define resources as "some part of organization assets that are inputs into the production process". In his point of view, an activity requires the cooperation and coordination of sets of resources of resources. He distinguishes between resources and capabilities. A capability is "the capacity for a set of resources to perform some task or activity". While resources are the source of a firm's capabilities, capabilities are the main source of its competitive advantage. Penrose (1959) argues that, strictly speaking, it is never *resources* themselves that are the "inputs" in the production process, but only the *services* that the resource can render. Resources consist of a bundle of potential services and can, for the most part, be defined independently of their use, while services cannot be as defined as the very word "service" implies a function, an activity.

Definition of the second group is based on Barney's definition in 1991. Barney (1991: 101) defines firm resources as "all assets, capabilities, organizational processes, firm attributes, information, knowledge, etc. controlled by a firm that enable the firm to conceive and implement strategies that improve its efficiency and effectiveness". In other words, resources are valuable for firms because they are sources of wealth creation and detriment prevention (Miller & Shamsie, 1996). This Definition is closer to that of Dierickx and Cool, 1989. They categorize all firm assets into two groups including; asset flow and asset stock. An asset flow is a firm resource that can be obtained or adjusted immediately while an asset stock is a firm resource which cannot be adjusted immediately and is built up over time from asset flows. In this regards that is asset stock – or with Barney's definition firm resources- which create a competitive advantage.

In such definition “resources” and “capabilities” are used interchangeably, i.e. R&D resources and R&D capabilities are the same. Figures 3.6 a, b, c show the differences between these three definitions, Grant, 1991, Barney, 1991 and Amit & Shoemaker, 1993.

As it is shown in figure 3.6, resources and capabilities are the main sources that directly or indirectly create a sustainable competitive advantage for a firm. However, only some of the firm resources lead to its competitive advantage.

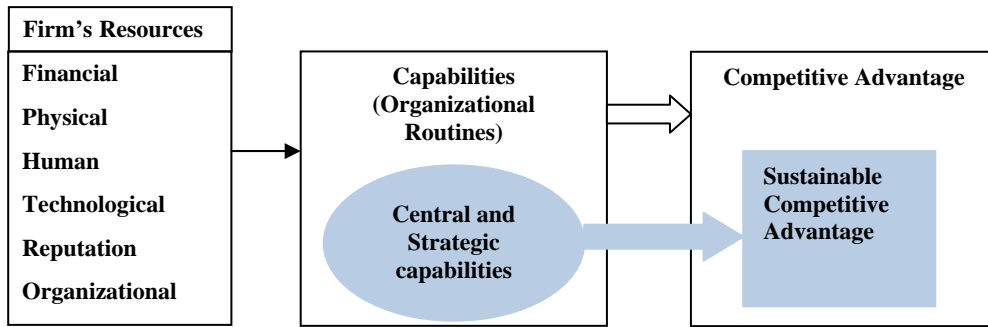
Those firm resources which create a sustainable competitive advantage are called “strategic assets” (Amit & Shoemaker 1993, Black & Boal, 1994). Strategic assets are those resources which are rare to find for a firm.

In this research we rely on definition of Amit and Shomaker, 1993. Firm resources and capabilities are not only different but also they affect each other. In order to convert resources to capabilities, not only a rich base of resources is necessary but also firm should benefit from the ability of coordinate and cooperate required resources to create capability. Moreover, this ability should be institutionalized in the firm and turned into a routine.

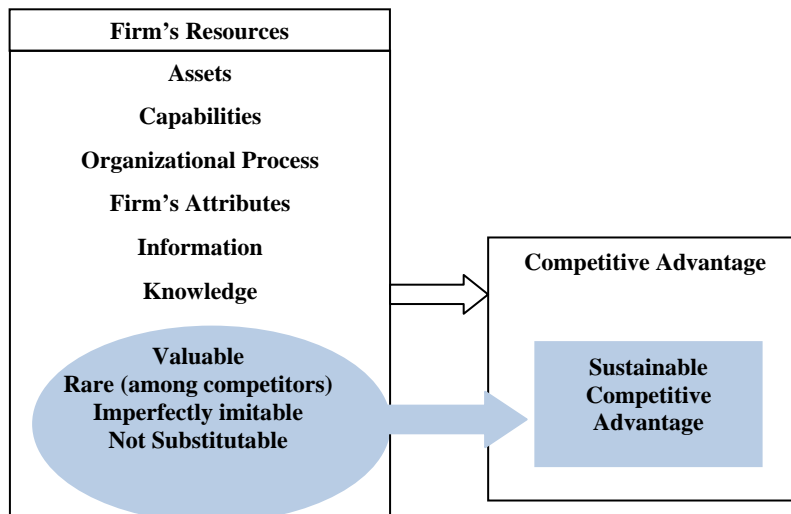
Different classifications of resources are proposed in the literature. This section explains all classification of resources which have been addressed in previous studies while determining the classification applied in this research. There are three classifications of resources including:

*Tangible versus intangible resources:* proposed by Yeoh & Roth, 1999, Wernerfelt, 1984, Grant, 1991, amongst others. Tangible resources are those assets which are visible (Itami & Roehl, 1987) such as Physical assets, financial assets & human assets. Intangible resources those who are not visible in the firm and they are mostly the sources of competitive advantages. Intangible or invisible resources have four following characteristics: (1) these resources are unattainable with money alone; (2) they are time consuming to develop; (3) they are capable of multiple simultaneous use; (4) these resources yield multiple, simultaneous benefits.

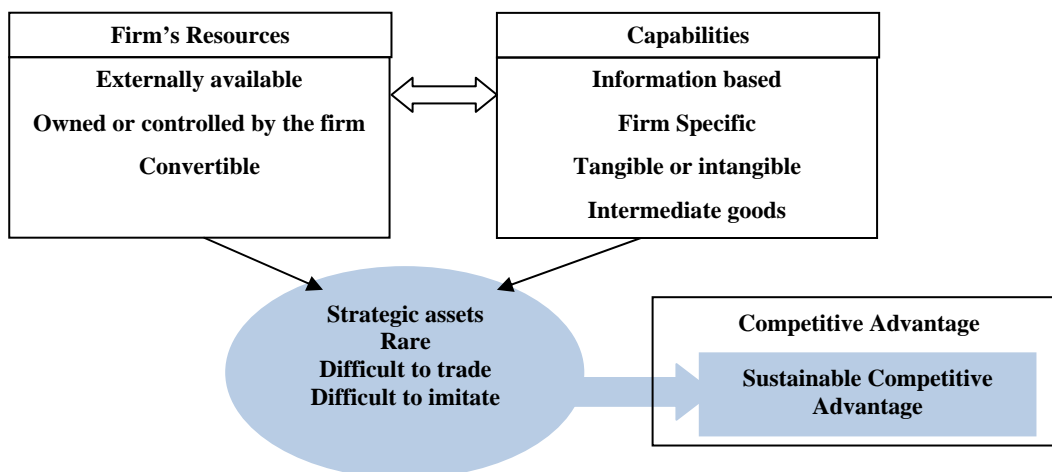
*Property-based versus knowledge-based resources:* the classification is proposed by Miller & Shamsie, 1996. Property-based resources are legal properties owned by firms, including financial capital, physical resources, human resources, etc. Owners enjoy clear property rights to these resources, or rights to use the resources, so that others cannot take them away without the owners’ consent. Knowledge-based resources refer to a firm’s intangible know-how and skills. In contrast to property-based resources, knowledge-based resources are not easily imitable owing to knowledge and information barriers. Others cannot easily copy or imitate knowledge-based resources, because they are vague and ambiguous.



a) Capabilities as sources of competitive advantage (source: Grant, 1991)



b) Resources (include capabilities) as sources of competitive advantage (source: Barney, 1991)



c) Strategic assets as sources of competitive advantage (source: Amit & Shoemaker, 1993)

Figure3.6- Resources and capabilities

These two classifications are similar. Whereas property-based (tangible) resources enjoy near-perfect legal protection, knowledge-based (intangible) resources are more vulnerable to unintended transfers.

Once others get adequate access to knowledge-based resources, it is difficult to keep these resources within the confines of the firm for long. Consequently, alliance partners will be concerned with losing their knowledge-based resources through an alliance.

*Thematic classification of resources:* This classification of resources deals with different categories of resources which the firm possesses, and it is more in detail rather other classification. Table 3.1, illustrates different categories of resources with their bibliographic references.

- **Technological resources** (also called R&D resources): include technological product aspects, and legal resources (e.g., knowledge of protecting innovations through legal means, patent and trademark). Furthermore tacit know-how and R&D capabilities are part of technological resources (Chi, 1994).
- **Financial resources** refer to the cash or financial capital that an organization possesses (Slotegraaf et al., 2003).
- **Human resources:** it includes training, experience, judgment, intelligence, relationships and insight of individual managers and workers in a firm (Barney, 1991). This definition encompasses all unskilled and skilled labor in a firm, contradictory with Slotegraaf et al., 2003 that points out human resources consists of knowledge embedded in a firm's staff.
- **Physical resources:** including tangible things, i.e. plant, equipment, land and natural resources, raw materials, semi-finished goods, waste products and by-products, and even unsold stocks of finished goods (Penrose, 1959, Barney 1991).
- **Managerial resources:** it encompasses wide varieties of resources. According to chi, 1994 it consists of valuable organization culture. (Chi, 1994). Gander, 1991 proposes a list of systems and routines in the firm including; reporting systems, planning tools, and financial expertise, which may be embodied in codified systems or reside within tacit routine. Capron et al., 1998, point out that managerial resources consist of managerial occupation employment in a firm.
- **Organizational Resources:** it include a firm's formal reporting structure, its formal and informal planning, controlling and coordinating systems, as well as informal relations among groups within a firm and those between a firm and its environment.
- **Reputation:** consist of Brand and trademark which a firm possesses.

- **Marketing resources:** it includes the skills of the importer that are related to the marketing operations of the importer, such as marketing/sales, marketing research, and personnel development resources.
- **Manufacturing resources:** refer to all production resources that a firm possesses. It includes production equipment, methods, and personnel (Capron et al., 1998).

Table3.1. Literature review of resources classification

Category of Resources	Technological	Financial	Human	Physical	Managerial	Organizational	Reputation	Marketing	Manufacturing
Hofer & Schendel, 1978	√	√	√	√	√	√			
Barney,1991			√	√		√			
Grant ,1991	√	√	√	√		√	√		
Miller & Shamsie,1996	√	√	√	√	√				
Das &Teng, 1998	√	√		√	√				
Jolly 2006	√	√	√	√	√	√			
Yalcinkaya et al. 2007	√							√	
Slotegraaf et al., 2003		√	√	√		√		√	
Capron et al.,1998	√	√			√			√	√

Amongst three aforementioned classifications of resources, the last one; thematic classification, fit better for the purpose of our research. Although we rely on thematic classification of resources, not all categories of resources (mentioned in table 3.1) could be applied in this research. Because this classification contain a list of diversified resources that overlap each other. As an example managerial and organizational resources are common on planning tools and controlling systems. Manufacturing resources overlap human, physical and organizational resources. Therefore a subset of categories is proposed. These categories should be selected with the intention of that they cover the whole firms' resources and have the least overlap. In this regard we propose following classification;

**Financial resources** (i.e. cash or financial capital of a firm), **human resources** (including knowledge, experience, judgment, intelligence, relationships, and insight of staff), **technological resources** (including R&D capabilities and tacit know-How), **physical resources** (including Plants and equipment, land, etc.), **organizational resources** (including corporate culture, inter-service teams, forecasting groups, new product development department, venture group) and **reputation** (including brands, well-known products/services).

Many researches confirm the relation between firms' resources and the selection of TSMs (Jones et al., 2000; Allerd & Swan, 2004). Prior researches propose that the need to source technology externally is affected by the *amount and type* of resources already available to the firm. In their empirical research, Allerd & Swan (2004) have shown the negative relationship between the amount of firms' resources and firms' reliance on external TSMs. Dyer et al. 2004, propose a relationship not only between firms' resources and the selection of TSMs but also between the kind of resources which firm intends to obtain and TSMs. They suggest if a firm needs mostly hard resources such as equipment and manufacturing product line, acquisitions are preferable while alliances are favorable when dealing with soft resources such as human resources and technological resources. In this research we don't deal with the resources that firm need, we mainly deal with the level of strengths in resources of a firm when deciding to obtain a technology.

If the firm is supposed to have the technological skills (perceived strength), logic suggests that they will be less likely to consider a cooperative relationship to develop technology. If the firm has some of the skills and knowledge required but lacks specific capabilities (perceived strengths and weaknesses), they are more likely to consider a technological cooperative relationship (Moenaert et al., 1990). Finally, if they have very few of the skills and capabilities associated with the technology (perceived weakness), they have little to offer a potential partner and are likely to pursue alternative means of technology acquisition such as licensing or acquiring a company with the desired skills (Roberts and Berry, 1985).

***Hypothesis 10:*** *As the level of internal resources of firm increases, the propensity to cooperate with others decreases.*

***Hypothesis 11:*** *As the level of internal resources of firm increases, the propensity to acquire the technology increases.*

**Hypothesis 12:** *As the level of internal resources of firm increases, the propensity to develop the technology internally increases.*

### 3.3.2. Absorptive Capacity

One of the factors affecting the choice of technology sourcing mode is Absorptive capacity which addresses effective learning in an organization. This concept was first defined by Cohen & Levinthal (1990) as the ability to assimilate, evaluate the knowledge and apply it to a commercial end. Other complemented definitions have been proposed by Mowery & Oxley (1995), Kim (1997a, b, 1998) and Zahra & George, 2001. Table 3.1, summarizes these definitions.

Table3.2- Absorptive Capacity Definitions (source: Zahra and George, 2001)

Authors	Definitions
Cohen & Levinthal, (1990)	The ability to assimilate, evaluate the knowledge and apply it to a commercial end.
Mowery & Oxley (1995)	A broad set of skills needed to deal with the tacit component of transferred knowledge and the need to modify this imported knowledge.
Kim (1997a,b, 1998)	The capacity to learn <i>and</i> solve problems.
Zahra & George, (2001)	A set of organizational routines and processes, by which firms acquire, assimilate, transform, and exploit knowledge to produce a dynamic organizational capability.

Comparing the above four definitions, we may conclude that:

- Definitions proposed by Cohen & Levinthal (1990) and Zahra and George (2001) are more similar to each other. Although Cohen & Levinthal do not refer to the ability of transforming knowledge, they acknowledge it in their article while talking about gatekeepers and the necessity of communications between organization's different departments and organization itself with its outside.
- Another difference between definitions relates to those of Kim (1997a, b, 1998) and Cohen & Levinthal, (1990). While Kim 1997a, quote problem- solving skills as the components of absorptive capacity, Cohen & Levinthal (1990) do not. They confirm that "learning capabilities involve the development of the capacity to assimilate existing knowledge, while problem-solving skills represent a capacity to create new knowledge." Therefore, absorptive capacity deals with existing knowledge while creative capacity deals with new knowledge

- Mowery & Oxley (1995) define absorptive capacity as the ability to assimilate the part of knowledge that is tacit and adapt it with organization's needs.
- Zahra and George (2001) cite absorptive capacity as a dynamic capability of organization that enhances a firm's ability to gain and sustain a competitive advantage. They classify it into two complementary parts; potential and realized absorptive capacity. The first kind of absorptive capacity; potential; is related to ability to assimilate and acquire knowledge and the latter one; realized; depends on the ability to transform and exploit acquired knowledge
- . This classification allows the authors to introduce a concept called efficiency factor as the ratio of realized absorptive capacity to the potential one. Efficiency factor suggests that firms are different in their ability to transform and exploit knowledge.

In this research, absorptive capacity is defined as “the ability to assimilate, acquire knowledge from external sources, transform it through the organization and exploit it to produce new product/service, enhance the performance of product/service or process and other organizational functions.” This definition is close to the one addressed by Zahra & George (2001). This definition may help the researchers to distinguish potential absorptive capacity from the realized one and give an idea to evaluate “efficiency factor”. It also helps the researchers to analyze the behavior of organizations in terms of their absorptive capacity.

Many previous studies have focused on the importance of absorptive capacity for knowledge transfer (e.g. Contractor, 1980, Lyles & Salk, 1996; Lane & Lubatkin, 1998; Lane et al., 2001, amongst others).according to Chen, 2004, firms with a high level of absorptive capacity are better able to learn or transfer knowledge from outside. Noting that internal R&D is a time and cost consuming project, firms which benefit from high level of absorptive capacity rely more on external sources of technology rather than develop it internally.

***Hypothesis 13: As the level of Firm's Absorptive Capacity increases, the propensity of firm to develop technology internally decreases.***

Firms with a high level of absorptive capacity rely more on the modes which make them less dependent to the source firm (Contractor & Ra, 2002). In addition, Firms with high level of absorptive capacity are likely to have a better understanding of the new knowledge and to harness new knowledge from other firms to help their innovative activities (Tsai, 2001, Oltra & FLor, 2003).Therefore, the cooperation will



become more performing (George et al. 2001) which motivate firms with higher levels of absorptive capacity to enter cooperative relations.

***Hypothesis 14:*** *As the level of Firm's Absorptive Capacity increases, the propensity of firm to cooperate with others increases.*

As a consequence of Contractor & Ra's proposition; a firm becomes more dependent to the source firm in acquisition modes, compared to when it chooses to make technology based on the firm's own knowledge (Chiesa, 2001; Steensma & Corley, 2002). Furthermore when a potential acquirer has little information about the true value of the technology, it will be unwilling to commit immediately to acquisition because the target firm may opportunistically misrepresent the value of its assets (Folta, 1998). Thus:

***Hypothesis 15:*** *As the level of Firm's Absorptive Capacity increases, the propensity of firm to acquire technology decreases.*

### **3.3.3. Successful Past Experiences**

One of the factors that influence TSMs selection is the firm's successful past experiences in a certain mode (Cho and Yu, 2000; Hernan et al., 2003; Kioyota & Okazaki, 2005 amongst others). *"Firms may be expected to behave in the future according to the routines they have employed in the past"* (Nelson & Winter, 1982: 134). Through using a mode, firms have developed abilities to manage different modes over the years and regard them as core competencies. They have created special teams to act as repositories of knowledge and institutionalized processes to identify targets, negotiate with them, handle due diligence, and tackle issues that arise after a deal is made (Dyer et al., 2004). They have learned the dos and don'ts from experience and created templates that help executives manage specific mode-related tasks. In addition, they have developed formal and informal training programs that sharpen managers' deal-related skills. Therefore, managers tend to duplicate their past experiences (Pisano, 1990). Accordingly, firms lacking experience in a mode of technology sourcing are less able to organize the necessities of the mode. For example when a firm has no experience in collaboration, it is difficult for it to search for partners and select the appropriate partners in order to learn more effectively from them, etc. (Westney, 1986). Based on a survey of 151 U.S. firms, Simonin (1997) tested a model of how firms learn from their strategic alliances. His results suggest that firms with greater collaborative experience achieve higher levels of collaborative know-how. Nevertheless, technology sourcing modes evolve over time along with the evolution of the external (or internal) context (see for

example, Doz, 1996). Therefore, the current state of technology sourcing modes is obviously affected by past choices and experience of the firm.

***Hypothesis 16:*** *As cooperative modes of technology sourcing used by firm successfully in the past increases, the propensity of firm to ally increases.*

***Hypothesis 17:*** *As internal development of technology used by firm successfully in the past, the propensity of firm to develop the technology internally increases.*

***Hypothesis 18:*** *As acquisition modes of technology used by firm successfully in the past, the propensity of firm to acquire the technology increases.*

#### **3.3.4. Strategic Objective**

Strategic motives a firm follows may influence the selection of technology sourcing mode. We propose to concentrate on two porter generic strategies; differentiation and cost leadership, in a broad market scope. Differentiation is the process of distinguishing a product to introduce to a market. Cost-leadership strategy involves the firm winning market share by appealing to cost-conscious or price-sensitive customers.

Firms' generic strategies influence TSMs which firms select. Firms which select internal development, prevent their competitors easily imitate the technology. In addition internally develop a technology allow the firm maintain its control over the technology (Kotabe & Murray, 1990).because competitors generally have access to the same technology market, internal development is a source of differentiation. On the contrary, Cooperation and acquisition facilitate gaining access to the technology and as a consequence to what make the technology differentiated.

***Hypothesis 19:*** *As the importance of a differentiation goal increases, the propensity of firms to internal development increases.*

Internal development is a time and cost consuming process. Collaborations and acquisitions are less costly, in exception of special cases. For example "where the new technology is central, or provides some crucial advantage, the company may be compelled to purchase it from others perhaps at an exorbitant price" (Jelinek and Schoonhoven, 1990, p. 426). It is the case also when would –be partners or buyers for a technology are limited (Meyers et al., 1999). In such cases firms with cost leadership strategy are more likely to internal development, unless the acquisitions are more preferred. Hypothesis 24 and 25 are suggested for the two cases.

**Hypothesis 20:** *As the importance of a low-cost goal increases, the propensity of firm to acquire increase.*

**Hypothesis 21:** *As the importance of a low-cost goal increases, the propensity of firm to internal development increases.*

### 3.3.5. Firm Size

Some precious study also confirm the effect of size on TSMs. Cassiman & Veugelers ( 2000, 1998) and Narula( 2004) have addressed the relation between firm size and selection of TSM . While large firms generally have more resources to offer (Narula, 2004), they are less innovative and flexible in comparison with small firms when it comes to responding to rapid changes. As a result, larger firms tend to look for technological innovations of SMEs to compensate for their lack of innovativeness and flexibility. SMEs' risk of forfeiting their technological competencies makes the costs of managing collaboration with large firms too high to afford (Narula, 2004). Therefore, SMEs prefer an autonomous approach rather than a collaborative one.

**Hypothesis 22:** *Larger firms are less likely to develop technology internally.*

**Hypothesis 23:** *Larger firms are more likely to cooperate.*

**Hypothesis 24:** *Larger firms are more likely to acquire technology.*

## 3.4. Conclusion

In this chapter we were concerned with hypothesis arguments. 19 hypotheses are argued for technology-related determinants and 15 for firm-specific ones. Table 3.2and 3.3, represent the number of hypothesis argued for each determinants.

Table3.3. Number of Argued Hypothesis for Technology-Related Determinants

Determinant	Technology Life Cycle	Uncertainty	Strategic Importance of Technology	Urgency	Total
Hypothesis NO.	7	4	4	1	16

Table3.4. Number of Argued Hypothesis for Firm-Specific Determinants

Determinant	Internal Resources	Absorptive Capacity	Successful Past Experiences	Strategic Objective	Size	Total
Hypothesis NO.	3	3	3	3	3	15

Next chapter is devoted to research methodology and the results of hypothesis testing are presented in chapter5.

## **Chapter4**

### **Research Methodology**

*This chapter discusses practical elements of the research. It explores the research questions in more depth, and explains what methods are the most appropriate ways given the aims and nature of the research. Different methods of data collection are addressed while focusing on why particular methods have been chosen over others. This is followed by a discussion of the practicalities of how the data collection was conducted, and the approaches taken to data analysis.*

## 4.1. Research Design

The research aims to answer the following essential questions:

- What are the determinants of technology sourcing modes?
- How determinants of technology sourcing modes, including firm-specific and technology-related determinants; affect the decision in Iranian enterprises?

In order to answer the above questions, a 7-step research procedure is designed (figure1, General introduction, P. 7). This chapter is devoted to describe prerequisites of step 5 of the research; hypotheses testing and data analyzing.

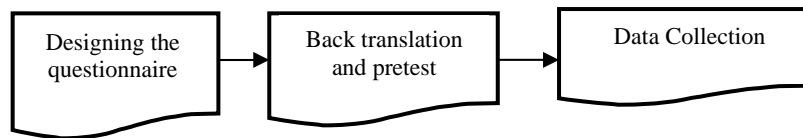


Figure4.1- Research design

In order to test the hypotheses, a structured questionnaire is designed to collect data about Iranian firms active in technology intensive industries including; telecommunications and microelectronics, information technology, biotechnology and nanotechnology. In order to study the effect of factors, a quantitative approach is selected.

## 4.2. Unit of Analyses and Industry Setting

The focus of the study is how characteristics of technology and firms influence the decision making regarding technology sourcing modes including; internal development, cooperation and acquisition. We adopt a multi-level research method, in which the first unit of analysis is the project of gaining access to a technology. This project could be realized with only one mode of technology sourcing or a combination of all the aforementioned three modes. This stage aims to investigate the effect of technology characteristics on the modes of technology sourcing. At the second level, we consider the firms as the unit of analyses and study the effect of firm's characteristics on the choice of technology sourcing modes.

In order to study these effects, we focus on technology-intensive firms in Iran. There are several reasons why the technology intensive industries are an attractive context to evaluate the hypotheses of our research. First, the market value of firms competing in these industries is based on their ability to develop, search for and exploit capabilities that they currently do not have (Myers, 1977, Kester, 1984);

therefore these firms are supposed to use a set of diversified modes of technology sourcing compared to firms competing in mature industries. Second, these industries represent an intensive rate of technological innovations, so using different modes of technology sourcing for these firms is inevitable. These firms, then, provide an opportunity to examine how factors (mentioned in chapter3, sections 3.2 and 3.3) may affect the way firms select the modes of technology sourcing. The next section explains the procedure of data gathering.

### 4.3. Procedure of Data Gathering

Technology intensive firms in Iran are mainly active in five industries, namely; microelectronics and telecommunications (including electronics), information technology, biotechnology, nanotechnology and industrial automation. The firms active in automation industries are excluded from the list because firstly the majority of these firms are declared to be the representative of some foreign companies and they do not possess the technologies. Secondly, a few firms were not interested in participating in our research.

Therefore, the population of this research includes Iranian firms active in four industries. In order to gain access to an ideal sample frame, we include all firms active in these four industries in Iran. To approach this ideal sample, all firms activated in these industries were contacted through different databases. As these databases were not up to date, the researcher verified the related information of the firms by checking their web sites or calling them. Finally a list including; the name, address, web sites address, telephone number and e-mail address of Iranian firms active in these industries in 2008 was prepared.

Table 4.1 represents total number of Iranian firms active in each industry.

Table 4.1- Firm population in each industry

Industry	Telecommunication & Electronic	Information Technology	Nanotechnology	Biotechnology	Total
Number of firms	60	46	36	25	167
Relative frequency	0.36	0.28	0.22	0.15	1.00

Because the data to be used in this research is not available through any archival sources <sup>7</sup>(Lee et al., 2009), a questionnaire was designed. The questionnaire consists of three parts. The first part is dedicated to firm related factors questions. The second part concerns the general information of the company requested to participate in our research, and finally the third part is designed for technology related factors questions. The latter section should be filled out for each technology sourcing project. Each firm was requested to fill out the third part for at least two technology sourcing projects. In total,

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<sup>7</sup> Even some general information such as market share -usually presented in databases- is not appeared in any database.

89 projects of technology sourcing in 63 firms were completed. The questionnaire is addressed to firm's chief executive officers. They are considered as key informants of our research. We asked them to fill out each part of questionnaire as well as its third part for different technologies while explaining that they could pass each part of questionnaire to the person who the CEOs consider as the key informant. For example, for two different technologies gained by the firm in two different periods of time, there may exist two different chief technology officers who are considered as the most knowledgeable persons about the process of gaining access to the technologies. Table 4.2 represents the position of persons who completed the questionnaire.

Furthermore, the questionnaires are addressed to the firms' CEOs and in some cases (20 cases of 63) the CEOs have passed the questionnaire to other people in position of R&D managers (10 firms), chief technology officers (5 firm) and project managers or marketing managers (5 firms in total).

Table 4.2- Position of completer the questionnaire

Completer position	CEO or Member of the board	R&D manager	CTO	Project or marketing manager
Number	43	10	5	5

In order to know whether the responses of persons with different positions are homogenous or heterogeneous, we conducted a Kruskal Wallis test. The results show no differences in the responses of persons in different positions except for two questions; 7 and 19. The responses of CEOs and member of the board is different with the responses of R&D managers and chief technology officers. Question 7 asked for the ability to assimilate knowledge from showrooms and exhibitions as an external source of knowledge. The ability of firm to assimilate knowledge is estimated less than those of R&D managers and CTO's. It is one part because R&D managers and CTOs are more deals with technologies and technical innovation in showrooms and exhibitions than CEOs. R&D managers and CTOs take more time to verify what is new in technical aspects with their rivals in showrooms, while CEOs are more likely to participate in meetings and interview sections and etc. Question 19 deals with estimation of financial strengths of the firm compared with the leader. In this question also the estimation of R&D managers and CTOs is more than those of CEOs and member of the board. Member of the board and CEOs' information on the leader strengths may more realistic than persons in other positions.

The data was collected from one-single respondent. Prior to distributing the questionnaire in a large scale, it was pretested by the following two approaches including a) interviewing 4 University professors working on learning organizations, strategic planning and strategic management of technology (including the director and co-director of the present thesis) as the experts in the field and b) asking 2 chief executive officers of firms. During interviews with the professors, at first we explained the



objective of our research and determinants whose effect on technology sourcing decisions concerns us, and then the following questions were asked: do the questions measure exactly the variable that they are designed to measure? Are the wordings and terminologies clear? After considering the remarks of professors,

some questions were added and some incremental changes were performed in the questionnaire. The main question addressing seven external sources (questions 1-7) were changed from “the evaluation of importance of each external source in firm’s innovation” to “firm’s ability to assimilate knowledge from each external source”. Questions 13 to 18 were added to the questionnaire in order to find out whether the firm’s absorptive capacity is institutionalized in the firm and verify the effectiveness of the routines. In our second approach, we explained the objective of our researches for 2 CEOs of technology intensive firms while asking them to fill out the questionnaire. Then, we asked them the following questions: Are the wordings and the terminologies clear? Is there any question that leads you to different purposes? Do the directions make sense? Also they were requested to determine the time that they devoted to filling out the questionnaire. In contrast to the responses given by the university professors, the remarks of managers did not result in applying major changes in the questionnaire. One important remark of managers concerned the number of questions and the time which they had to devote to filling out the questionnaire (between 20- 30 minutes) according to the number of technology that they preferred to filling out in the third part of questionnaire. Moreover, the managers were concerned about questions number 40- 42, they declared that “being aware of the conditions in Iran, most of managers may not respond to the questions 40 to 42 as a) they would not like to reveal the financial revenue of their firm, and b) regarding the annual budget devoted to R&D, the managers may not respond because they do not devote a specific R&D budget for the firm”. Therefore, we expected that the managers would respond to these questions, which is the case for the majority of firms. Amongst 63 firms, we could obtain information of annual revenue of only 15 firms, annual R&D budget of 26 firms and total payments of R&D personnel of 17 firms. These interviews also served as a check point for verifying of the content validity of measures. As the original version of questionnaire was designed in English, and we expected that some managers might prefer to be asked in Persian, we followed a back translation process. This process ensures the English version and Persian version of questionnaire to be equivalent. Therefore, using either English or Persian version of questionnaire may not bias the responses. Despite taking this precaution, we compared the two groups of questionnaire (i.e. English and Persian versions) to verify their equivalency. The results show the equivalency of using two questionnaires (Appendix III).

In order to pretest the English version of the questionnaire, we mailed it to 20 firms. This measure ensured verified the reliability and validity of the questionnaire (section 4.5).

The reworked questionnaire was mailed out in a five- step process following Dillman's (2000) recommendations. It is important to note that some steps of Dillman's recommendations are adapted for the conditions of Iranian firms. First, we called the CEOs to inform them of the purpose of our research and its importance while requesting them to participate in it. Second, according to what the CEO's preferred, a packet was sent them by e-mail, post or fax. The packet included a cover letter and the questionnaire. The cover letter reminded recipients of the purpose and importance of the research and guaranteed confidentiality of the responses. The letter included the cell phone number and e-mail address of the basic researcher for the respondents to contact her if necessary. Third, a contact was made with the firms in order to be certain that all of them received the packet. Fourth, after a period of 4 to 6 weeks, the firms were contacted for one last time to a) thank those who had completed the questionnaire with the promise of emailing them a summary of the findings when the study was completed, (by e-mail) and b) remind the others to fill out the questionnaire (by telephone). After sending the questionnaire, some firms declared that they were not willing to fill out the questionnaire. After a period of 2 months, again we contacted those firms that hadn't already responded to our previous request (neither positive nor negative) and requested them to do so. In some cases, the managers demanded another copy of questionnaire which we provided. Fifth, finally we had to participate in some exhibitions of technology intensive firms persuade the managers in person to fill out our questionnaire. The process of data collection took a period of 9 months. Finally, amongst 167 technology intensive firms, 63 firms filled out our questionnaire; i.e. a response rate of only 37%. Compared to the response rate in our pilot study; about 85%, we expected to obtain more completed questionnaire. Three reasons may have contributed to this low response rate. The first reason may be due to the specific political and economic conditions in Iran after June 2009. Some firms were in financial crises which discouraged the managers to participate in our research while some others did not have adequate motivations to participate in the research. Second, the type of data that the questionnaire aimed to collect – information about revenue of the firm and some attributes of technologies- were deemed proprietary and confidential by some firms. In an effort to mitigate these concerns for respondents, confidentiality was promised and in some measures were taken to ensure this issue in the questionnaire. For example, in the third part of questionnaire, the managers asked to give a code for technology if the name could not be noted (Question 44). Despite of all these efforts, some of the sample members contacted us to inform that they would not be completing the questionnaire due

to these concerns. Finally the third reason may come from using two different approaches in the pilot study and the present research. Data in our pilot study were collecting by the researchers during an interview reunion with the top managers of Iranian firms, while data of the present research are collecting via a questionnaire and the managers themselves are supposed to complete the questionnaire. The presence of researchers and a face to face meeting increased the trust of managers and augmented the response rate. Copies of cover letter and the questionnaire and confirmation of the message sent are provided in Appendix II.

From the 63 completed questionnaires, data were collected for a total of 89 technologies. Of the 63 firms providing complete data, 47 firms provided information on one technology, 8 firms provided information on two technologies, 6 firms provided information on three technologies, 2 firms provided information on four technologies, and one firm did not provide information on any technology. Figure 4.2 shows the distribution on technologies among firms.

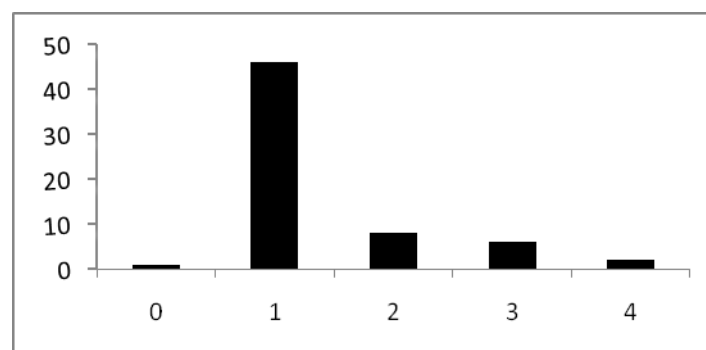


Figure 4.2 - Distribution of technologies among firms

#### 4.4. Measures

In the empirical tests of hypothesis, we took note of three types of variables: dependent, independent, and control variables. Dependent variables are the level of firm's propensity to internal development, to ally and to acquire. Independent variables are classified in two groups; technology related factors and firm related ones. Technology related variables consist of stage of technology life cycle, level of technical and commercial uncertainty which firms may foresee for a technology, degree of strategic importance of technology, and degree of urgency of technology. The firm-specific independent factors consist of level of firm's internal resources which a firm possesses compared with the leader firm in the industry, level of firm's absorptive capacity, firms successful past experiences in a mode of technology sourcing, strategic objective of the firm and firm size. The control variables at the firm level include the number of patents, rate of firm's innovativeness and its age. At the technology level, control variable is the

duration of time that the firm has the technology in its portfolio. All variables were evaluated through the questions mentioned in our questionnaire. We proposed a measure for absorptive capacity which could be considered as the contribution of our research. In our research the potential and realized absorptive capacity are separately evaluated. This is why the number of questions that evaluate absorptive capacity is more than the questions for other variables. Measures for other variables are either based on or adapted from the literature. Table 4.3 and 4.4 provides a synopsis of variables at firm level and technology level.

Table 4.3- Synopsis of Firm-Level Variables

Variable (question number)	Type	Label	Definition	Number of items in questionnaire
Firm's Propensity to internal development(27)	dependent	PFR&D	Firm's willingness to develop technology internally	1
Firm's Propensity to cooperate(28)	dependent	PFCOOP	Firm's willingness to cooperate with others	1
Firm's Propensity to acquire(29)	dependent	PFACQ	Firm's willingness to acquire the technology or technology owner	1
Absorptive capacity(1-12)	independent	AC	Firm's ability to assimilate, evaluate and apply it to commercial end	12
Internal resources (19-24)	independent	INRES	Firm's strengths in internal resources compare with the leader	6
Financial Resources (19)	independent	FINRES	Firm's strengths in financial resources compare with the leader	1
Human Resources(20)	independent	HUMRES	Firm's strengths in human resources compare with the leader	1
Technological Resources (21)	independent	TECHRES	Firm's strengths in technological resources compare with the leader	1
Physical Resources (22)	independent	PHYRES	Firm's strengths in physical resources compare with the leader	1
Organizational resources (23)	independent	ORGRES	Firm's strengths in organizational resources compare with the leader	1
Reputation (24)	independent	REPT	Firm's strengths in reputation compare with the leader	
Strategic objective (25,26)	independent	STOBJ	Firm's strategic objective; Differentiation versus cost leadership	2
Successful past experience in R&D(48.1)	independent	EXPR&D	Firm's past experiences in internal development	1
Successful past experience in cooperation(48.2)	independent	EXPCOOP	Firm's past experiences in cooperation	1
Successful past experience in acquisition(48.3)	independent	EXPACQ	Firm's past experiences in acquisition	1
Firm size(36, 37)	independent	Size	Number of employees or number of R&D employees	2

Table 4.4- Synopsis of technology-Level Variables

Variable (question number)	Type	Label	Definition	Number of items in questionnaire
Percentage of internal development of technology (46.1)	dependent	PTR&D	The proportion of a specific technology which gained by internal development	1
Percentage of technology cooperation(46.2)	dependent	PTCOOP	The proportion of a specific technology which gained by cooperation	1
Percentage of technology acquisition(46.3)	dependent	PTACQ	The proportion of a specific technology which gained by acquisition	1
Technology life cycle (49)	independent	TLC	The stage of life cycle the technology was it when deciding on gaining access to it	1
Commercial Uncertainty (50)	independent	CUNC	Degree of commercial uncertainty related to a specific technology	1
Technical Uncertainty(51)	independent	TUNC	Degree of technical uncertainty related to a specific technology	1
Importance strategic of technology (52,53)	independent	SITECH	The degree that the technology is strategic for the firm (in term of degree of competitiveness and market share)	2
Urgency (54)	independent	TURG	The extent to what gaining access to the technology is urgent	1
Successful past experiences in internal development	independent	TEXR&D	Firm's past experiences in internal development before deciding to gain access to a specific technology	1
Successful past experiences in Cooperation	independent	TEXCOOP	Firm's past experiences in cooperation before deciding to gain access to a specific technology	1
Successful past experiences in Acquisition	independent	TEXACQ	Firm's past experiences in acquisition before deciding to gain access to a specific technology	1
Age of Technology in the firm (45)	Control	AGETECH	Time that the firm has the technology in its portfolio	1

#### 4.4.1. Dependent Variables

As explained in chapter 3, according to our model, three types of dependent variables are identified and described as following:

**"Propensity to internal development"** is defined as the likelihood that a company is interested in internal development of a technology.

**"Propensity to ally"** is defined as the likelihood that a company participates in joint ventures and another forms of alliances.

**"Propensity to acquire"** is defined as the likelihood that a company makes an acquisition, such as license purchase, R&D outsourcing, firm take over, etc.

In our definition, **propensity is a general willingness or "tendency" to internal development, ally or acquire**. In order to measure the above variables, different tools are proposed in the literature. These tools could be divided into two main groups: those which estimate the propensity to ally/ internal development /acquisition with the number of real cases that have occurred for firm in order to gain access to a technology- for example, to estimate the firm's propensity to ally, the collaborative modes used by the firm are counted in a defined period of time. In the majority of these researches, the unit of analyses is the firm. In other words, in this group of researches the words "willingness", "propensity" or "tendency" to cooperate/ internal development/acquisition are equally estimated by the number of cooperation/ internal development/acquisition projects realized by the firm in a period of time. As represented in table 4.5, a dummy variable is defined to describe a firm's propensity.

Table4.5- List of references estimating propensity of TSMs with real case

References	Dependent Variable /Studied Mode	Measures	Unit of Analyses
Hung & Tung, 2008	Level of resource commitment R&D collaboration/ licensing/ JV	Number of R&D collaboration, licensing agreements and Joint ventures realized in the firm.	Organizational mode
Belderbos et al., 2004	Likelihood of R&D collaboration/ R&D collaboration	Number of R&D cooperation contracts during a certain period.	Firm
Bishop, 2003	Propensity to collaborate/ Collaboration	Number of firms which was currently involved in a formal collaborative agreement with another firm.	Firm
Hernan et al., 2003	Willingness to join an RJV / Research Joint Venture	Number of firms (in the sample) who have participated in at least one RJV during a certain period.	Firm
Bayona et al. 2001	Willingness of cooperation/ R&D collaboration	Number of firms who have cooperated in R&D during the period 1994–1996.	Firm
Roberts & Liu, 2001	Propensity to ally and propensity to acquire	- Firm's total number of alliances normalized by sales. - Total number of acquisitions normalized by sales.	-----
White, 2000	Likelihood to make, buy and ally/ internal development, cooperation and acquisition	Number of make, buy or ally decisions during a period.	Organizational mode of TSM
Veugelers & Cassiman, 1999	Make or buy decision	Number of firms which does R&D and number of firms which acquire the technology through licensing and R&D outsourcing	Firm
Shan, 1990	Propensity to collaborate/ cooperation	Number of firm's cooperation agreements during a period of times	Organizational mode of T.S.M.

The second group of researchers propose to measure “the propensity to ally or make” in different ways; i.e. designing some questions to interview the managers or proposing some parameters which could be measured objectively; such as No. of R&D projects performed in the firm / No. of all projects of firm. In these kinds of research, the unit of analyses is mostly the project of gaining access to a technology (simply the technology which the firm intends to obtain) or the organizational mode used in order to gain access to a technology. Table 4.6 illustrates the second group and the literature background.

Table4.6- List of references measuring propensity to select TSMs

References	Dependent Variable /Studied Mode	Measures	Unit of Analyses
Chen & Yuan,2007	Internal R&D and technology acquisition( License purchase, patent purchase, buy the equipment, hiring personnel,...)	The amount of expenditure that firm has dedicated to each mode	Firm
Allerd & Swan 2004, Jones et al. 2000	Reliance on external technology sourcing/ Internal R&D and external technology sourcing mode	The authors used a five-scale Likert measure for following questions: - My business unit develops the technology it requires through its own research. - My business unit spends more on developing its own technology than on purchasing it from other companies. - My business unit's products are based primarily on technology we developed - We are heavily dependent on other companies to supply us with new product technology - We rely on external sources to provide us with new generations of the technology we utilize. - Percentage your business unit relies on external sources for technology.	Technology
Arora & Fosfuri,2000	Propensity to internalize/ Wholly owned subsidiaries in other country and licensing a technology	No. of R&D projects performed in the firm / No. of R&D projects + No. of license agreements	Firm
Dolinger et al. 1997	Propensity to ally	Based on technology conditions, would you proceed with the strategic alliance? Yes or No	Technology
Tyler & Steensma, 1995	Willingness to cooperate/ cooperation (alliance)	-Based upon provided information (the information about the technology), and your experience and knowledge, please rate the attractiveness of this situation for a cooperative/partnering relationship. Very unattractive 1 2 3 4 5 6 7 Very attractive -What is the probability that you would recommend this cooperative relationship? Place an X in the appropriate space. Low probability 1 2 3 4 5 6 7 High probability The degree of willingness to cooperate is the summation of respond to 2 above questions	Firm

Relying on the methods used by each group has some advantages and disadvantages. The first way of measuring is not effective if one technology is gained by a combination of modes different percentages. For example, if during the period of study a technology is gained by 20% of internal R&D and 80% of cooperation, or conversely by 80% of internal R&D and 20% of cooperation, this method could not

distinguish these two technologies, regarding the percentage of using the modes. Another disadvantage is that, in certain conditions (especially external conditions); the firms' propensity may not be realized. In such conditions estimating the propensity with the realized case may lead s to a biased Data analyzes. When studying Iranian firms, this issue should be taken into consideration. Specific political conditions and governmental formalities prevent the managers to use a specific mode (or a combination of modes) in order to gain access to a technology. There are many cases in which managers decide to gain a technology by specific modes but the external conditions oblige them to select to another mode<sup>8</sup>. Despite of disadvantage of the method used by the first group, its simplicity and comprehensiveness for the managers motivate us to use this way for measuring our dependent variables while taking some precautions to minimize the effect of disadvantages.

In this research, we measure the propensity of firm to cooperate/ internal development and acquisition by the percentage of each mode. As explained before, we have two levels of study; a technology to which a firm intends to gain access and a firm. Therefore, questions 27, 28 and 29 for firm level and question 46 for technology level are designed.

- Indicate the percentage of firm's technologies that are developed internally (question 27)?
- Indicate the percentage of firm's technologies that you develop with a partner (question 28)?
- Indicate the percentage of firm's technologies that you acquired externally (license purchase, firm take over, outsource) solely or with others (question 29)?

Another question for technology level is the question 46 mentioned below:

Please indicate the percent of modes which is used to gain access to this technology?

The mode used to gain access to the technology	Percent of technology gained by this mode
Internal development	
Cooperation	
Acquisition (license purchase, firm take over, outsource)	
Total	100

This approach relies on the method of devising questions used by the first group of researchers while we tried to eliminate its disadvantages. The first disadvantage is eliminated by asking the managers to

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<sup>8</sup> The results are drawn from the interviews of our pilot study fully presents in Appendix I.



determine the percentage of each mode of technology sourcing in a project. In order to verify the effect of external conditions on the propensity of firm; question 60 is designed. Comparing responses given to questions 60 and 46 enables us to test this hypothesis if firm's propensity is different with what is realized for Iranian firms. In this question, managers are requested to indicate the percentage of their preferred way of gaining access to the technology for internal development, cooperation and acquisition separately. The results of comparing responses given to the two questions 46 and 60 are fully described in chapter 5.

#### **4.4.2. Independent Variables**

This section is concerned with description of all independent variables evaluation.

##### **4.4.2.1. Variables at Technology- Level**

All questions about these variables are mentioned in the third part of questionnaire, where the managers are requested to complete the questions for multiple technologies.

In order to perform an effective data gathering, the managers are requested to consider the situation the company was confronted when deciding to gain access to the technology.

Technology life cycle: This variable refers to the stage (birth, growth, maturity or laggard) at which the technology is when it comes into the firm's portfolio. This method of evaluation is proposed by Khalil (2000) amongst others (Question 49 in the questionnaire)

Uncertainty: This variable refers to the degree of uncertainty of technology; technically and commercially, when the technology comes into the firm's portfolio. This evaluation criterion is proposed based on Cho and Yu (2000) proposition (the possibility of commercial and technical success in the process of gaining access to the technology). Degree of uncertainty is conversely related to the degree of success (Questions 50 and 51).

Strategic importance of the technology: This variable refers to the importance the technology has for a firm in terms of the level of competitiveness which a technology could create for the firm amongst rivals. As explained in chapter 2, the whole set of technologies of the firm are classified in four groups; distinctive, niche, background and marginal while relying on classifications of Patel & Pavitt (1997). In the best of our knowledge, there is no research which operationalizes the technological competence of the firm. For example, Patel & Pavitt (1997) measure technological competences of large firms in a specific field in terms of the ratio of number of patents registered in the field on the number of total patents. In our research this way is not applicable because of the following two reasons;

- Our research deals with firms of different sizes; small, medium and rarely large.
- Patents are not an appropriate factor for studying firms in developing countries– and Iranian firms in particular-. As Pakes & Griliches (1980) point out; this issue may be due to a) the high cost of registering a patent in comparison with the low protection gained by the firms and b) minor improvements such as adaptation of imported technologies for local use are needed, but usually not sufficient to be granted as patents.

Therefore, in order to classify technologies, we proposed two factors, namely; ability of the technology to create competitive advantage for a firm and the capacity to create resources for the firm.

Accordingly, the following two questions (questions 52 and 53 in the questionnaire) were designed.

How do you assess the impact of this technology on your competitiveness?

Very Weak 

1	2	3	4	5
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 Very High

How do you evaluate the potential market share (application-field) gained by this technology?

Very Weak 

1	2	3	4	5
---	---	---	---	---

 Very High

Consequently, the following method is applied in order to categorize technologies into one of the four group mentioned below;

- In the cases that potential market share is evaluated high and very high (4, 5) and competitiveness is evaluated medium, high and very high (3, 4, 5) the technology is classified as distinctive.
- In the cases that competitiveness is evaluated medium, high and very high (3, 4, 5) and potential market share is evaluated medium, weak and very weak (1, 2, 3) the technology is classified as niche.
- In the cases that potential market share is evaluated medium, weak and very weak (1, 2, 3) and competitiveness is evaluated weak and very weak (1, 2) the technology is classified as marginal.
- In the cases that potential market share is evaluated high and very high (4, 5) and competitiveness is evaluated weak and very weak (1, 2) the technology is classified as background.

- For the cases with middle level of potential market share and competitiveness (3, 3), we consider the technology as non- classified.

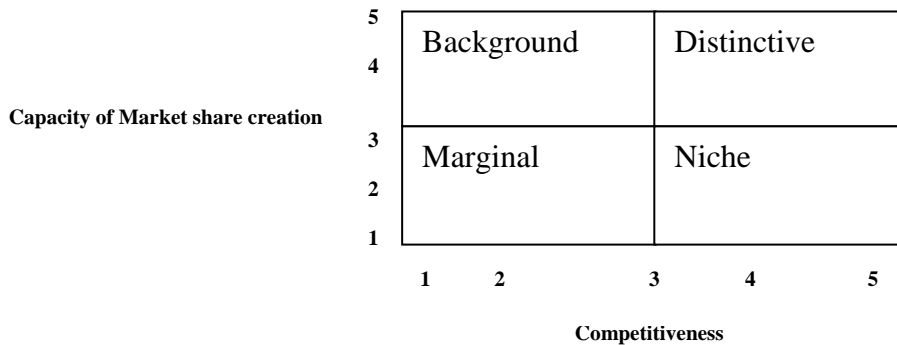


Figure 4.3- Evaluation of strategic Importance of technology

**Urgency:** this variable refers to the degree that gaining access to a technology is considered urgent. In the questionnaire; managers are requested to determine to what extent gaining access to the technology was urgent (question 54).

#### 4.4.2.2. Variables at Firm- Level

All questions about these variables are mentioned in the first and the second part of questionnaire.

**Internal Resources:** Internal resources refer to the level of the firm's strength compared to the market leader. In the questionnaire, the managers are asked to compare their level of six internal resources compared to the leader. These six internal resources consist of financial, human, technological, physical, organizational, and reputation. Questions 19 to 24 are designed to evaluate firms' internal resources.

**Absorptive Capacity:** As pointed out in chapter 3, absorptive capacity is defined as "a firm's ability to assimilate external knowledge, evaluate it and apply it to a commercial end" (Cohen and Levinthal, 1990).

In the literature, different measures of absorptive capacity are proposed. Table 4.7 represents these measures at organization level with bibliographic references. We propose a direct method to measure absorptive capacity while distinguishing between potential and realized one. Questions 1-7 were designed in order to measure potential absorptive capacity and questions 8-10 for realized absorptive capacity, this distinction is proposed by Zahra & George, 2001. In questions 1 to 7, managers are requested to estimate their firm's ability to gain access and assimilate knowledge from external sources including suppliers, clients, competitors, universities, research institutions, conferences and journals, and showrooms and exhibitions. Questions 8- 10 were designed in order to measure realized absorptive

capacity. A firm with a specific ability to assimilate knowledge from external sources (questions 1-7) should be able to evaluate and transfer this assimilated knowledge and apply it at the commercial end. In order to measure these three stages of absorptive capacity, we focus on the final stage. Therefore, we ask the managers about the extent to which a firm is capable to enhance the performance of its process (question 8), or its products/services (question 9) and create new product or process or systems (question 10). The answers to these three questions may provide the level of realized absorptive capacity.

Table 4.7- Evaluations of Absorptive Capacity

Reference	Measures
Cohen and Levinthal, 1990	R&D intensity, responsiveness of R&D to learning incentives
Boynton et al., 1994	Managerial IT knowledge, Managerial IT processes effectiveness
Szulanski, 1996	Measures that capture the ability to value, assimilate and apply new technology
Veugelers, 1997	R&D with fully staffed, R&D department with Doctorates, R&D departments engaged in fundamental research
Cockburn and Henderson, 1998	Number of scientific publications
Kim, 1998	Intensity of efforts and speed of efforts
Drejer & Lund Vinding, 2007	Number of university graduates in firm's product development staff, number of employee participating in supplementary training, and the extent of in-house R&D in relation of product innovation

We believe that our method of evaluating the firm's absorptive capacity is new. Therefore, relying on two other factors determining the level of absorptive capacity; **intensity of firm's efforts and speed of firm** to identify and gather knowledge from external sources ( Kim 1998), we also asked the managers to evaluate their firm according to these factors (questions 11 and 12) .

Absorptive capacity is known as the dynamic capability of firm which consists of a set of organizational routines and process enabling the firm to gain and sustain competitive advantage (Zahra and George, 2001). Questions 13, 14, 15, 16, 17 and 18 are designed in order to shed light on whether absorptive capacity in Iranian enterprises is routinized or if it depends on some key persons in the firm. Relying on Zahra and George (2001), in order to have a good perspective of these routines which may construct absorptive capacity; we classify the routines combining absorptive capacity in three factors as mentioned below;

- Routines for analyzing, interpretation and understanding information obtained from external sources;
- Routines for adding, deleting new knowledge or interpreting previous knowledge in new manner; and
- Routines to harvest and incorporate knowledge into its operations.

In questions 13, 15 and 17, managers are asked whether these routines exist in their firm. In the cases of a positive answer to each question, managers are questioned about the degree of effectiveness of routines in questions 14, 16 and 18.

**Successful Past Experiences:** Firm's past experience is measured by the question 48 in the third part of the questionnaire. For each technology, managers are requested to determine their successful experience in each three modes of technology sourcing. Although this factor is one of the firm related factors in our study, the question to measure it is included at the third part of questionnaire because, for each technology, we needed to determine the successful past experiences of the firm had had before having access to the same technology.

**Strategic objectives:** Defined as strategic approaches which a firm follows and two generic strategies including differentiation and low-cost (as proposed by Porter, 1985). In questions 25 and 26, the managers are asked to determine firm's strategic objective.

**Firm size:** It is measured by logarithm of number of employees (question 36).

#### **4.4.3. Other Variables**

**Firm Age:** In question 35, we asked which year the firm was established and we calculated the age of firm till 2009. It may be considered as a control variable.

**Time that the technology is in the firm's portfolio:** Question 45 could be served as a control variable; it asks for the period of time that the technology is in the firm's portfolio.

**Semi-open question:** In order to ensure that no important factor has been overlooked in our study, question 47 was designed openly. In this question, managers are asked to determine factors that are considered in order to select the mode of access to a specific technology. These factors are classified into three groups, namely; technology –related, firm-specific and environmental and consist of Technology life cycle, Importance strategic of technology, Degree of urgency to gain access to the technology (technology-related factors), financial resources, other resources, and firm's learning

capacity as firm-related factors, and Legislations, Political conditions, Intellectual property rights and bargaining power of partners as environmental factors. In order to take consideration of other items which is not mentioned in the questionnaire, item “others” was added at the end of factors.

#### 4.5. Reliability and Validity

There are two kinds of questionnaire or survey pretest, namely; *participatory* and *undeclared*.

*Participatory pretests* dictate the researchers to tell respondents that the pretest is a practice run; rather than asking the respondents to simply fill out the questionnaire. Participatory pretests usually involve an interview setting where respondents are asked to explain reactions to question form, wording and order. This kind of pretest will help researchers to determine whether the questionnaire is understandable. When conducting an *undeclared pretest*, researchers simply ask respondents to fill out the questionnaire. The survey is given just as researchers intend to conduct it for real. This type of pretest allows researchers to check the standardization of the survey. According to Converse and Presser (1986), if researchers have the resources to do more than one pretest, it might be best to use a participatory pretest first, then an undeclared test. Therefore, we conducted a participatory pretest by 4 university professors and 2 CEOs and an undeclared pretest by 20 firm managers. The changes which were made in the questionnaire after participatory pretest have been described before in this chapter (section 3). In this section, we explain the results of the reliability and validity of our undeclared pretest in detail.

At the first step, size of sample to pretest the questionnaire and the overall sample size should be determined. In order to determine our sample size, we used stratified sampling method. This method is used for classified population. As our sample of high tech firms is classified into four groups and the variance of changes in each group is more than the variances of changes between groups, this mode is the most effective one (Ray and Parker, 1992) for cases like our study. Noting population of each industry, number of sample in each industry could be calculated using the following formulation:

$$n = \frac{N \cdot z_{\alpha/2}^2 \cdot p \cdot q}{e^2 (N - 1) + z_{\alpha/2}^2 \cdot p \cdot q}$$

In where:

Z: function of Normal distribution;

$\alpha = 0.1$  is probability of error;

$p = q = 0.5$  represents that each firm in the population has the same chance to be selected;

$N$  = total number of firms = 167

The amount  $\alpha$  could vary between 0.1 and 0.05, while choosing 0.05 gives the most number of sample, we chose 0.1. Using the above formulation, we calculated the sample size for pretest and for final research (table 4.8).

Table 4.8- Population and sample size of firms in each industry

industry	Telecommunication & Microelectronic	Information Technology (IT)	Nanotechnology	Biotechnology	Summation
Population	60	46	36	25	167
Sample size for pretest	6	4	3	2	15
Final sample size	7	6	4	3	20
Final Collecting Data	21	15	20	7	63

Reliability is an assessment of measurement error. In other words, during a reliable survey, question must be answered by respondents in the same way each time (Nunnally, 1978). The extent of reliability, or internal consistency, is calculated by Cronbach's alpha. The alpha values are reported in table 4.9. In the process of calculating alpha, questions 13, 15 and 17 that are yes or no questions were omitted. Questions 27 to 29 which indicate the percentage of firm's technologies that is gained by each three modes were also omitted. Questions 30, 31 and 32 were also omitted. These questions ask the name, web address and field of activity of firms. The alpha values are reported in table 4.9 and range from 0.859 to 0.606. The alpha values are ranged from 0.489 to 0.870 for pretest sample and from 0.614 to 0.817 for our total sample.

Table4.9- Cronbach's alpha of variables

Variables	Cronbach's alpha(pretest)	N(pretest)	Cronbach's alpha	N
Strategic Importance of technology	0.768	30	0.695	88
Degree of uncertainty	0.721	30	0.614	87
Past experience	0.489	29	0.635	86
Absorptive capacity	0.848	20	0.817	63
Potential absorptive capacity	0.768	20	0.701	56

Realized Absorptive capacity	0.789	20	0.707	63
Internal resources	0.870	20	0.812	62

Alphas in the range of 0.70 and higher present a good level of reliability, but the values can be lower (Nunnally, 1978) for newer scales. Alphas as low as 0.54 and .0529 have been also reported in the studies which used similar measures to our study (e.g. Steensma & Corley 2000 and Takacs, 2005). The validity of a survey question is determined by how well it measures the concept(s) it is intended to measure. As explained in section 4.3, the validity of our questionnaire is checked by interviewing the experts of the field.

## **4.6. Conclusion**

This chapter addressed the methodology of research while describing our research design. The procedure of data gathering as well as our sample study was described. Methods of evaluating different variables were presented and finally the reliability and validity of the research was examined.



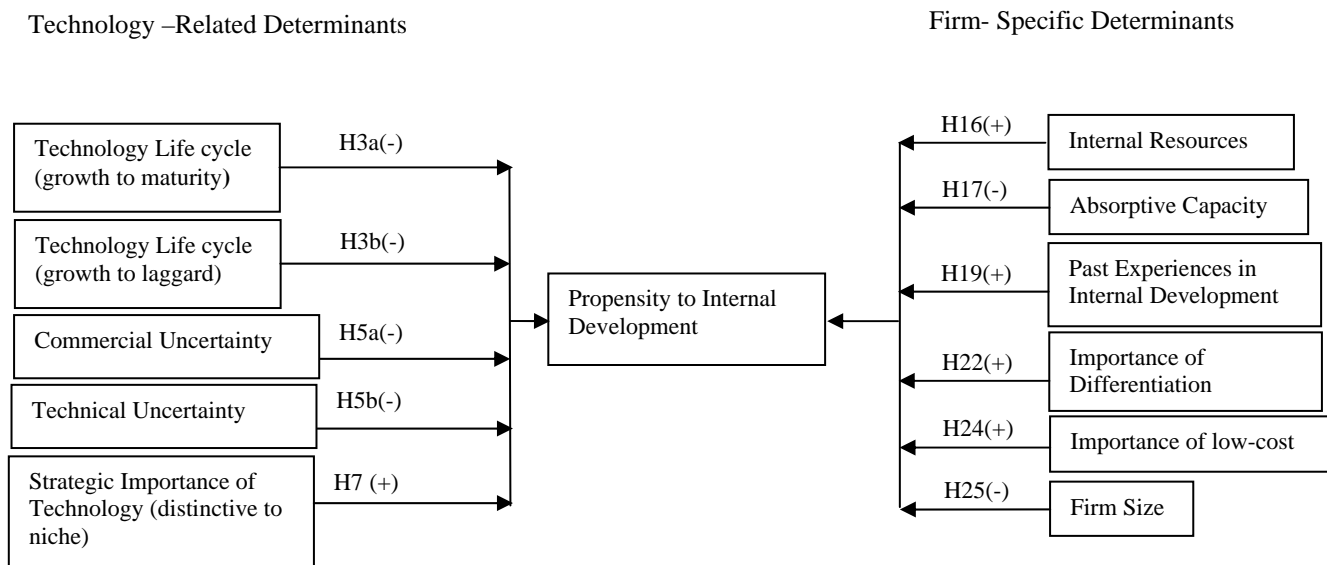
## **Chapter5**

### **Results and Analyses**

*This chapter deals with the statistical results of our research including testing the hypotheses. Employing statistical models such as factor analysis, regression, ANOVA, etc., factors affecting technology sourcing modes in the context of Iranian high-tech industries are identified. These statistical models are provided using SPSS software, version 15. Section 5.1 addresses descriptive statistics. Section 5.2 describes correlation analyses of research variables. Section 5.3 is devoted to hypotheses testing. The hypotheses of research are separately tested and the results are described. We use regression method in order to test how both technology related factors and firm-related ones predict a technology could be sourced internally, or gained by cooperation or through acquisition. The results of regression models are represented in section 5.4.*

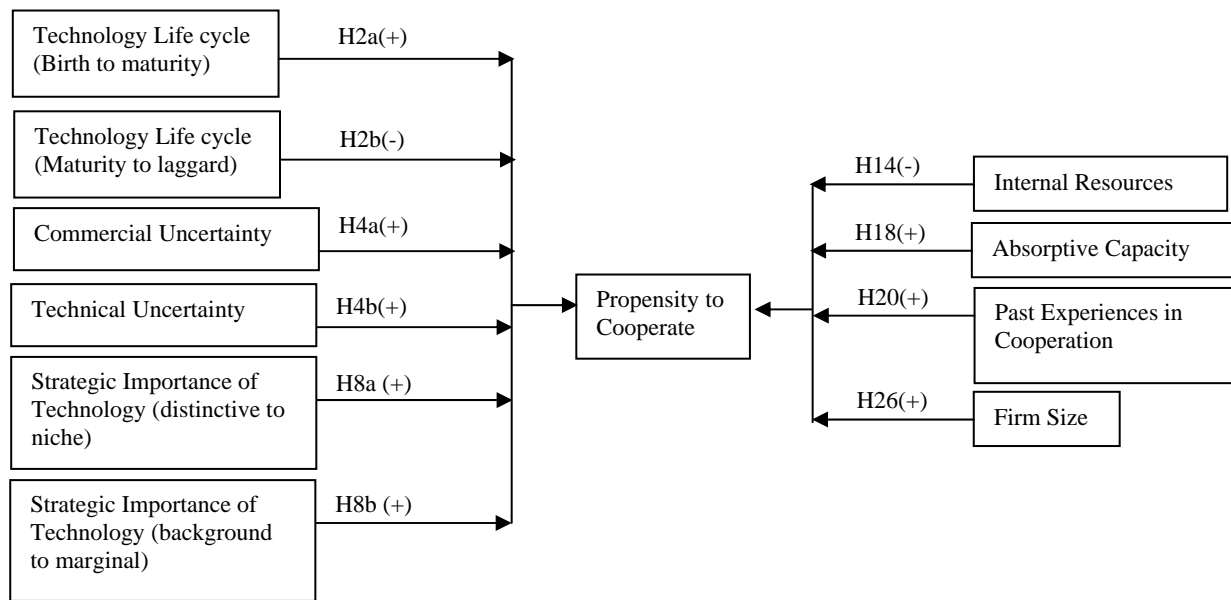
## 5.1. Descriptive Analyses

In order to present the descriptive analysis of our research, three kinds of data are defined; general information, dependent variables and independent variables. General information consists of all information about the firms in the studied sample, including field of activity, age of the firm, number of registered and non-registered patents, rate of innovativeness, and the length of time that the technology is in the firm portfolio. Additionally, descriptive analyses for some open questions like question number 47<sup>9</sup> are mentioned in section 5.1.1. Section 5.1.2 addresses dependent variables including propensity to internal development, propensity to cooperate and propensity to acquire, which are defined in two levels of analyses; technology and firm. Independent variables may be also classified in two groups; technology related and firm related. The stage of the life cycle in which the technology is situated, strategic importance of technology, degree of commercial and technical uncertainty, complexity, and technology urgency are the independent variables which are classified in the first group. Absorptive capacity, strengths of internal resources, successful past experiences in each TSM, strategic objectives and size of the firm are classified in the second group as independent variables. Figure 5.1 illustrates dependent and independent variables and related hypothesis.



<sup>9</sup> This question deals with the factors that influenced managers' decision to select a mode of technology sourcing. We nominated a list of factors and demand managers indicate which one was affected their decision of selected mode.

## Technology –Related Determinants



## Technology –Related Determinants

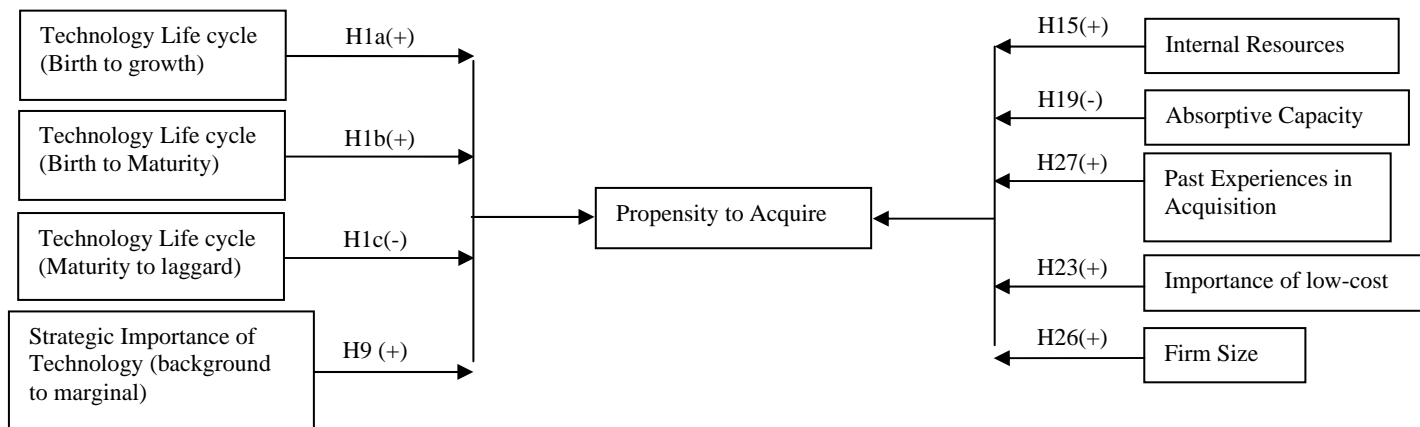


Figure 5.1- Technology Sourcing Model

The analyses are performed using SPSS logistic, version 15.

### 5.1.1. General Information

Type of firms in the sample: All studied companies in our sample are private and no company is public.

Amongst them 42 companies are manufacturer, 11 companies are service developer and 10 companies are declared both manufacturer and service developer. The sample companies have been established between one year and thirty seven years old (since year 2009). Frequency of companies in each group of age is presented in table 5.1. As it is shown in the table, the numbers of companies in our sample which have less than 10 years old and more than 10 years old are proportional.

Table 5.1- Distribution of Firms' Age in the Sample

Group	Number of companies	percent
<= 5 Years	24	38
5< age <= 10	10	16
10< age <= 15	9	14
15< age <= 20	7	11
More than 20 years	13	21

Patents: The average number of registered patents which each sample firm possesses is 2.42. Adding 'the number of patents which firms are able to register (but for some reasons don't do)' to 'the average of registered patents', the average of each firm augments up to 4.26 which means that about one half of firms' patents are not registered. The summation of registered and non-registered patents is shown in figure 5.2. We inquire about number of unregistered patents because in developing countries managers are not motivated to register the patents. Although this research is conducted in high-tech industries, majority of firms have between 0 to 10 registered and non-registered patents. The number of (registered and non-registered) patents is much less compared to the number of registered patents in similar industries in developed countries<sup>10</sup> possess (Archibugi & Pietrobelli, 2003). This situation is due to the fact that technology development is mostly imitative rather than innovative in developing economies. Thus, latecomer economies may grow over long periods based on imitative learning or improvements in production and organization which are not of patentable significance (Radošević & Kutlača, 1998).

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<sup>10</sup> In nanotechnology while U.S.A. with 32% and Germany with 12.9% registered patents are leading countries, developing countries such as South Korea (3.9%), Taiwan (0.3%) and India (0.5%) are far from developed countries. amongst developing countries China with 20.3% of registered patents is being part of leading countries (Maclurcan, 2005).

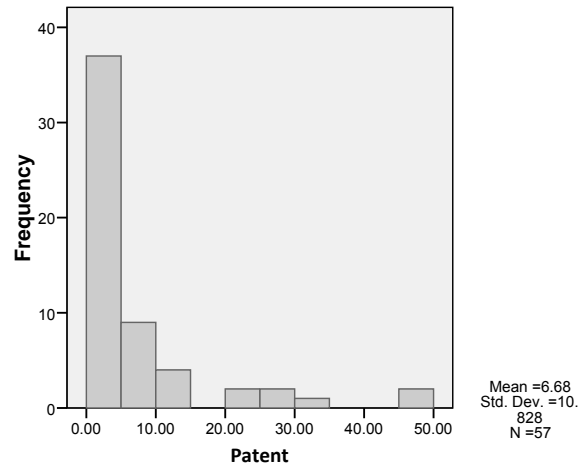


Figure 5.2- Frequency of Patents

Distribution of patents in each studied industry is also different. Figure 5.3 represents the distribution of registered patents of firms in different industries. Among Iranian high-tech industries, more than 50% of registered patents belong to firms activated in Nano technology. After Nano technology firms, firms activated in Biotechnology field possess the most registered patents. While firms active in IT and telecommunication and electronic industries have registered fewer patents, they have almost the same share in knowledge creation (measured by unregistered patent ratio) as firms active in Nano technology (figure 5.4).

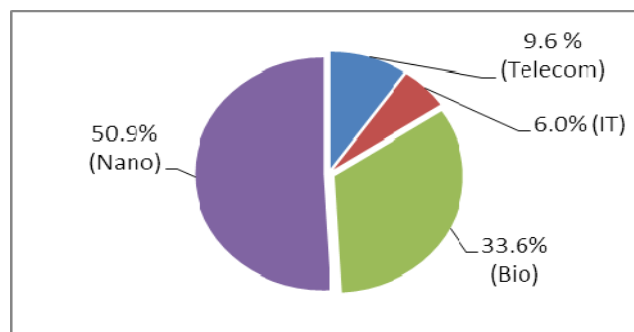


Figure5.3- Distribution of registered patents in Iranian high tech industry (2005 -2008)

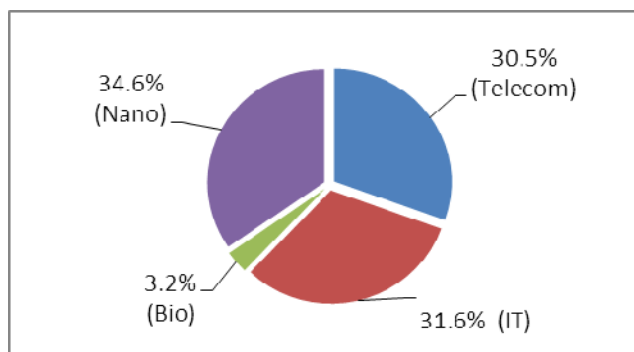


Figure5.4- Distribution of Non-registered patents in Iranian high tech industry (2005 -2008)

Comparing the share of different industries in knowledge creation, we may conclude that;

- Nanotechnology firms are the pioneers in knowledge and technology creation. Due to newness of Nano-sciences, it is evident that barrier to entry is low and many firms are active in this field. Another reason for this fact is protective legislations of Iranian government that encourage firms to work in the nanotechnology field.
- While biotechnology firms have 33% of the registered patents, they exploit the weakest number of unregistered patents. This situation may be related to characteristics of bio technology activities. Biotechnology firms studied in present research produce medical and healthcare productions, drugs and medical instruments in medicine as well as bio-fertilizers in agriculture. These kinds of productions necessitate specific tests, authorizations, certificates and standards at international level. The procedure to gain the certificates and standards also motivate the managers to register the patents.
- In contrast to bio-technology firms, IT and telecommunication and electronic industries possess the weakest tendency to register the patents while simultaneously they have the same share of knowledge creation that is not registered as patents. In these industries, Iranian firms are mostly followers and don't move on the technology. Moreover, as most of these firms are active in local market, they don't need to register their innovation as patents.

**Innovativeness:** This variable is measured by the percentage of annual revenue each firm gains by producing new product/service. As it is shown in figure 5.5, the majority of firms are situated in the first and second group (less than 50% of revenue is gained by product/ service innovation).

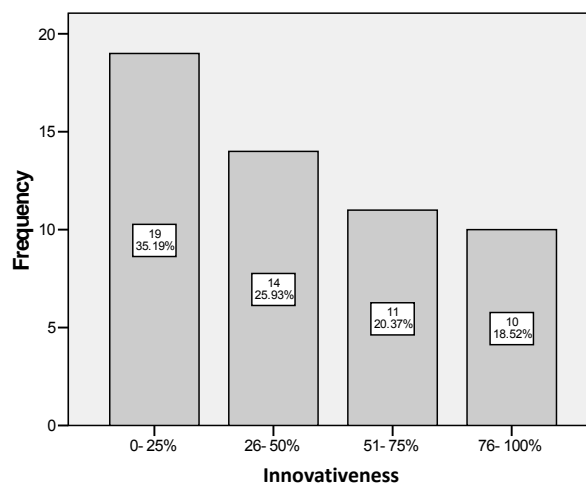


Figure 5.5- Rate of Innovativeness

Age of technology in the firm: By the age of technology, we refer to the period of time which a particular technology has been in the firm's portfolio (AGETECH). The respondents determined the age of technology for each technology for which they have completed the questionnaire. The selected technologies are between 1 month and 324 months (17 years) old. Although technologies with greater age (up to 100 months) could not create differentiation for the firms unless they may be transformed to techniques, these technologies or techniques may function as low cost strategy of the firm. Figure 5.6 shows the distribution of the variable.

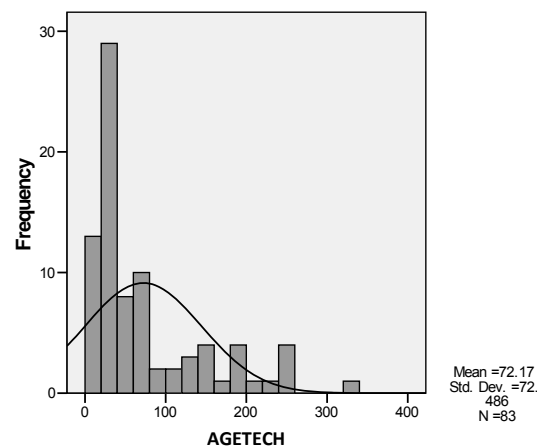


Figure 5.6- Distribution of Technology Age

As represented in the histogram, the majority of selected technologies (72%) are between 0 to 80 months old. This fact may guarantee the validity of the answers to the questions related to technologies because the third part of questionnaire necessitates considering the time and situation in which the managers decided to select a mode or combination of modes of technology sourcing. Therefore, we may conclude that: 'the more recent the technology in the firm portfolio, the more reliable the information given about'.

Semi-open question: This question is designed to prioritize the list of factors affecting TSMs while ensuring that all important determinants are considered in the questionnaire. Descriptive statistics of determinants are presented in table 5.2. Degree of independence of firm is mostly considered as one of characteristics of each mode (Chiesa, 2001).

Table 5.2- Descriptive Statistics of Factors Affecting Technology Sourcing Modes (Question 47)

	Technology life cycle (TLC)	Strategic Importance of Technology (SITECH)	Degree of Technology urgency (TURG)	Legislations (LEG)	Political Conditions (POLT)	Intellectual property Rights (IPR)	Bargaining Power of Partners (BARGPOW)	Financial Resources (FINRES)	Other Resources (RES)	Learning Capacity (LEAR)	Degree of Firm's independency (INDEP)	Other factors (OTHER)
Valid	86	86	86	86	86	86	86	86	86	86	86	86
Missing	3	3	3	3	3	3	3	3	4	3	3	3
Sum	31	48	34	23	28	22	18	40	11	35	41	2

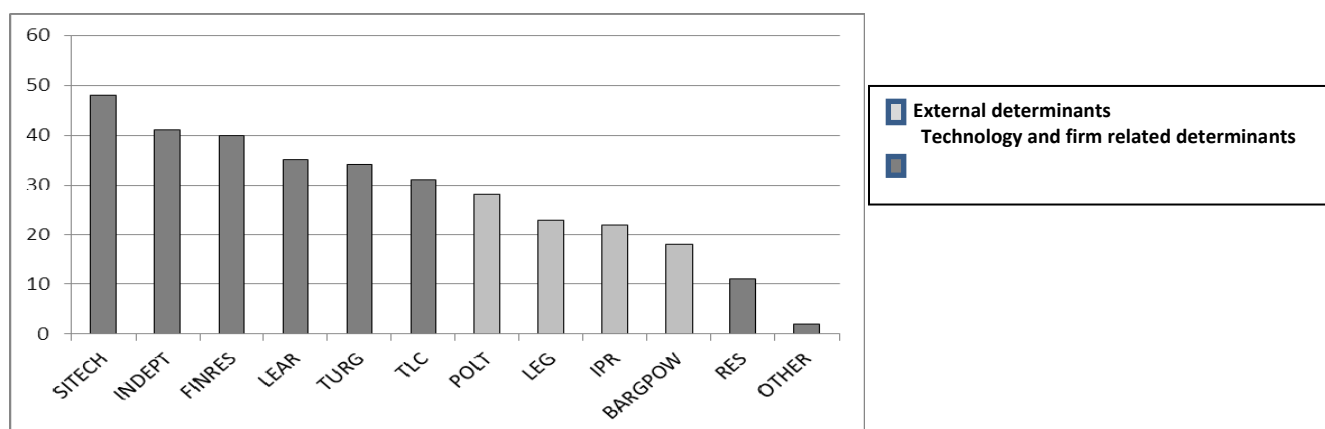


Figure 5.7- Hierarchy of Factors Affecting Technology Sourcing Modes

As represented in figure 5.7 the most appropriate factors that are considered by management in the procedure of technology sourcing modes selection are technology related and firm related ones. Environmental factors like political conditions of the country in question, legislations, intellectual property rights and other factors are placed in the less important order. Such order may explain why we have concentrated on these two groups of factors in the present research. Although environmental factors play an important role in selection of more appropriate modes of technology sourcing according to the literature research (Driffieled & Love, 2005; Oxely, 1999 and Veugelers & Cassiman, 1999) and while our pilot study confirms this fact (Jolly & Karamipour, 2006), thanks to Iranian managers' point of view the environmental factors are less considered in the process of technology sourcing mode selection. One reason which explains this fact is that environmental factors are rarely changeable by firms' managers, thus the managers are obliged to accept the situation.

In the next section, descriptive statistics of dependent variables are explained.

### 5.1.2. Dependent Variables

As it is explained in chapter 3, our studies include two types of dependent variables. These two types of variables differentiate mostly on the level of study: firm and technology. For each firm, managers are



requested to determine the percentage of the whole technologies which are gained by internal development, cooperation and acquisition. Figures 5.8 to 5.10 represent the total propensity of firms to each mode, including: internal development (PFR&D), cooperation (PFCOOP) and acquisition (PFACQ).

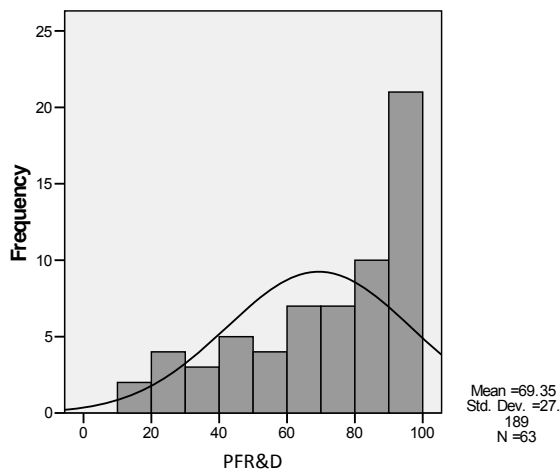


Figure 5.8- Distribution of Firms' propensity to Internal Development

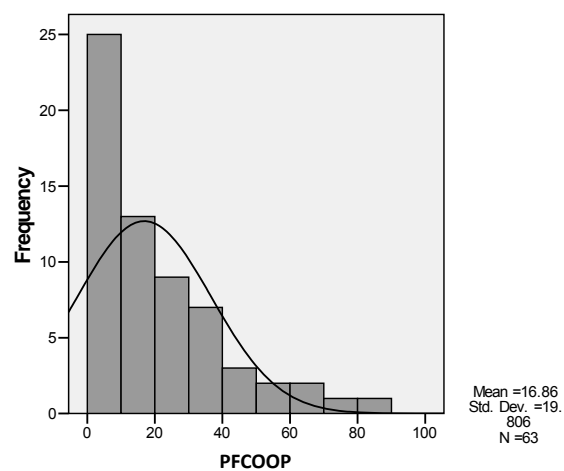


Figure 5.9- Distribution of Firms' propensity to Cooperate

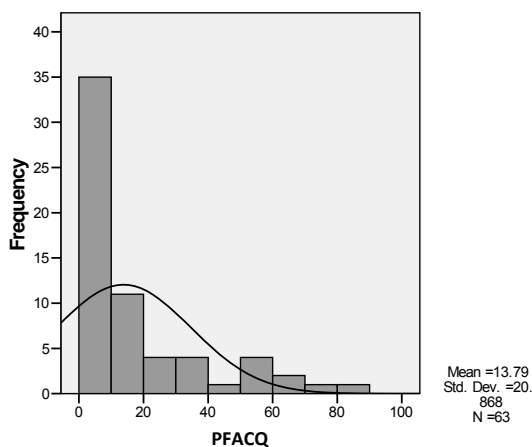


Figure 5.10- Distribution of Firms' propensity to Acquisition

Distribution of each dependent variable at technology level is represented in figures 5.11, 5.12 and 5.13.

Comparing the figures in two levels of studies (firm and technology) for each mode, consistency of the firms' behavior and technology could confirm the reliability of the responses to the questionnaires. In brief, it seems that Iranian firms are most likely to develop a technology internally and after internal development, cooperation is mostly used. Noting that firms active in technology –intensive industries are relying more and more on external sources of technology (Allred & Swan, 2004,) in the world wide,

it is surprising that Iranian firms emphasize more on internal R&D. In order to explain this fact, again we recall the specific environmental conditions of Iran. On the one hand, the political situation (especially the international sanctions against Iran) prevents foreign firms to make long-term technological cooperation with Iranian firms. On the other hand, lack of intellectual property protections within the country demotivates the managers to enter make a cooperative agreement with compatriot firms.

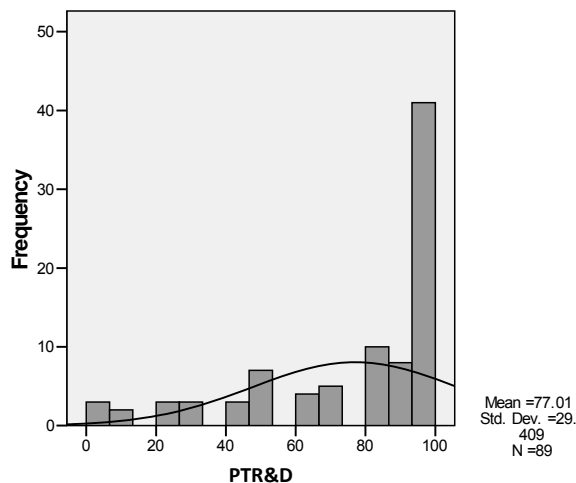


Figure 5.11- Distribution of Firms' propensity to Internal Development (Technology Level)

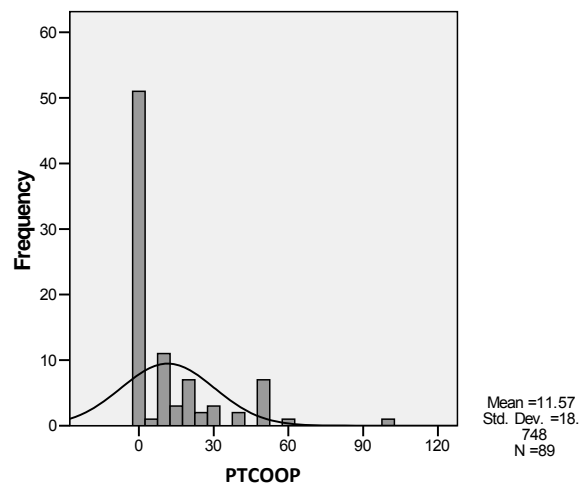


Figure 5.12- Distribution of Firms' propensity to Cooperate (Technology Level)

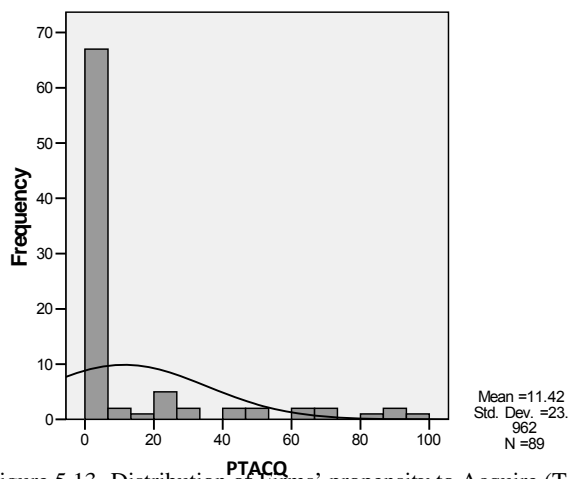


Figure 5.13- Distribution of Firms' propensity to Acquire (Technology Level)

At the technology level, firms' propensity to internal development is also higher compared to cooperation and acquisition. To explain this situation, we recall two technology specifications including: the stage of life cycle and the strategic importance of technologies. As explained later (in section 5.1.3.1), the majority of studied technologies are classified as distinctive and niche. These technologies are those which create competitive advantages for the firms and evidently firms are more likely to

develop them internally. Moreover, the increasing tendency of firms to internal development results from the fact that many studied technologies are in the second stage of life cycle, growth. In this stage, firms are more likely to develop the technology internally, unless they enter in a cooperative agreement or acquire the technology before (Lambe & Spekman, 1997). According to our descriptive statistics, firms' propensity to internal development decreases when the technology moves from birth and growth to maturity or laggard, table 5. Represents this changes for distinctive and niche technologies. As it is shown in the table 5.3, propensity to cooperate also decreases.

Table5.3-Technology sourcing modes according to changes in Life cycle and strategic importance

Strategic Importance of Technology	Technology life cycle	percentage of technology gained by:		
		Internal R&D	Cooperation	Acquisition
Distinctive	Birth & Growth	78.7	14.2	7.05
	Maturity & Laggard	65.25	8.75	26
Niche	Birth & Growth	85	12.5	2.5
	Maturity & Laggard	80	3.1	16.9

### 5.1.3. Independent Variables

Descriptive statistics for independent variables are classified into two levels corresponding to the two levels of study, i.e. descriptive analysis for technology–level variables ( section5.1.3.1) and firm-level variables(section 5.1.3.2).

#### 5.1.3.1. Technology –Level Variables

Technology Life Cycle: Amongst the questionnaires completed for 89 technologies, 81 respondents have answered to the question related to the life cycle of their firms' technology. This yields technologies with different ages including, 14 technologies in the first stage of their life cycles (birth), 39 of them in growth stage, 24 technologies in maturity phase, and only 4 of them in the laggard stage. It is important to note that by “The stage of technology life cycle” we mean the stage in which the technology was situated at the moment of decision making on gaining access to it in the industry at universal level. Figure 5.14, shows the percentage and frequency of technologies in each stage of life cycle.

According to the data represented in figure 5.14, the majority of technologies studied in this research are in the growth stage (48.15%) and maturity stage (29.63%). As it is expected, a very rare number of technologies are in their laggard stage (4.94%). These results confirm that managers have selected the technologies which are mostly new to the firm. In addition, considering that the majority of technologies

are strategically important for the firm<sup>11</sup>, they should have been in first stages of their life cycle. More over the respondents may be reluctant to declare using laggard technologies.

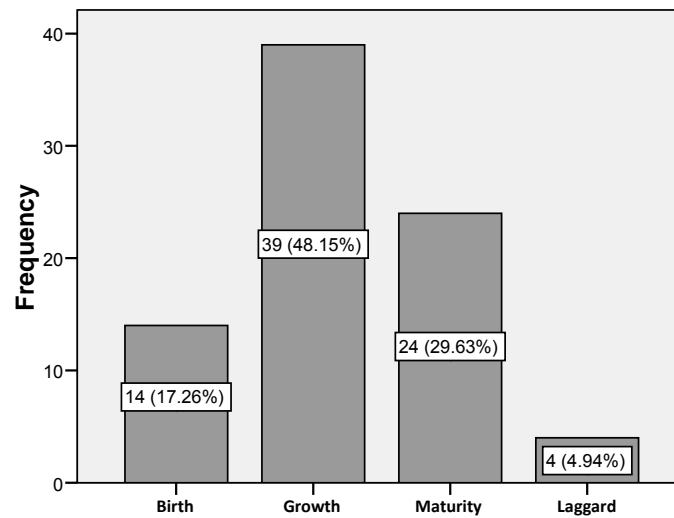


Figure 5.14- Distribution of Technologies according to Stage of Life Cycle

**Uncertainty:** Two kinds of uncertainty are studied in this research, namely; technical (TUNC) and commercial (CUNC). Data in descriptive statistics represents that technologies for which the questionnaire is completed are mostly employed with low degree of uncertainty, either commercial or technical. Table 5.3 represents the frequency and percentage of technologies which are considered commercially and technically uncertain in five degrees; form very low to very high uncertainty. As observed in the table 5.4, very few technologies are estimated with high and very high (4, 5) degree of uncertainty. One reason for such high degrees of uncertainty is that, in developing countries, innovations are mostly adapted from developed countries; it is evident that these technologies are applied in developed countries where they test technologies commercially and technically before applying them. Thus the technologies are not considered fully uncertain.

Table5.4- Commercial and Technical Uncertainty

		Frequency of CUNC	Cumulative Percent of CUNC	Frequency of TUNC	Cumulative Percent of TUNC
Valid	Very Low (1.00)	35	39.8	35	40.2
	Low(2.00)	31	75.0	33	78.2
	Medium (3.00)	16	93.2	16	96.6
	High (4.00)	4	97.7	3	100.0
	Very High (5.00)	2	100.0	0	100.0
	Total	88		87	
Missing	System	1		2	
Total		89		89	

<sup>11</sup> See subsection related to strategic importance of technology in this section.

As it is observed in the table, the responses on degree of commercial and technical uncertainty are consistent. We may conclude that respondents' perception of technical and commercial uncertainty makes no difference to their response. Section 5.2 addresses different effects of these two factors on each mode of technology sourcing while testing the related hypothesis.

**Strategic Importance of Technology:** In chapter 3, four kinds of technologies were defined for the firm, including; distinctive, niche, background and marginal. Table 5.5 represents the number of technologies in each group. The majority of technologies for which the questionnaire is completed is distinctive and niche. As marginal technologies are not numerous, their related hypothesis (H7b and H8) could not be tested.

Table 5.5- Distribution of Technologies According to their Strategic Importance

Technologies	Distinctive	Niche	Background	Marginal	Sum
Number in each group	61	21	1	2	85

**Urgency:** As it is represented in figure 5.15, the majority of technologies studied in this research are supposed to be urgent for the firms to gain access to them. Noting that rate of technological innovation in high-tech industries is high; even in developing countries, it is evident that many technologies are considered urgent to gain.

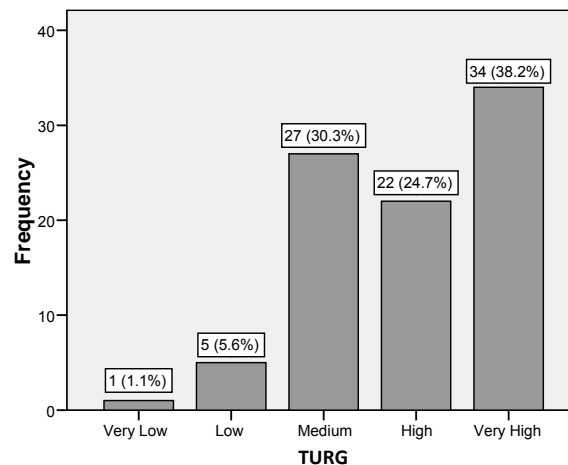


Figure 5.15- Degree of Urgency of Technologies

### 5.1.3.2. Firm-Level Variables

**Internal Resources:** In order to estimate the level of internal resources of a firm, we asked six questions about different kinds of firm's resources and requested the managers to evaluate and rate each of their firms' resources compared with the industry leader in terms of from very weak to very high levels. Table 5.6 represents the results of descriptive statistics.

Table 5.6- Distribution of Firms' Internal Resources

		Financial	Human	Technological	Physical	Organizational	Reputation
N	Valid	63	63	63	63	63	62
	Missing	0	0	0	0	0	1
Mean		2.87	3.76	3.94	3.27	3.43	3.89
Median		3.00	4.00	4.00	3.00	4.00	4.00
Mode		3	4	4	4	4	4
Std. Deviation		1.326	.893	.948	1.066	1.058	1.026
Variance		1.758	.797	.899	1.136	1.120	1.053
Minimum		1	2	1	1	1	1
Maximum		5	5	5	5	5	5

As observed in the above table, all the respondents evaluate their firm's internal resources as up to the average (about high); only the financial resource is estimated less than average. Noting that high-tech industries are characterized by strong intangible resources (Goman, 2001); the responses show validity. Amongst intangible resources; the human ones don't include very weak option. Noting that technological and human resources are similar with very few differences, the results show that managers also estimated two resources nearly (an average of 3.76 for human resources compared to 3.94 for technological resources). It may be concluded from figures 5. 17 to 5.22 that while the majority of firms have evaluated themselves up to the average for five kinds of internal resources (namely; human, technological, physical, and organizational and reputation), they have considered their financial resources as weak. However, it seems that financial resources are underestimated because a) financial resources are necessary to enrich other resources, therefore one condition to benefit from a high level of other resources is to encompass a good level of financial resources and b) sometimes the managers are unwilling to give financial information<sup>12</sup>.

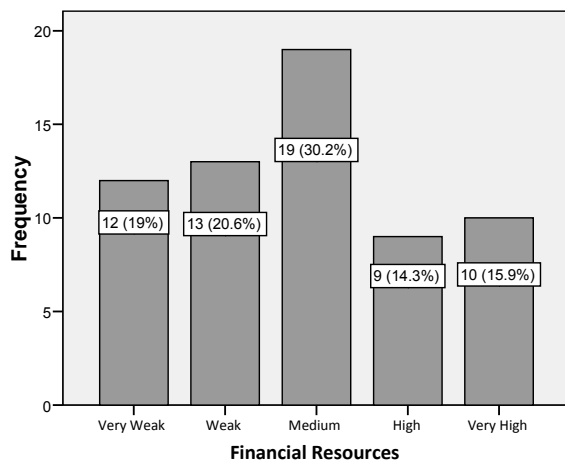


Figure 5.16- Distribution of Financial Resources

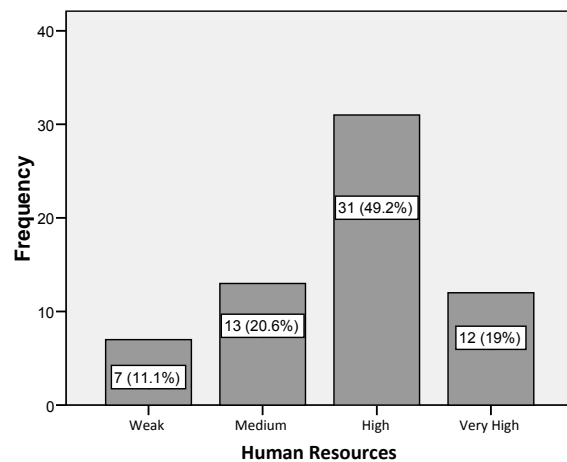


Figure 5.17- Distribution of Human Resources

<sup>12</sup> Only 15 of a total 63 managers give financial information of their firm.

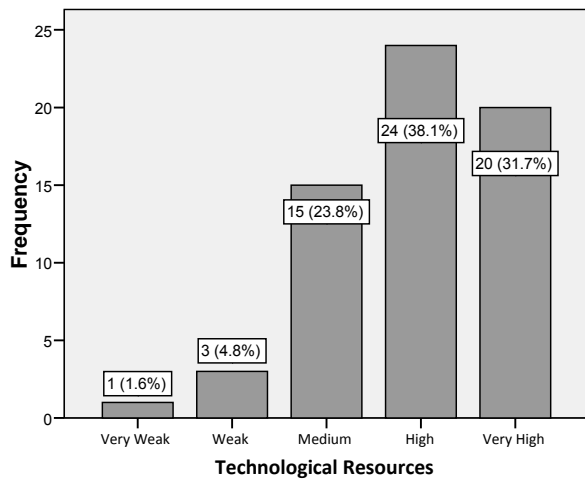


Figure 5.18- Distribution of Technological Resources

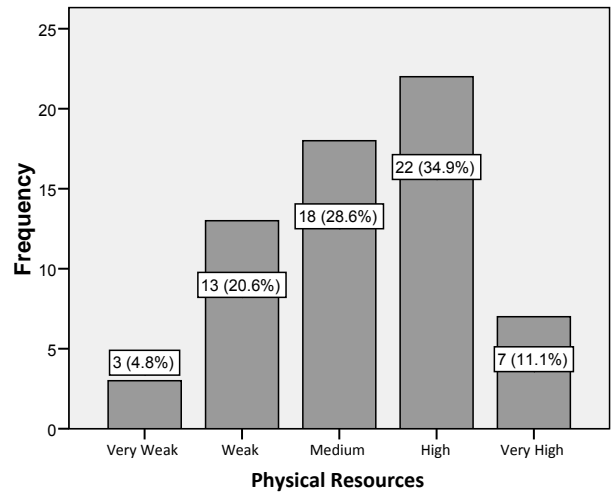


Figure 5.19- Distribution of Physical Resources

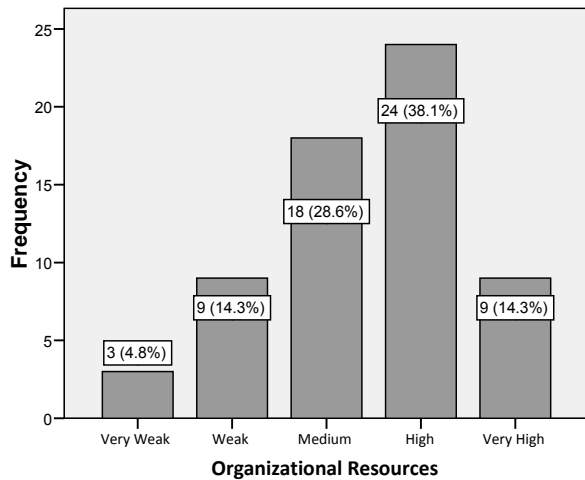


Figure 5.20- Distribution of Organizational Resources

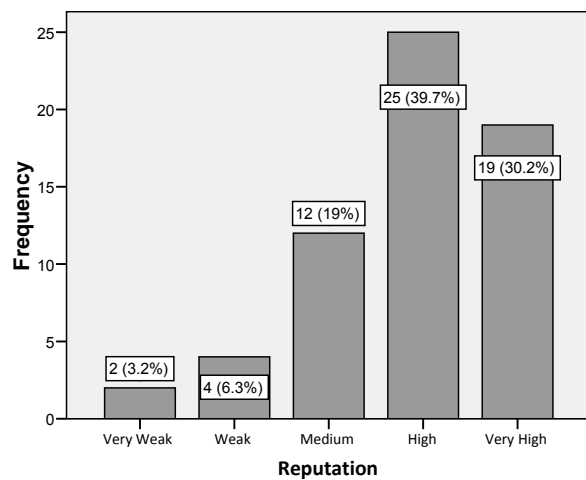


Figure 5.21- Distribution of reputation Resources

**Absorptive Capacity:** As explained in chapter 4, questions 1 to 10 are designed to measure absorptive capacity of the firm; questions 1 to 7 measure potential absorptive capacity and questions 8 – 10 measure realized absorptive capacity. Figures 5.23 to 5.25 show how levels of absorptive capacity and its components, namely; potential and realized, change in Iranian firms.

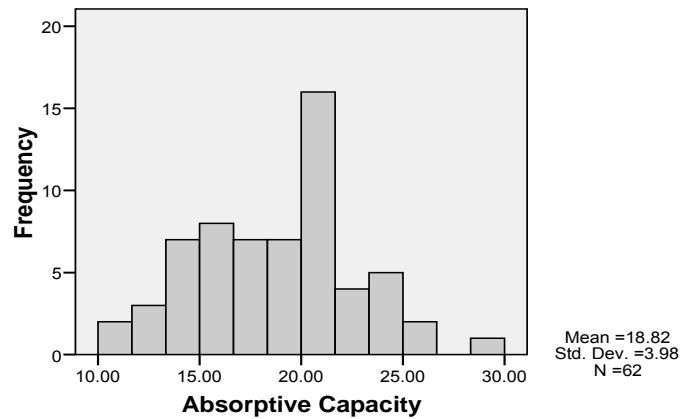


Figure 5.22- Level of Absorptive Capacity

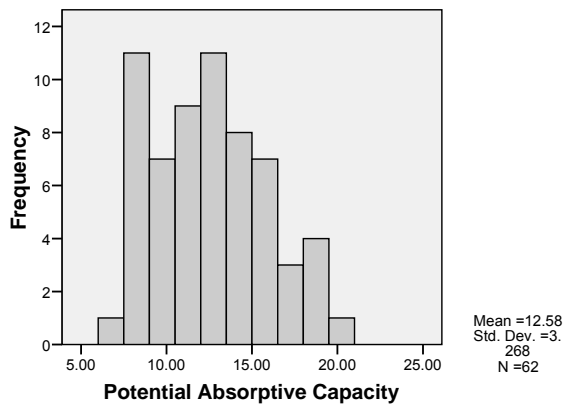


Figure 5.23- Level of Potential Absorptive Capacity

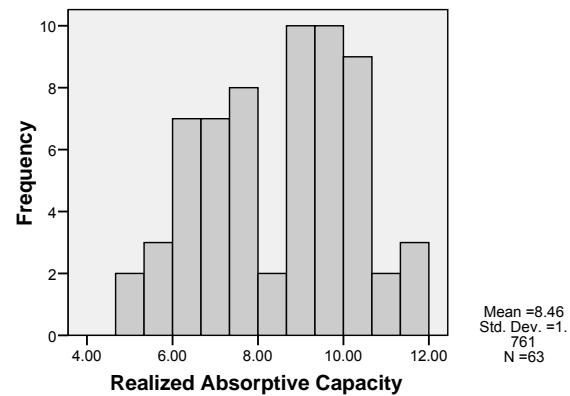


Figure 5.24- Level of Realized Absorptive Capacity

Using principal component Index, absorptive capacity takes an amount between 10 to 30, potential absorptive capacity changes from 6 to 21 and the realized one changes from 4 to 12 (table 5.7).

Table 5.7- Absorptive Capacity and its components

		Realized Absorptive Capacity	Potential Absorptive Capacity	Absorptive capacity
N	Valid	63	62	62
	Missing	0	1	1
Mean		8.4637	12.5831	18.8151
Std. Deviation		1.76131	3.26836	3.98042
Minimum		4.76	6.73	10.09
Maximum		11.90	20.66	29.21



The respondents evaluate their ability to assimilate knowledge from external sources next to the average as compared with industry leader in Iranian market. Accordingly, the ability of firms to assimilate knowledge from exhibitions and showrooms, suppliers, conferences and scientific journals and customers are estimated upper than average while the ability to attract competitors is nearly equal to average. The ability of the firm to assimilate knowledge from research centers is evaluated less than average. This fact may not represent the firm's ability but it may be due to other reasons; such as lack of independent research centers in Iran, and also the fact that the majority of this rare research centers are public.

The respondents estimate the level of realized absorptive capacity more than the level of potential absorptive capacity; with means 3.37, 3.62, 3.70 respectively for questions 8, 9, 10. Noting that the median and mode of these questions are 4, and the variances are less than variances of questions 1 to 7; the average level of realized absorptive capacity may be estimated high (4) in Iranian enterprises.

Respondents also evaluate two other determinants of absorptive capacity; **intensity of firm's efforts and speed of the firm** to identify and gather knowledge from external sources. Intensity level of firms' efforts is about high while speed of firms is about average.

In order to institutionalize firms' absorptive capacity, three types of routines should be routinized, including; routines for analyzing, interpretation and understanding information obtained from external sources (Routine 1), routines for adding, deleting new knowledge or interpreting previous knowledge in new manner (Routine 2), and routines to harvest and incorporate knowledge into the operations (Routine 3) (Zahra & George, 2001). Table 5.8 represents to what extent the firm has routinized absorptive capacity.

Table5.8-Distribution of Routines in the Sample

		Frequency (Routine 1)	Valid Percent (Routine 1)	Frequency (Routine 2)	Valid Percent (Routine 2)	Frequency (Routine 3)	Valid Percent (Routine 3)
Valid	No	28	44.4	27	42.9	24	38.1
	Yes	35	55.6	36	57.1	39	61.9
	Total	63	100.0	63	100.0	63	100.0

Routine1: Routines for analyzing, interpretation and understanding information obtained from external sources.

Routine2: Routines for adding, deleting new knowledge or interpreting previous knowledge in new manner.

Routine3: Routines to harvest and incorporate knowledge into the operations.

Number of Using equality of proportions test to compare firms that have routinized absorptive capacity, we conclude that distribution of all the three routines amongst firms is statistically equal. Test of homogeneity of variance is significant with  $\alpha = .300$ . Results of equality of means testing are presented in table 5.9.

Table 5.9- Homogeneity of Routines

	Sum of Squares	df	Mean Square	F	Sig.
<b>Between Groups</b> (Combined)	.138	2	.069	.279	.757
Linear Term	.127	1	.127	.515	.474
Deviation	.011	1	.011	.043	.836
Within Groups	45.841	186	.246		
Total	45.979	188			

Figures 5.26 to 5.28 represent percentage of our sample firms with different degrees of effectiveness in each routine. To clarify the relations of these three routines, we also present the mean of effectiveness of firms which have routine 1 (NF1), firms which only have routine 2 (NF2) and firms which just have routine 3 (NF3). These measures are represented in table 5.10. It seems that the efforts of firms which routinize the first routine are more effective than the others.

Table 5.10- Effectiveness of Routines without Other Routines

	NF1	NF2	NF3
N			
Valid	35	12	10
Missing	28	51	53
Mean	3.4571	1.3333	3.2000
Median	3.0000	1.0000	3.0000
Std. Deviation	.70054	.88763	1.03280
Variance	.491	.788	1.067

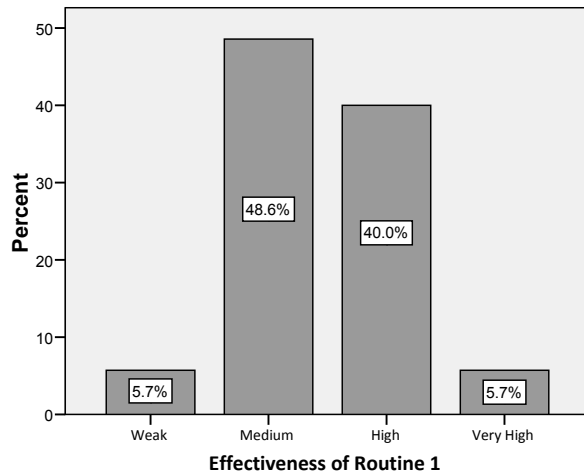


Figure 5.25- Percentage of Firms with Different Effectiveness of Routine 1

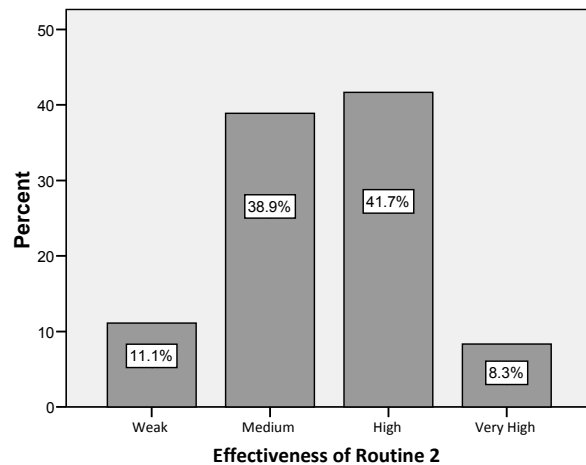


Figure 5.26- Percentage of Firms with Different Effectiveness of Routine 2

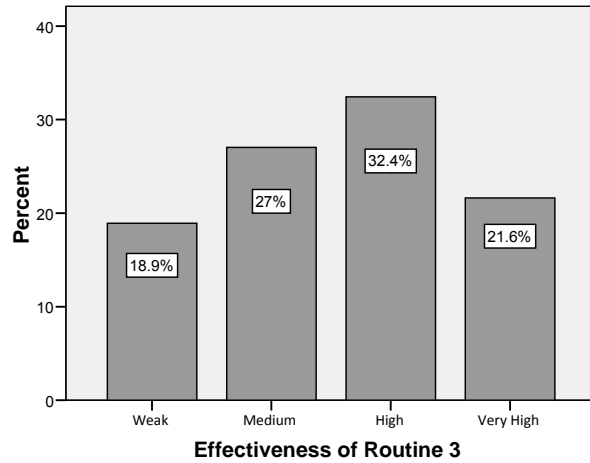


Figure 5.27- Percentage of Firms with Different Effectiveness of Routine 3

**Successful Past Experiences:** Respondents are asked to determine the amount of successful past experiences in each mode before deciding to gain access to a specific technology. The level of past experience range from “no successful past experiences (1) to a lot of successful past experiences (5), in a five point likert scale. Figures 5.29 to 5.31 represent the variables; TEXR&D, TEXCOOP, and TEXACQ.

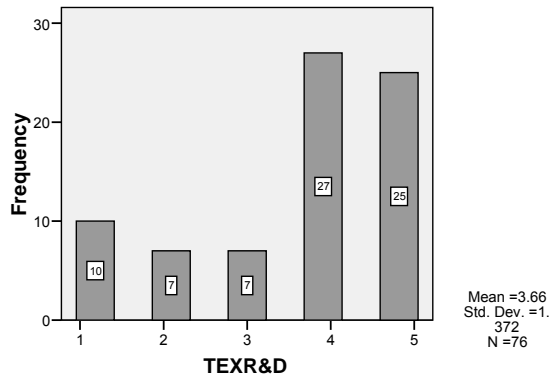


Figure 5.28- Successful Past Experiences in Internal Development

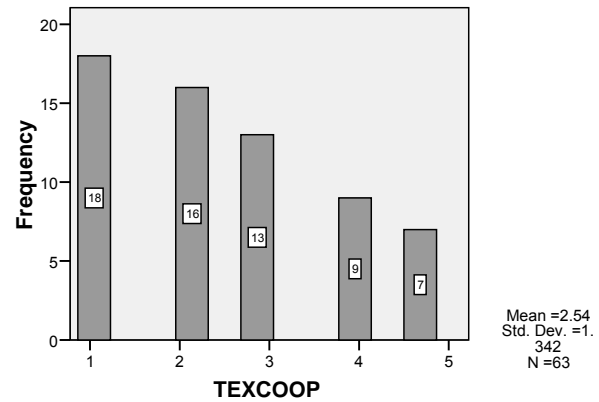


Figure 5.29- Successful Past Experiences in Cooperation

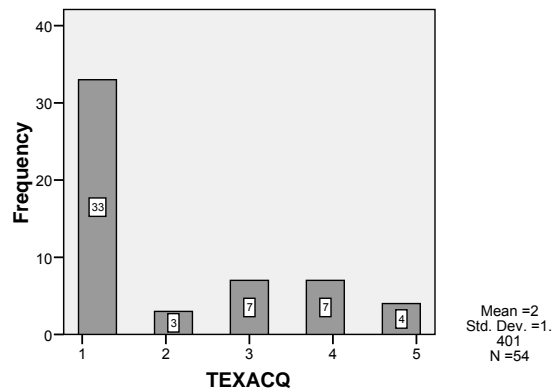


Figure 5.30- Successful Past Experiences in Acquisition

As observed in the above figures, the majority of successful past experiences are respectively in internal development and cooperation while the majority of firms declare rare successful experiences in acquisitions. Such statistic may explain why the majority of technologies have been developed internally.

**Strategic Objectives:** Respondents are asked to determine the extent to which the strategy of firms is differentiation or cost leadership. As it is observed in figure 5.32, the majority of firms are declared with differentiation goal (30 firms amongst 63) and only 9 firms follow the strategy of cost leadership. The rest of respondents (24) declare that their firms follow two strategies, including differentiation and cost leadership simultaneously.

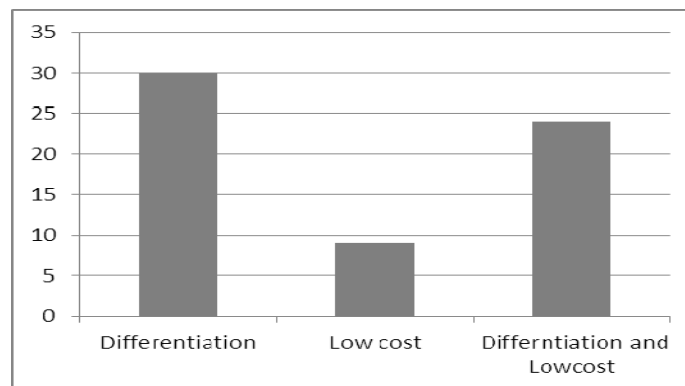


Figure 5.31- Strategic Objectives of Firms

The majority of respondents are being part of firms which propose the unique products or services in the local market; this is why the managers declare their tendency to pursue differentiation strategy.

Firm size: Relying on the number of employees to measure size of company, the majority of respondents declare that they have less than 200 employees. Different countries define SMEs differently. Table 5.11 represents European Union’s definition of firm size in 2005. Since we are confronted with lack of financial information like firms’ turnover or balance sheet, in this research we rely on the number of employees. Moreover, as our focus is on the technology intensive industry with an average of staff less than other industries, we rely on the definition of European commission.

Table 5.11- Firm Size Definition

Firm size	Headcounts (USA definition)	Headcounts (European Union)	Turnover	Balance sheet total
Large	>= 500			
Medium	<500	< 250	<= 50 million €	<= 43 million €
Small	<100	< 50	<= 10 million €	<= 10 million €
Micro	<10	< 10	<= 2 million €	<= 2 million €

Considering this definition, amongst 63 studied firms; eight firms are classified as micro size, thirty firms are small and sixteen firms are medium size and only five firms are large. We could not access the data for four firms.

Figure 5.33 represents the distribution of firms according to number of employees. We also define the ratio of number of R&D staff on the number of employees as “R&D Intensity”. Figure 5.34 shows distribution of this ratio in studied firms.

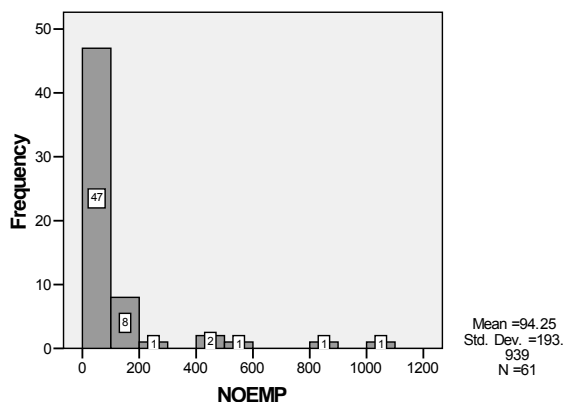


Figure 5.32- Distribution of Firm Size

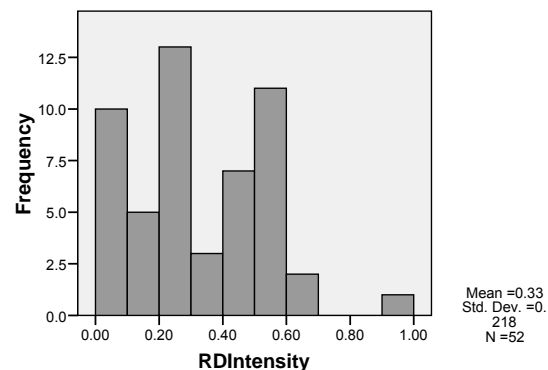


Figure 5.33- Percentage of R&D Staff on Total Employee

Next section concerns with correlation analyses of the variables.

## **5.2. Correlation Analysis**

This section provides correlations for the variables, i.e. both technology and firm related ones. Noting that our research is conducted at two level; technology and firm, two tables are prepared for reporting correlations variables at each level separately. Table 5.12 represents the correlations of technology – level variables and table 5.13, shows correlations at firm level.

Table 5.12- Correlations of Variables at Technology Level

Number	Variable	Means	s.d.	1	2	3	4	5	6	7	8	9	10
1	Age of Technology in the Firm (AGETECH)	72.17	72.49	1									
2	Technical Uncertainty (TUNC)	1.85	.84	.100	1								
3	Commercial Uncertainty (CUNC)	1.94	.99	-.038	<b>.448 (**)</b>	1							
4	Urgency of technology (TURG)	3.93	1.01	-.010	<b>-.368 (**)</b>	-.026	1						
5	Successful past experiences in R&D at technology level (TEXR&D)	3.23	1.75	<b>.224 (*)</b>	-.132	.125	.089	1					
6	Successful past experiences in Cooperation at technology level (TEXCOOP)	1.86	1.61	-.049	-.116	.075	-.035	<b>0.409 (**)</b>	1				
7	Successful past experiences in Acquisition at technology level (TEXACQ)	1.26	1.47	.162	-.069	.109	.059	<b>.256 (*)</b>	<b>.447 (**)</b>	1			
8	Percentage of internal development of technology (PTR&D)	77.01	29.41	.119	<b>-.169 (*)</b>	-.046	.101	.163	<b>-.236 (*)</b>	<b>-.271 (*)</b>	1		
9	Percentage of technology cooperation (PTCOOP)	11.57	18.79	-.166	<b>.261 (**)</b>	.052	-.069	-.118	<b>.310 (**)</b>	.067	<b>-.582 (**)</b>	1	
10	Percentage of technology acquisition (PTACQ)	11.42	23.96	-.015	0.36	-.027	-.069	-.112	.068	<b>.364 (**)</b>	<b>-.772 (**)</b>	-.068	1

\*\*\*Correlation is significant at the 0.001 level (2-tailed).

\*\* Correlation is significant at the 0.01 level (2-tailed).

\* Correlation is significant at the 0.05 level (2-tailed).

At *technology-level*, some significant correlations exist between independent variables and three dependent variables, including; percentage of technology gained by internal development, cooperation and acquisition (table 5.12). Three independent variables have mild negative correlations with percentage of technology gained by **internal development (PTR&D)**. These variables are degree of technical uncertainty (-0.169) and successful past experiences in cooperation (-0.236) and successful past experiences in acquisition (-0.271). The negative correlation between **degree of technical uncertainty** (TUNC) and propensity to internal development means that firms are more likely to develop the technologies which are less uncertain; these technologies may be before developed by other companies. These technologies may not be new to the world or the country; they are mostly new to the firm. Two other variables **successful past experiences in cooperation and acquisition** are also negative effect on propensity to internal development. It means that the more firms have successful past experiences in other modes, the less they rely on internal development.

Two independent variables show significant positive correlations with percentage of technology gained by **cooperation (PTCOOP)**. These variables are: degree of technical uncertainty (TUNC) (0.261) and firm's successful past experiences in cooperation (TEXCOOP) (0.310). As the **degree of technical uncertainty** for a technology increases firms are more likely to cooperate with others. The main incentives in such relations are sharing cost and risk related to technical uncertainty. Second independent variable that influence positively propensity to cooperate is firms' **successful past experiences in cooperation**. This relation may also explain the reason of less rate of cooperation between studied firms; since firms don't practice successful experiences in cooperation, they have not enough motivation to use it.

The only independent variable which shows correlations with the third dependent variables; percentage of technology gained by **acquisition (PTACQ)**, is the firm's successful past experiences in acquisitions (0.364). As the firm's successful past experiences in acquisition increases, the propensity to acquire the technology increases.

Independent variables are also correlated in some cases. **There is a positive strong correlation between technical uncertainty and commercial uncertainty** (0.448) which may explain why the two concepts are very similar and make it difficult to distinguish between these two variables in many cases. For instance, in some studies the two concepts are considered interchangeably (Hoffman and Shaper-Rinkel, 2001, White, 2000). Moreover, because in the questionnaire two questions are successive, the respondents may reproduce similar responses.



**A negative strong correlation exists between technical uncertainty and urgency of gaining access to the technology (-0.368).** This means that the more the technical uncertainty related to a technology the less urgent the technology to obtain. In such situations firms are searching substitute technologies with lower degree of uncertainty.

**A positive mild correlation exists between firms' successful past experiences in R&D and age of technology in the firm (0.224).** Noting that average of technologies' ages in a firm and the age of firm itself are strongly correlated (0.396); it can be concluded that the correlation between age of the firm and successful past experiences in internal development causes the first correlation.

Table 5.13- Correlations of Variables at Firm Level

NO.	Variable	Means	s.d.	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
12	Internal resources (INRES)	15.17	3.29	1																		
13	Financial Resources (FINRES)	2.87	1.33	.144	1																	
14	Human Resources(HUMRES)	3.76	0.89	.635 (**)	.465 (**)	1																
15	Technological Resources (TECHRES)	3.94	0.95	.722 (**)	.404 (**)	.477 (**)	1															
16	Physical Resources (PHYRES)	3.27	1.07	.688 (**)	.470 (**)	.221	.400 (**)	1														
17	Organizational Resources (ORGRES)	3.43	1.06	.678 (**)	.315 (*)	.246	.413 (**)	.45 (**)	1													
18	Reputation (REPT)	3.89	1.03	.796 (**)	.527 (**)	.449 (**)	.497 (**)	.386 (**)	.531 (**)	1												
19	Absorptive Capacity (AC)	18.81	3.98	.382 (**)	.290 (*)	.258	.366 (**)	.305 (*)	.196	.208	1											
20	Potential Absorptive Capacity (PAC)	12.58	3.27	.350 (**)	.282 (*)	.212	.305 (*)	.286 (*)	.171	.198	.932 (**)	1										
21	Realized Absorptive Capacity (RAC)	8.46	1.76	.237	.123	.138	.295 (*)	.261 (*)	.130	.135	.769 (**)	.496 (**)	1									
22	Successful past experience in R&D at firm level (FEXR&D)	3.33	1.97	.115	.157	.015	.067	.143	.052	.054	-.165	-.179	-.110	1								
23	Successful past experience in cooperation at firm level (FEXCOOP)	1.99	1.62	.037	.002	.068	.049	.027	.156	-.089	.002	.047	-.135	.363 (**)	1							
24	Successful past experience in acquisition at firm level (FEXACQ)	1.37	1.57	.083	-.002	-.075	.029	.103	.273 (*)	.013	-.152	-.145	-.171	.163	.455 (**)	1						
25	Differentiation as Firm's strategic objective (DIFF)	4.10	.783	.043	.011	-.083	.096	.123	.008	.014	.057	-.010	.151	-.018	-.030	.274 (*)	1					
26	Cost leadership as Firm's strategic objective (LOWCOST)	3.30	1.34	-.065	-.132	.128	.010	-.103	-.002	-.037	.192	.138	.199	-.118	.151	-.132	-.012	1				
27	Firm size (SIZE)	1.49	.618	.288 (**)	.289 (*)	.229	.071	.415 (**)	.051	.153	.055	-.019	.099	.345 (**)	.200	.246	.158	-.045	1			
28	Firm's Propensity to R&D (PFR&D)	69.35	27.19	-.089	-.075	-.096	.235	-.057	-.153	-.167	-.149	-.138	-.02	.092	-.346 (**)	-.318 (*)	-.238	-.208	-.264 (*)	1		
29	Firm's Propensity to cooperate (PFCOOP)	16.86	19.81	-.031	-.052	.142	-.219	.023	-.006	-.023	.205	.181	.088	.081	.470 (**)	.062	-.213	.044	.132	-.646 (**)	1	
30	Firm's Propensity to acquire (PFACQ)	13.79	20.87	.144	.148	-.010	-.098	.053	.205	.237	-.008	0.009	-.057	-.179	.037	.339 (**)	.148	-.199	.220	-.690 (**)	-.107	1

At *firm level*, some significant correlations exist between independent variables and three dependent variables, including; Propensity to internal development, cooperation and acquisition (table 5.13).

Three independent variables have negative correlations with firms' **propensity to internal development (PFR&D)**. These variables are successful past experiences in cooperation and acquisition as well as firm size. The negative correlation between propensity to internal development and **successful past experiences in cooperation** (-0.346) and **acquisition** (-0.318) means that the less firms have successful past experiences in other modes of technology sourcing (cooperation and acquisition) the more they rely on internal development. Propensity of the firm to internal development is negatively correlated with **firm size** (-0.264). Larger firms are less likely to develop a technology internally, because they have access to more financial and physical resources which provide initial conditions to rely on other modes. In our research, while positive strong correlation exists between firm size and level of strengths in physical and financial resources, no correlation exist between other resources such as human and technological and organizational resources. The three later resources play important role to make decision on internal development (Bayona et al., 2001). **Propensity to cooperate (PTCOOP)** is positively correlated with firms' **successful past experiences in cooperation** (0.470). As a firm's past experiences in cooperation increases, it rely more on cooperation.

The third dependent variable, i.e. **propensity to acquisition (PTACQ)**, is positively correlated with firms' **successful past experiences in acquisition** (0.339).

There are several correlations among independent variables at the firm level. With regard to level of **firm's resources (INRES)**, there is a **positive correlation with human resources** (0.635), **physical resources** (0.688), **technological resources** (0.722), **organizational resources** (0.678), and **reputation** (0.796). Noting that INRES is defined as a function of six kinds of resources; the positive correlation between INRES and other resources is mathematically evident.

**There are strong positive correlations between financial resources and five other kinds of resources; human, technological, physical, organizational and reputation.** It may be concluded that financial resources influence other resources; a necessary condition to develop resources is having access to financial resources. While **technological and human resources are positively correlated** (0.477), there are no correlations between human resources and physical and organizational resources. Technological and human resources are conceptually confusing. The R&D capabilities and tacit know –how are generally embedded in the employees; also two questions are situated consecutive in the questionnaire, these two fact explain positive strong correlation between two variables.

**A positive strong correlation exists between human resources and reputation** (0.449). That may mean the managers are relying the two concepts to each other. In other words benefiting from

qualified human resources give strengths on reputation. **There are positive correlations between absorptive capacity and financial (0.290), technological (0.366) and physical resources (0.305).** In the literature absorptive capacity is evaluated with R&D capabilities and also R&D budget of a firm (Cohen & Levinthal, 1990, Stock et al., 2001 amongst others). In our research technological resources refer directly to firms' R&D capabilities. We may explain the mild correlation between absorptive capacity and financial and physical resources by indirect impact which financial resources have on annual firm's R&D budget and also on recruitment of qualified employee which may increase the level of absorptive capacity. One other reason for this correlation is because all kind of resources are positively correlated with financial resources. it is also true for Physical resources that are strongly and positively correlated with financial resources.

(0.382) and firm size (0.288). A rising level of firm's resources in a firm accompanies a rising level of all kinds of firm resources except the financial one and, to a lesser extent, rising level of firm's absorptive capacity and size. With regard to human resources, there is a positive correlation with Financial (0.465), technological (0.477) and reputation (0.449) resources as well as firm size (0.289). In other words, a rising level of human resources accompanies a rising level of financial, technological and reputation and also firm size.

**Firm size positively correlates with physical resources (0.415) and whole of the firm's resources (0.288) while this correlation with financial resources is represented to a lesser extent (0.289).** in our research firm size is estimated by natural logarithm of number of employees. Number of employees and financial resources are positively correlated (0.200), thus strengths on financial resources may lead firm to recruit more employees. Internal resources and physical resources are positively correlated with financial resources.

### 5.3. Hypothesis Testing

This section is devoted to analyze the suggested hypotheses with statistical methods. Since different hypotheses are studied in this research, different statistical modeling is used to test these hypotheses. In order to test the hypotheses, we use ANOVA, LRT<sup>13</sup> and chi-square test. A LRT model assumes that the underlying probabilities follow a normal cumulative distribution, but this case may not be true for all variables. Therefore, we also use chi-square test.

The methodology for statistical modeling is ordinary regression and ordinal regression model.

#### 5.3.1. Hypothesis Regarding Technology-related Determinants

Technology Life Cycle: Seven hypotheses are proposed to test the effect of technology life cycle on different modes of technology sourcing, including; H1a, H1b, H1c, H2a, H2b, H3a, and H3b. The proportion of each stage of lifecycle in our study is presented in table 5.14.

Table 5.14- Technology Life Cycle Descriptive Data

TLC	Birth	Growth	Maturity	Laggard	Total
N	14	39	23	4	80
Proportion	0.17	0.49	0.29	0.05	1

***H1a: The propensity of a firm to acquire technology increases from technology birth to technology Growth.***

H1a states that along technology life cycle from birth to growth stages, firm's propensity to acquire increases. Table 5.15 represents descriptive data for firm's propensity to acquire (PTACQ) in each stage.

Table5.15- Descriptive Analysis of H1a

TLC	N	Mean	Std. Deviation	Std. Error Mean
PTACQ Birth	14	5.00	9.405	2.514
Growth	39	6.03	14.563	2.332

Using ANOVA method, we test the hypothesis. The results are shown in table 5.16.

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<sup>13</sup> Likelihood Ratio Test

Table5.16- Hypothesis Testing Analysis of H1a

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
PTACQ	Equal variances assumed	.546	.463	-.245	51	.807	-1.026	4.187	-9.431	7.379
	Equal variances not assumed			-.299	35.906	.767	-1.026	3.429	-7.980	5.929

In ANOVA model to compare means of different groups, equality of variances should be tested. In SPSS, this test is applied by Leven's test. Hypothesis of equality of variances in two stage of technology life cycle; birth and growth is accepted with significance of  $.463 > 0.05$ . Nevertheless H1a is not significant since  $(.807 > 0.05)$ . It means that a firm's propensity to acquire is not different in birth and growth.

**H1b: *The propensity of a firm to acquire technology increases from technology birth to technology Maturity.***

H1b states that along technology's growth from birth to maturity stages, firm's propensity to acquire increases.

Hypothesis of equality of variances of dependent variable (PTACQ) in two stages of technology life cycle (birth and maturity) is rejected (with significance of  $0.00 < 0.05$ ). Moreover, hypothesis of equality of means is rejected (with significance of 0.02) too while the mean of PTACQ in maturity (22.13) is far greater than the mean of PTACQ in birth (5). These findings support H1b. Tables 5.17 and 5.18 represent the results of analyses.

Table5.17- Descriptive Analysis for H1b

TLC		N	Mean	Std. Deviation	Std. Error Mean
PTACQ	Birth	14	5.00	9.405	2.514
	Maturity	24	22.13	31.762	6.483

Table 5.18- Hypothesis Testing Analysis of H1b

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
PTACQ	Equal variances assumed	16.414	.000	-1.958	36	.058	-17.125	8.747	-34.864	.614
	Equal variances not assumed			-2.463	29.265	.020	-17.125	6.954	-31.341	-2.909

**H2a: The propensity of a firm to ally with a partner increases from technology birth to technology maturity.**

H2a states that along the technology's growth from birth to maturity, firm's propensity to cooperate increases. This hypothesis is not supported by this study. Tables 5.19 and 5.20 represent the results of analyses.

Table 5.19- Descriptive Analysis for H2a

TLC	N	Mean	Std. Deviation	Std. Error Mean
PTCOOP Birth	14	15.00	20.286	5.422
Maturity	24	6.25	12.181	2.486

Table 5.20- Hypothesis Testing Analysis of H2a

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
PTCOOP	Equal variances assumed	5.886	.020	1.668	36	.104	8.750	5.247	-1.891	19.391
	Equal variances not assumed			1.467	18.578	.159	8.750	5.965	-3.753	21.253

**H1c: The propensity of a firm to acquire technology decreases from technology maturity to laggard.**

A similar analysis to test H2a is proposed for H1c and results do not support the hypothesis. Tables 5.21 and 5.22 represent the results of analyses. It definitely means the propensity of firm is not different in Maturity and Laggard.

Table5.21- Descriptive Analysis for H1c

TLC		N	Mean	Std. Deviation	Std. Error Mean
PTACQ	Maturity	24	22.13	31.762	6.483
	Laggard	4	22.50	45.000	22.500

Table 5.22- Hypothesis Testing Analysis of H1c

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
PTACQ	Equal variances assumed	.612	.441	-.021	26	.984	-.375	18.123	-37.627	36.877
	Equal variances not assumed			-.016	3.516	.988	-.375	23.415	-69.076	68.326

**H2b: The propensity of a firm to ally with a partner decreases from technology maturity to laggard.**

Hypothesis H2b states that along the technology maturity to laggard stage, firm's propensity to cooperate decreases.

Hypothesis of equality of variances of dependent variable (PTCOOP) in two stages of technology life cycle (maturity and laggard) is accepted (with significance of  $0.231 > 0.05$ ). Moreover, hypothesis of equality of means is accepted (with significance of  $0.692 > 0.05$ ) too. While the mean of PTCOOP in maturity (6.25) is greater than the mean of PTCOOP in laggard (3.75), these findings are not support statistically. Tables 5.23 and 5.24 represent the results of analyses.

Table5.23- Descriptive Analysis for H2b

TLC		N	Mean	Std. Deviation	Std. Error Mean
PTCOOP	Maturity	24	6.25	12.181	2.486
	Laggard	4	3.75	4.787	2.394



Table 5.24- Hypothesis Testing Analysis of H2b

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
PTCOOP	Equal variances assumed	1.505	.231	.400	26	.692	2.500	6.249	-10.345	15.345
	Equal variances not assumed			.724	11.258	.484	2.500	3.451	-5.075	10.075

**H3a: The propensity of a firm to internal development decreases from technology growth to maturity.**

Hypothesis H3a states that along technology's growth to maturity stage, firm's propensity to internal development decreases. Equality of variances of dependent variable (PTR&D) in two stages of technology life cycle; growth and maturity, is rejected (with significance of  $0.008 < 0.05$ ), while hypothesis of equality of means is not rejected (with significance 0.231). Therefore, there is not a significant difference between PTR&D in growth and maturity stages. Thus H3a is not supported.

Tables 5.25 and 5.26 represent the results of analyses.

Table 5.25- Descriptive Analysis for H3a

TLC		N	Mean	Std. Deviation	Std. Error Mean
PTR&D	Growth	39	81.28	23.416	3.750
	Maturity	24	71.63	34.197	6.981

Table 5.26- Hypothesis Testing Analysis of H3a

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
PTR&D	Equal variances assumed	7.624	.008	1.331	61	.188	9.657	7.257	-4.855	24.169
	Equal variances not assumed			1.219	36.355	.231	9.657	7.924	-6.408	25.722

**H3b: The propensity of a firm to internal development decreases from technology growth to laggard.**

Hypothesis H3b states that along the technology growth to laggard stage, firm's propensity to develop the technology internally decreases. Results do not support this hypothesis. Tables 5.27 and 5.28 represent the results.

Table 5.27- Descriptive Analysis for H3b

TLC	N	Mean	Std. Deviation	Std. Error Mean
PTR&D Growth	39	81.28	23.416	3.750
Laggard	4	73.75	46.075	23.038

Table 5.28- Hypothesis Testing Analysis of H3b

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
PTR&D	Equal variances assumed	4.326	.044	.557	41	.581	7.532	13.524	-19.780	34.844
	Equal variances not assumed			.323	3.161	.767	7.532	23.341	-64.655	79.719

**Uncertainty:** Four hypotheses are proposed related to uncertainty; H4a, H4b, H5a and H5b. independent variables in these four hypotheses are ordinal, to investigate the hypotheses; two methods are proposed, LRT and Chi-square test. For each hypothesis, we describe the method and related analysis.

**H4a: the propensity of firm to cooperate increases as the level of commercial uncertainty increases.**

**H4b: the propensity of firm to cooperate increases as the level of technical uncertainty increases.**

H4a states that hat higher levels of commercial Uncertainty necessitates higher propensity to cooperate. Using Kendall's tau correlation test that examines the correlation between these two variables; propensity to ally (PTCOOP) and degree of commercial uncertainty (CUNC), H4a is not supported. As it is shown in table 5.29, Kendall's tau correlation coefficient between two variables is 0.052 with 0.572 of significance. It means that there is no relation between PTCOOP and CUNC.

Table 5.29- Hypothesis Testing Analysis of H4a

			CUNC	PTCOOP
Kendall's tau_b	CUNC	Correlation Coefficient	1.000	.052
		Sig. (2-tailed)	.	.572
		N	88	88
	PTCOOP	Correlation Coefficient	.052	1.000
		Sig. (2-tailed)	.572	.
		N	88	89

H4b states that higher levels of technical uncertainty necessitates higher propensity to cooperate.

Using Kendall's tau correlation test, correlation between two variables propensity to ally (PTCOOP) and degree of technical uncertainty (TUNC); is 0.261. The significance of test (0.005) means that there is a positive relation between two variables (table 5.30).

Table 5.30- Hypothesis Testing Analysis of H4b

			TUNC	PTCOOP
Kendall's tau_b	TUNC	Correlation Coefficient	1.000	.261(**)
		Sig. (2-tailed)	.	.005
		N	87	87
	PTCOOP	Correlation Coefficient	.261(**)	1.000
		Sig. (2-tailed)	.005	.
		N	87	89

\*\* Correlation is significant at the 0.01 level (2-tailed).

LRT and Chi-square tests are also using to verify such relations.

**H5a: The propensity of firm to internal development increases as the level of commercial uncertainty decreases.**

**H5b: The propensity of firm to internal development increases as the level of technical uncertainty decreases.**

H5a states that hat higher levels of commercial Uncertainty necessitates lower propensity to internal development. Similar to H4a and H4b, using Kendall's tau correlation test H5a is not supported. As it is shown in table 5.31, Kendall's tau correlation coefficient between two variables is -0.046, which is in the hypothesized sense, but with 0.603 of significance. It means that there is no relation between PTR&D and CUNC.

Table 5.31- Hypothesis Testing Analysis of H5a

			CUNC	PTR&D
Kendall's tau_b	CUNC	Correlation Coefficient	1.000	-.046
		Sig. (2-tailed)	.	.603
		N	88	88
	PTR&D	Correlation Coefficient	-.046	1.000
		Sig. (2-tailed)	.603	.
		N	88	89

Hypothesis 5b states that a higher level of technical uncertainty necessitates lower level of propensity to internal development. As it is shown in table 5.32, Kendall's tau correlation coefficient between two variables; PTR&D and TUNC is -0.169 with 0.062 of significance. It means that there is a negative relation between two variables.

Table 5.32- Hypothesis Testing Analysis of H5b

			TUNC	PTR&D
Kendall's tau_b	TUNC	Correlation Coefficient	1.000	-.169 (*)
		Sig. (2-tailed)	.	.062
		N	87	87
	PTR&D	Correlation Coefficient	-.169	1.000
		Sig. (2-tailed)	.062	.
		N	87	89

\* Correlation is significant at the 0.1level (2-tailed).

#### Strategic Importance of Technology:

Four hypotheses of H6, H7a, H7b and H8 are proposed to describe the relation between strategic importance of a technology and the propensity to gain access to it.

**H6: The propensity of firm to internal development increases when strategic importance of technology moves from niche to distinctive.**

**H7a: The propensity of firm to cooperate increases when strategic importance of technology moves from distinctive to niche.**

study is presented in table 5.33.

Table 5.33- Distribution of Technologies According to their Strategic Importance

Technologies	Distinctive	Niche	Background	Marginal	Sum
Number in each group	61	21	1	2	85
Proportion	0.72	0.25	0.012	0.024	1

H6 states that if strategic importance of a technology moves from niche to distinctive, propensity of firm to internal development increases. Table 5.34 shows descriptive data for firm's propensity to internal development (PTR&D) for each kind of strategic importance.

Table5.34- Descriptive Analysis for H6

SITECH		N	Mean	Std. Deviation	Std. Error Mean
PTR&D	Niche	21	82.38	24.679	4.024
	Distinctive	61	73.67	31.428	5.385

Using ANOVA method, we test the hypothesis. The results are shown in table 5.35.

Table 5.35- Hypothesis Testing Analysis of H6

		Levene's Test for Equality of Variances		t-test for Equality of Means					
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
PTR&D	Equal variances assumed	2.340	.130	1.152	80	.253	8.709	7.561	-6.338 23.755
	Equal variances not assumed			1.295	43.995	.202	8.709	6.723	-4.840 22.258

In ANOVA model to compare means of different groups, equality of variances should be tested. IN SPSS, this test is applied by Leven's test. Hypothesis of equality of variances for two kind of strategic importance of technology; niche and distinctive is accepted with significance of  $0.130 > 0.05$ .

Nevertheless H6 is not significant since  $(0.253 > 0.05)$ . It means that a firm's propensity to internal development is not different for niche and distinctive technologies.

H7a states that if strategic importance of a technology moves from distinctive to niche, propensity of firm cooperate increases. Table 5.36 represents descriptive data for firm's propensity to cooperate (PTCOOP) for each kind of strategic importance.

Table 5.36- Descriptive Analysis for H7

		N	Mean	Std. Deviation	Std. Error Mean
PTCOOP	Niche	21	9.76	17.210	3.756
	Distinctive	61	13.52	19.903	2.548

Using ANOVA method, we test the hypothesis. The results are shown in table 5.37.

Table 5.37- Hypothesis Testing Analysis of H7

		Levene's Test for Equality of Variances		t-test for Equality of Means					
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
PTCOOP	Equal variances assumed	.789	.377	-.772	80	.442	-3.763	4.874	-13.463 5.937
	Equal variances not assumed			-.829	39.841	.412	-3.763	4.539	-12.936 5.411

Hypothesis of equality of variances for two kind of strategic importance of technology; niche and distinctive is accepted with significance of  $0.377 > 0.05$ . Nevertheless H7a is not significant since  $(0.442 > 0.05)$ . It means that a firm's propensity to cooperate is not different for niche and distinctive technologies.

**Urgency:** One hypothesis is proposed, namely; H9 that suggests an inverse relationship between the urgency of gaining access to a technology and the propensity to develop it internally.

**H9: The more gaining access to a technology is urgent, the propensity to internal development decreases.**

The hypothesis is not supported in this research and the correlation (.101) is in the reverse hypothesized direction and not significant.

Table 5.38 represents synopsis of hypothesis related to technology.

Table5.38- Synopsis of Hypotheses Test Results (technology-related)

Hypothesis	Results
H1a- The propensity of a firm to acquire technology increases from technology birth to technology Growth.	Not Supported
H1b- The propensity of a firm to acquire technology increases from technology birth to technology Maturity.	Supported
H1c- The propensity of a firm to acquire technology decreases from technology maturity to technology laggard.	Not Supported
H2a- The propensity of a firm to cooperate with a partner increases from technology birth to technology maturity.	Not supported
H2b- The propensity of a firm to cooperate with a partner decreases from technology maturity to technology laggard.	Not supported
H3a- The propensity of a firm to internal development decreases from technology growth to technology maturity.	Not Supported
H3b- The propensity of a firm to internal development decreases from technology growth to technology laggard.	Not Supported
H4a- The propensity of firm to cooperate increases as the level of commercial uncertainty increases.	Not supported
H4b- The propensity of firm to cooperate increases as the level of technical uncertainty increases.	Supported
H5a- The propensity of firm to internal development increases as the level of commercial uncertainty decreases.	Not supported
H5b- The propensity of firm to internal development increases as the level of technical uncertainty decreases.	supported
H6- The propensity of firm to internal development increases when strategic importance of technology moves from niche to distinctive.	Not Supported
H7a- The propensity of firm to cooperate increases when strategic importance of technology moves from distinctive to niche.	Not Supported
H7b- The propensity of firm to cooperate increases, when strategic importance of technology moves from background to marginal.	Not adequate data to test
H8- The propensity of firm to acquire increases, when strategic importance of technology moves from marginal to background.	Not adequate data to test
H9- The more gaining access to a technology is urgent, the propensity to internal development decreases.	Not Supported

### 5.3.2. Hypothesis Regarding Firm-specific Determinants

In this sub-section, the firm specific hypotheses are tested by related statistical methods and the results are represented.

Internal resources: Three hypotheses, namely; H10, H11 and H12, are proposed in order to define the relationship between internal resources and three modes of access to the technology. In order to dedicate one measure to internal resources (as it is considered an index for internal resources), we use factor analysis with principal component as an extraction method. Table 5.39 represents the KMO and Bartlett's test.

Table5.39- KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.788
Bartlett's Test of Sphericity	Approx. Chi-Square	108.997
	df	15
	Sig.	.000

Noting that the amount of KMO is 0.788 and it is good enough (more than 0.6) and the Bartlett test is significant, thus using factor analysis is appropriate.

The eigenvalues and respective variance of these factors are as given in Table 5.40. Only the first factor or principal component has an eigenvalue larger than one and explains about 52% of the total variance. There is a large difference between the eigenvalue and variance explained by the first and the next principal component. Hence, the first principal component is adequate to serve as the composite index representing the combined variance of different six aspects of internal resources.

Table 5.40- Eigen Values and Variance Explained By Principal Components

Component	Eigen Values	% of Variance	Cumulative %
1	<b>3.103</b>	<b>51.712</b>	51.712
2	.889	14.822	66.534
3	.664	11.060	77.594
4	.571	9.520	87.114
5	.438	7.302	94.416
6	.335	5.584	100.000

Extraction Method: Principal Component Analysis.

The factor loadings for each of the six original variables are given in Table 5.41. Amongst different types of resources; reputation, financial and technological resources are more influential.

Table 5.41- Principal Component of Internal Resources

Internal Resources	Variables	Factor Loading
Financial Resources	<b>FINRES</b>	<b>.744</b>
Human Resources	HUNRES	.655
Technological Resources	<b>TECHRES</b>	<b>.743</b>
Physical Resources	PHYRES	.679
Organizational Resources	ORGRES	.683
Reputation	<b>REPT</b>	<b>.800</b>
Total Variance Explained		51.71%

Having computed an internal resources index (*INRES*) for each of the sample companies, it is now possible to rank them in terms of relative strengths in internal resources. We test our hypothesis with this index.

**H10: As the level of internal resources of firm increases, the propensity to cooperate with others decreases.**

H10 proposes a negative relationship between level of internal resources and propensity of firm to cooperate. Using Pearson correlation test that examines the correlation between these two variables; propensity to ally (PFCOOP) and level of firms' internal resources (INRES), H10 is not supported. As it is shown in table 5.42, Pearson correlation coefficient between two variables is -0.031 with 0.808 of significance. It means that there is no relation between PFCOOP and INRES. Despite the lack of adequate reasons to support H10, The negative correlation between the two variables confirms reverse relationship.

Table 5.42- Hypothesis Testing Analysis of H10

		PFCOOP	INRES
PFCOOP	Pearson Correlation	1	-.031
	Sig. (2-tailed)		.808
	N	63	62
INRES	Pearson Correlation	-.031	1
	Sig. (2-tailed)	.808	
	N	62	62

**H11: As the level of internal resources of firm increases, the propensity to acquire the technology increases.**

Hypothesis H11 proposes that higher level of firm's internal resources increases firm's propensity to acquire the technology. Using Pearson correlation test that examines the correlation between these two variables; propensity to acquire (PFACQ) and level of firms' internal resources (INRES), H11 is not



supported. As it is shown in table 5.43, Pearson correlation coefficient between two variables is 0.144 with 0.263 of significance. It means that there is no relation between PFACQ and INRES. Despite the lack of adequate reasons to support H11, The positive correlation between two variables confirms a direct relationship.

Table 5.43- Hypothesis Testing Analysis of H11

		INRES	PFACQ
INRES	Pearson Correlation	1	.144
	Sig. (2-tailed)		.263
	N	62	62
PFACQ	Pearson Correlation	.144	1
	Sig. (2-tailed)	.263	
	N	62	63

**H12: As the level of internal resources of firm increases, the propensity to develop the technology internally increases.**

Hypothesis H12 proposes that higher level of internal resources increases firm's propensity to develop a technology internally. Using Pearson correlation test that examines the correlation between these two variables; propensity to internal development (PFR&D) and level of firms' internal resources (INRES), H12 is not supported. As it is shown in table 5.44, Pearson correlation coefficient between two variables is -0.089 with 0.494 of significance. It means that there is no relation between PFR&D and INRES. Negative relations between internal resources and propensity to internal development are not supported.

Table 5.44- Hypothesis Testing Analysis of H12

		PFR&D	INRES
PFR&D	Pearson Correlation	1	-.089
	Sig. (2-tailed)		.494
	N	63	62
INRES	Pearson Correlation	-.089	1
	Sig. (2-tailed)	.494	
	N	62	62

Although no relation of dependent variables with the internal resources Index is yielded, there may be relation between each dependent variable and each specific kind of resources which explains why we have employed regression. Equations 5.1, 5.2, and 5.3 represent the effect of each kind of resources on three dependent variables at the firm- level analysis.

$$PFR\&D_i = 72.28 - 7.42 * HUMRES_i + 13.16 * TECHRES_i - 7.97 * ORGRES_i + \epsilon_i \quad (5.1) \quad i = 1, \dots, 63 \text{ (is the } i^{th} \text{ firm)}$$

$$PFCOOP_i = 20.27 + 7.02 * HUMRES_i - 7.58 * TECHRES_i + \epsilon_i \quad (5.2)$$

$$PFACQ_i = 8.11 - 6.05 * TECHRES_i + 7.62 REPT_i + \epsilon_i \quad (5.3)$$

$\epsilon_i$  is the difference between the value of the dependent variable predicted by the model, and the true value of the dependent variable. One method of estimation is mean square method (MSE).

For each equation the MSE is presented below:

MSE (5.1) = 632.25, MSE (5.2) = 357.98, MSE (5.3) = 403.30

These values are less than the MSEs of other models and is acceptable for our model.

Employing backward regression represents the impact of three kinds of resources on **propensity to internal development**, including; human resources, technological and organizational assets. Other resources including financial, physical and reputation don't influence propensity to internal development. Using backward regression for relation between "**propensity of firm to cooperate**" and internal resources shows that the factor of human resources has a direct effect on the propensity of firm to cooperate and the factor of technological resources have a negative effect on it. As it is observed in equation 5.3, technological resources have a negative impact and reputation resources have a positive impact on **firm's propensity to acquire**.

In our research **technological resources** refer to R&D capabilities and tacit know-how. Firms tend to develop the technology internally when they possess high level of technological resources. This is because those firms possessing high level of competence usually involve with various leading-edge technologies that are highly related to the core competitiveness of the firms (Howells, 1999a; Narula, 2001). Rather than trying to develop them externally under the risk of dilution of competence, firms may consider developing via in-house R&D to strength internal integration of technological competency (Kessler et al., 2000; Narula, 2004; Teece, 1986). Accordingly firms with low level of R&D capabilities, search for external sources of knowledge to provide these kinds of capabilities, the fact that explain the negative effect of technological resources on propensity to cooperate and acquire. **Human resources** have a positive impact on propensity to cooperate, meanwhile a negative impact on propensity to internal development. The positive effect of human resources on propensity to cooperate may explain by importance of learning in such relations. According to Pucik, 1988, Knowledge acquisition is a process that requires commitment of human resources, in particular, managerial time, attention, and effort. Commitment of human resources get more importance when cooperation is learning- oriented<sup>14</sup> rather than output- oriented (Westney, 1988). According to Dogson, 1997 management of human resources also provides the critical factor determining the success of partners within collaborations.

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<sup>14</sup> Westney (1988) distinguishes between two types of cooperative strategies: output-oriented and learning-oriented. The first has as its goal the production of a certain output for the parent to use; the focus is on the achievement of operational objectives. The second type may also aim at the production of a specific output, but it has the additional goal of learning.

While in the regression model (section 5.4), the effect of human resources on propensity to acquire is not significant; Dyer et al., 2004 propose that with a high level of human resources and when companies have to generate synergies by combining human resources, it's a good idea to avoid acquisitions.

**Organizational resources** have a negative impact on propensity to internal development. In our research organizational resources refer to resources resulting from a good team working in the firm such as corporate culture, inter-service teams, forecasting groups, etc. benefiting from a good level of organizational resources may motivate managers to search external sources of technology and cooperating with others, in such situation managers may rely less on internal development. Interestingly, **reputation** has positive effects on propensity to acquire. Otherwise, as the level of firm's reputation increases, the propensity of firm to acquisition increases. Modes of acquisition consist of license purchase, firm take over and R&D outsourcing. Firms with strength reputation and brand on one hand are able to guarantee an acceptable market share (especially in the case of license purchase and take over). On the other hand they represent more reliability for other firms in respect to both technological success and trust creation.

It is important to note that the aforementioned results are significant in the absence of other independent variables. In the presence of other variables, the effect of each kind of resources may change. In section 5.4, the effect of all independent variables is analyzed and final results are addressed.

**Absorptive Capacity:** Three hypotheses are proposed related to the firm's level of absorptive capacity and its propensity to select modes of technology sourcing; H13, H14 and H15. Noting that 10 questions are designed to measure the level of a firm's absorptive capacity, in order to dedicate one measure to absorptive capacity (as it is considered an index for absorptive capacity), we use factor analyses with principal component as an extraction method. Table 5.45 represents the KMO and Bartlett's test.

Table5.45- KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.683
Bartlett's Test of Sphericity	Approx. Chi-Square	181.179
	df	45
	Sig.	.000

Noting that the amount of KMO is 0.683 and it is more than 0.6 and the Bartlett test is significant, thus using factor analyses is appropriate.

The eigenvalues and respective variance of these factors are as given in Table 5.46. Three first factors or principal components have the eigenvalues larger than one and explains over 63% of the total variance.

**Table 5.46-** Eigen Values and Variance Explained By Principal Components

Component	Eigenvalues	% of Variance	Cumulative %
1	<b>3.565</b>	<b>35.647</b>	<b>35.647</b>
2	<b>1.619</b>	<b>16.191</b>	<b>51.838</b>
3	<b>1.206</b>	<b>12.063</b>	<b>63.901</b>
4	.857	8.572	72.474
5	.754	7.543	80.017
6	.571	5.714	85.731
7	.468	4.675	90.406
8	.427	4.266	94.672
9	.284	2.844	97.516
10	.248	2.484	100.000

Extraction Method: Principal Component Analysis.

The factor loadings or components for each of ten original variables are given in Table 5.47.

Table5.47-Principal Components of Absorptive Capacity

	Questions measured absorptive capacity	Component 1	Component 2	Component 3
Potential Absorptive Capacity	Ability to assimilate knowledge from following external sources:			
	✓ Suppliers	.453	<b>-.660</b>	-.028
	✓ Customers	.391	-.164	<b>.789</b>
	✓ competitors	<b>.654</b>	-.110	<b>.499</b>
	✓ Universities	<b>.702</b>	.392	-.068
	✓ Research institutes	<b>.660</b>	.470	-.180
	✓ Conferences and journals	.373	<b>.718</b>	.024
	✓ Showrooms and exhibitions	<b>.588</b>	.180	.184
Realized Absorptive Capacity	With applying knowledge gained from above sources, Firm's ability to enhance its performance on:			
	✓ process	.722	-.171	-.308
	✓ product/service	.678	-.291	-.185
	✓ new product/service	.620	-.328	-.364
	Cumulative variance explained (%)	35.65%	51.84%	63.9%

These three components describe 63.9% of total variance. The first component represents absorptive capacity, the second and third components may represent a part of potential absorptive capacity, because the coefficients of the last three questions are negative. The last three questions are designed to measure the effect of knowledge obtained from external sources on firm performance. The second component may deal with a part of potential absorptive capacity that is research dependent. Having computed an absorptive capacity index (AC) for each of the sample companies (using the first component), the value of absorptive capacity is estimated and related hypotheses are tested.

**H13: As the level of Firm's Absorptive Capacity increases the propensity of firm to develop technology internally decreases.**

H13 states that a higher level of absorptive capacity decreases the propensity of firm to internal development. Using Pearson correlation, the coefficient of variable absorptive capacity agrees with hypothesized direction and its statistical significance is 0.273, so there are not adequate reasons to reject H13 (table 5.48).

**H14: As the level of Firm's Absorptive Capacity increases the propensity of firm to cooperate with others increases.**

H14 states that a higher level of firm's absorptive capacity increases the firm's propensity to cooperate. The coefficient of variable absorptive capacity agrees with the hypothesized direction and its statistical significance is 0.144, so there are not adequate reasons to reject H14 (table 5.49).

**H15: As the level of Firm's Absorptive Capacity increases the propensity of firm to acquire technology decreases.**

H15 states that a higher level of firm's absorptive capacity decreases the firm's propensity to acquire. This hypothesis is strongly rejected (statistical significance is 0.955). Tables 5.50 represent related analyses of H15.

Table 5.48- Hypothesis Testing Analysis of H13

		PFR&D	AC
PFR&D	Pearson Correlation	1	-.149
	Sig. (2-tailed)		.273
	N	63	56
AC	Pearson Correlation	-.149	1
	Sig. (2-tailed)	.273	
	N	56	56

Table 5.49- Hypothesis Testing Analysis of H14

		PFCOOP	AC
PFCOOP	Pearson Correlation	1	.188
	Sig. (2-tailed)		.144
	N	63	62
AC	Pearson Correlation	.188	1
	Sig. (2-tailed)	.144	
	N	62	62

Table 5.50- Hypothesis Testing Analysis of H15

		PFACQ	AC
PFACQ	Pearson Correlation	1	-.008
	Sig. (2-tailed)		.955
	N	63	56
AC	Pearson Correlation	-.008	1
	Sig. (2-tailed)	.955	
	N	56	56

**Successful Past Experiences:** Three hypotheses are proposed in order to test the effect of successful past experiences in a certain mode and the propensity of firm to reapply that mode for gaining access to another technology.

**H16: As internal development of technology used by firm successfully in the past increases, the propensity of firm to develop the technology internally increases.**

**H17: As cooperative modes of technology sourcing used by firm successfully in the past increases, the propensity of firm to ally increases.**

**H18: As acquisition modes of technology used by firm successfully in the past increases, the propensity of firm to acquire the technology increases.**

H16, H17 and H18 states a positive relation between successful past experiences in a certain mode and the propensity of firm to reapply this mode. As explained in chapter 3, although this factor is classified as a firm related factor, related question (No. 48) is requested for each technology. Successful past experiences in a certain mode consist of the sum of all successful experiences which a firm possesses for all technologies. Based on this logic, we analyze the hypothesis in two level; technology and firm. In the first level, we study the relation between past experiences of firm before gaining access to a technology and the percentage of the technology which is gained by a mode (PTR&D, PTCOOP and PTACQ). The second level deals with each firm's past experience in terms of the average of successful past experiences in each mode for all the technologies for which the third part of questionnaire is completed. Then, we analyze the relation between these past experiences and propensity of firm to use a mode (PFR&D, PFCOOP and PFACQ). At technology level for hypothesis H16, although coefficient (0.163) is in the hypothesized direction, there are no adequate reasons to reject the hypothesis. Table 5.51 represents the results of analyses.

Table 5.51- Hypothesis Testing Analysis of H16

		TEXR&D	PTR&D
TEXR&D	Pearson Correlation	1	.163
	Sig. (2-tailed)		.133
	N	86	86
PTR&D	Pearson Correlation	.163	1
	Sig. (2-tailed)	.133	
	N	86	89

At technology level, the hypotheses H17 and H18 are supported with significance 0.996 and 0.999.

Tables 5.52 and 5.53 represent the results of analyses.

Table 5.52- Hypothesis Testing Analysis of H17

		TEXCOOP	PTCOOP
TEXCOOP	Pearson Correlation	1	.310(**)
	Sig. (2-tailed)		.004
	N	86	86
PTCOOP	Pearson Correlation	.310(**)	1
	Sig. (2-tailed)	.004	
	N	86	89

\*\* Correlation is significant at the 0.01 level (2-tailed).

Table 5.53- Hypothesis Testing Analysis of H18

		TEXACQ	PTACQ
TEXACQ	Pearson Correlation	1	.364(**)
	Sig. (2-tailed)		.001
	N	86	86
PTACQ	Pearson Correlation	.364(**)	1
	Sig. (2-tailed)	.001	
	N	86	89

\*\* Correlation is significant at the 0.01 level (2-tailed).

At firm level, logically we should obtain the same results. Analyzing the hypotheses in this level confirms validity of responses. In order to test the hypotheses at firm level, we calculate FEXR&D, FEXCOOP and FEXACQ as following:

$$FEXR\&D_i = \sum_{j=1}^n \text{TEXR\&D}_{ji} / \text{NTECH}_i \quad (5.4)$$

$$FEXCOOP_i = \sum_{j=1}^n \text{TEXCOOP}_{ji} / \text{NTECH}_i \quad (5.5)$$

$$FEACQ_i = \sum_{j=1}^n \text{TEXACQ}_{ji} / \text{NTECH}_i \quad (5.6)$$

$\forall j=1, \dots, 4$  (j is number of technologies which is selected by the respondents to give the information about and it is different for each company),

NTECH<sub>i</sub>: Number of selected technologies by firm i (the third part of questionnaire is completed for this number)  
i=1, ..., 63

After calculating the above variables, we study the effect of these variables on PFR&D, PFCOOP and PFACQ. Reanalyzing the hypothesis confirms the above results (at  $\alpha=0.001$ ) for H17 and H18, and for H16 there are no adequate reasons to reject this hypothesis.

**Strategic Objectives:** Hypotheses H19, H20 and H21 are proposed to determine the effect of a firm's strategic objective, namely; differentiation and low-cost, on the choice of TSMs.

**H19: As the importance of a differentiation goal increases, the propensity of firms to internal development increases.**

H19 states that as the importance of a differentiation goal increases, the propensity of firms to internal development increases. The correlation (-.238) is neither significant nor in the hypothesized direction.

**H20: As the importance of a low-cost goal increases, the propensity of firm to acquire increase.**

H20 proposes a positive relationship between the importance of low-cost and firm's propensity to acquire. The correlation (-.194) is neither significant nor in the hypothesized direction.

**H21: As the importance of a low-cost goal increases, the propensity of firm to internal development increases.**

H21 proposes a positive relationship between the importance of low-cost and firm's propensity to internal development. The correlation (-.208) is neither significant nor in the hypothesized direction.

Tables 5.54 to 5.56 represent results of analyses of H19, H20 and H21.

Table 5.54- Hypothesis Testing Analysis of H19

		PFR&D	DIFF
PFR&D	Pearson Correlation	1	.054
	Sig. (2-tailed)		.677
	N	63	62
DIFF	Pearson Correlation	.054	1
	Sig. (2-tailed)	.677	
	N	62	62

Table 5.55- Hypothesis Testing Analysis of H20

		PFACQ	COST
PFACQ	Pearson Correlation	1	-.113
	Sig. (2-tailed)		.377
	N	63	63
COST	Pearson Correlation	-.113	1
	Sig. (2-tailed)	.377	
	N	63	63



Table 5.56- Hypothesis Testing Analysis of H21

		PFR&D	COST
PFR&D	Pearson Correlation	1	-.055
	Sig. (2-tailed)		.667
	N	63	63
COST	Pearson Correlation	-.055	1
	Sig. (2-tailed)	.667	
	N	63	63

**Firm Size:** Three hypotheses; H22, H23 and H24, are proposed in order to define the relationship between firm size and the choice of TSM.

***H22: Larger firms are less likely to develop technology internally.***

***H23: Larger firms are more likely to cooperate.***

***H24: Larger firms are more likely to acquire technology.***

H22 states that larger firms are less likely to develop a technology internally. This hypothesis is supported (at  $\alpha=0.05$ ). H23 proposes a positive relationship between the size of the firm and propensity to cooperate. The hypothesis is not supported. H24 proposes a positive relationship between the firm size and its propensity to acquire, this hypothesis is supported at  $\alpha=0.1$ .

Table 5.57 shows the synopsis of hypothesis related to firm.

Table5.57- Synopsis of Hypotheses Test Results (firm-related)

Hypothesis	Results
H10- <i>As the level of internal resources of firm increases, the propensity to cooperate with others decreases.</i>	Not supported
H11- <i>As the level of internal resources of firm increases, the propensity to acquire the technology increases.</i>	Not supported
H12- <i>As the level of internal resources of firm increases, the propensity to develop the technology internally increases.</i>	Not supported
H13- <i>As the level of Firm's Absorptive Capacity increases the propensity of firm to develop technology internally decreases.</i>	No adequate reasons to reject
H14- <i>As the level of Firm's Absorptive Capacity increases the propensity of firm to cooperate with others increases.</i>	No adequate reasons to reject
H15- <i>As the level of Firm's Absorptive Capacity increases the propensity of firm to acquire technology decreases.</i>	Not supported
H16- <i>As internal development of technology used by firm successfully in the past increases, the propensity of firm to develop the technology internally increases.</i>	Not supported
H17- <i>As cooperative modes of technology sourcing used by firm successfully in the past increases, the propensity of firm to ally increases.</i>	supported
H18- <i>As acquisition modes of technology used by firm successfully in the past increases, the propensity of firm to acquire the technology increases.</i>	supported
H19- <i>As the importance of a differentiation goal increases, the propensity of firms to internal development increases.</i>	Not supported
H20- <i>As the importance of a low-cost goal increases, the propensity of firm to acquire increase.</i>	Not supported
H21- <i>As the importance of a low-cost goal increases, the propensity of firm to internal development increases.</i>	Not supported
H22- <i>Larger firms are less likely to develop technology internally.</i>	supported
H23- <i>Larger firms are more likely to cooperate.</i>	Not supported
H24- <i>Larger firms are more likely to acquire technology.</i>	Partially supported

## 5.4. Regression Models

This section addresses the best fitted models for three dependent variables in two levels; technology and firm, while proposing and analyzing six models. In five cases, regression model suits the conditions relevant to our research (Montgomery, 2007).

### 5.4.1. Determinants of Internal Development

This section is devoted to determinants of propensity to internal development. The two following subsection deal with such determinants at two level; technology and firm.

#### 5.4.1.1. Technology Related Determinants of Internal Development

In this level of analyze, we consider the length of time that the firm has the technology in its portfolio as a control variable and study its effect on dependent variable, namely; percentage of technology which is gained by internal development, by regression. The results show no correlation between the

two variables. Using regression, amongst different models we select the best fitted model, which is presented below. The best model is the model with larger (or sometimes largest) amount of adjusted  $R^2$  and with Durbin- Watson Statistic near to 2. Table 5.58 shows the coefficient of variables and their significance.

Table 5.58- Determinants of Propensity to Internal Development at Technology Level

Variables	Propensity to internal development	Technology Life Cycle	Technical Uncertainty	past experiences in acquisition	N	R	adjusted $R^2$	Durbin-Watson Statistic
Model	131.62 (.000) ***	- 11.24 (.009) ***	-7.11 (.055) *	-8.83 (.001) ***	51	.577	.292	2.023
VIF	-----	1.431	1.478	1.157	-----	-----	-----	-----

For each variable the estimated coefficient is given with the standard error below it in parentheses.

\* $p \leq 0.1$ ; \*\*  $p \leq 0.05$ ; \*\*\*  $p \leq 0.01$

The regression equation which describes the effect of technology-related factors on internal development is:

$$PTR\&D_i = 131.62 - 11.24 * TLC_i - 7.11 * TUNC_i - 8.83 * TEXACQ_i + \epsilon_i \quad (5.7)$$

In where:  $i = 1, \dots, 63$  (is the  $i^{th}$  firm)

$\epsilon_i$  is the difference between the value of the dependent variable predicted by the model, and the true value of the dependent variable. One method of estimation is mean square method (MSE).

For this equation the MSE is 565.51 and less than the MSEs of other models; thus it is acceptable for our model.

Propensity to internal development is affected negatively by technology life cycle, degree of technical uncertainty and past experiences in acquisition.

#### 5.4.1.2. Firm specific Determinants of Internal Development

Firstly, we study the effect of three control variables, including; the number of patents, rate of innovativeness and the age of firm in model one. None of these control variables have any significant effect on dependent variable; "propensity to internal development". Therefore, we don't consider these three variables in complete models. Using regression with all independent variables, amongst different models we select the best fitted model, which is presented below. The best model is the model with larger (or sometimes largest) amount of adjusted  $R^2$  and with Durbin- Watson Statistic near to 2. Table 5.59 represents the model and its characteristics.

Table 5.59- Determinants of Propensity to Internal Development at Firm Level

Variables	Propensity to internal development	Technological resources	reputation	past experiences in R&D	past experiences in cooperation	size	N	R	adjusted R <sup>2</sup>	Durbin-Watson Statistic
Model	72.54 (.000)***	13.16 (.002)***	-10.19 (.009)**	4.36 (.011)**	-8.47 (.000)***	-9.64 (0.066)*	57	.636	0.343	1.839
VIF	-----	1.431	1.478	1.251	1.157	1.168	-----	-----	-----	-----

For each variable the estimated coefficient is given with the standard error below it in parentheses.

\*p≤ 0.1; \*\* p≤0.05; \*\*\* p≤0.01

Using backward regression, the equation which describes the effect of firm-related factors on internal development of a technology is:

$$PFR\&D_i = 72.54 + 13.16 * TECHRES_i - 10.19 * REPT_i + 4.36 * FEXR\&D_i - 8.47 * FEXCOOP_i - 9.64 * SIZE_i + \epsilon_i \quad (5.8)$$

In where:  $i = 1, \dots, 63$  (is the  $i^{th}$  firm)

$\epsilon_i$  is the difference between the value of the dependent variable predicted by the model, and the true value of the dependent variable. One method of estimation is mean square method (MSE).

For this equation the MSE is 467.89 and less than the MSEs of other models; thus it is acceptable for our model.

Table 5.59 represents factors which validate the model as well as the co-linearity between independent variables measured by VIF<sup>15</sup>. Moreover, the hypothesis of normality of standard errors in the model is accepted with a significance ratio of 0.200 (table 5.60).

Table 5.60- Test of Normality

	Kolmogorov-Smirnov		
	Statistic	df	Sig.
Standardized Residual	.088	56	.200(*)

\* This is a lower bound of the true significance.

Propensity to internal development of a technology increases with increasing level of firm's technological resources and also growing level of past experiences in R&D. On the contrary, this variable has a negative correlation with the size of the firm as well as the firm's past experiences in cooperation and the level of reputation. The negative effect of past experiences in cooperation may lead us to the following interpretation: cooperation and internal R&D are substitutes. In other words,

<sup>15</sup> The **variance inflation factor (VIF)** quantifies the severity of multi-collinearity in an ordinary least squares regression analysis. It provides an index that measures how much the variance of an estimated regression coefficient (the square of the estimate's standard deviation) is increased because of collinearity. To have a good rate of independence, VIF less than 5 is proposed.

when Iranian firms can gain access to a technology through cooperation, they don't use internal development. Moreover; reputation has a negative effect on propensity to internal development.

#### 5.4.2. Determinants of Cooperation

This section is devoted to determinants of propensity to cooperate. The following two subsections address such determinants at two level; technology and firm.

##### 5.4.2.1. Technology Related Determinants of Cooperation

Running regression for propensity to cooperate at technology level, we cannot obtain an appropriate model. The co-linearity between independent variables is high and the hypothesis regarding normality of residual errors is rejected. Thus, we convert the variable to its natural logarithm (Ln function). Using regression for natural logarithm of PTCOOP, amongst different models we select the best fitted model, which is presented below. The best model is the model with larger (or sometimes largest) amount of adjusted  $R^2$  and with Durbin- Watson Statistic near to 2. The results are presented in table 5.61.

Table 5.61- Determinants of Propensity to Cooperate at Technology Level

Variables	Ln of Propensity to Cooperate (PTCOOP)	Technical Uncertainty	Commercial Uncertainty	past experiences in cooperation	past experiences in R&D	N	R	adjusted $R^2$	Durbin-Watson Statistic
Model	.586 (.584)	.899 (.001)***	-.500 (.022)*	.523 (.000)***	-.372 (.007)**	77	.582	.302	2.100
VIF	-----	1.321	1.266	1.078	1.126	-----	-----	-----	-----

For each variable the estimated coefficient is given with the standard error below it in parentheses.

\* $p \leq 0.1$ ; \*\*  $p \leq 0.05$ ; \*\*\*  $p \leq 0.01$

As it is shown in table 5.56, Variables which affect the propensity to cooperate in this level and their coefficients are presented in equation 5.9.

$$\ln(\text{PTCOOP}_i) = 0.586 + 0.899 \cdot \text{TUNC}_i - 0.500 \cdot \text{CUNC}_i + 0.532 \cdot \text{TEXCOOP}_i - 0.372 \cdot \text{TEXR\&D}_i + \epsilon_i \quad (5.9)$$

In where:  $i = 1, \dots, 63$  (is the  $i^{\text{th}}$  firm)

$\epsilon_i$  is the difference between the value of the dependent variable predicted by the model, and the true value of the dependent variable. One method of estimation is mean square method (MSE).

For this equation the MSE is 2.61 and less than the MSEs of other models; thus it is acceptable for our model.

As it is presented in above equation, propensity to cooperate in technology level positively correlates with successful past experiences in cooperation as well as degree of technical uncertainty of technology. Higher degree of technical uncertainty for a specific technology increases the propensity to gain access to the technology by cooperation. Conversely, the successful past experiences in internal development decreases the propensity to cooperate. Another variable which has a negative

effect on the propensity to cooperate is degree of commercial uncertainty. The more commercial uncertainty related to a technology, the less the propensity to cooperate to gain access to the technology.

#### 5.4.2.2. Firm specific Determinants of Cooperation

Firstly, the effect of three control variables, including; number of patents, rate of innovativeness and the age of firm is studied. None of these control variables has a significant effect on the dependent variable of “propensity to cooperate”. Therefore, we don’t consider these three variables in complete models.

Using regression, amongst different models we select the best fitted model, which is presented below. The best model is the model with larger (or sometimes largest) amount of adjusted  $R^2$  and with Durbin- Watson Statistic near to 2. The results are presented in table 5.62.

Table 5.62- Determinants of Propensity to Cooperate at Firm Level

Variables	Propensity to Cooperate (PFCOOP)	Human Resources	past experiences in cooperation	Absorptive capacity	Technological Resources	N	R	adjusted $R^2$	Durbin-Watson Statistic
Model	-13.72(.345)	6.41 (.025)**	3.019 (.031)**	1.81 (.004)***	-7.37 (.015)**	40	.606	.295	1.681
VIF	----	1.338	1.001	1.086	1.434	----	----	----	----

For each variable the estimated coefficient is given with the standard error below it in parentheses.

\* $p \leq 0.1$ ; \*\*  $p \leq 0.05$ ; \*\*\*  $p \leq 0.01$

The regression equation which describes the effect of firm-related factors on cooperation of a technology is:

$$PFCOOP_i = -13.72 + 6.41 * HUMRES_i + 3.09 * FEXCOOP_i + 1.086 * AC_i - 7.37 * TECHRES_i + \epsilon_i \quad (5.10)$$

In where:  $i = 1, \dots, 63$  (is the  $i^{th}$  firm)

$\epsilon_i$  is the difference between the value of the dependent variable predicted by the model, and the true value of the dependent variable. One method of estimation is mean square method (MSE).

For this equation the MSE is 195.350 and less than the MSEs of other models; thus it is acceptable for our model.

The model proposed a positive effect of level of human resources, absorptive capacity and past experiences in cooperation on propensity to cooperate and a negative effect of level of technological resources on the dependent variable.

### 5.4.3. Determinants of Acquisition

This section is devoted to determinants of propensity to acquire. The following two subsections deal with determinants at two level; technology and firm.

#### 5.4.3.1. Technology Related Determinants of Acquisition

In this section, using a regression model even with a conversion of dependent variable is not useful because distribution of dependent variable (i.e. propensity to acquire at technology level) could not be fitted to a normal distribution at all. As it is presented in table 5.63, for 62 technologies we have 0% of acquisition, and for the remaining 27 technologies, the distribution ratio of the variable varies between 1% and 100%.

Table 5.63- Distribution of the ratio of “Propensity to Acquire” at Technology Level

Propensity to acquire (PTACQ) (%)	0	1	5	10	15	20	30	40	50	60	70	80	90	100
No. of technologies	62	1	4	2	1	5	2	2	2	2	2	1	2	1

In this situation discretization of dependent variable is a better way to formulate its behavior (Johnson & Albert, 1999). The variable is discretized in three intervals; PTACQ=0, PTACQ<=50, and PTACQ>50. This classification is proposed due to a conceptual reason; we would like to know when propensity to acquire is less than 50% or greater than 50%. We use “Generalized Ordinal Model” that is the best model in such cases (Zelterman, 2006). The results of running the model is presented in table 5.64.

Table 5.64- Determinants of Propensity to Acquire at Technology Level

Coefficients	Value	t value
PTACQ (from 0 to more)	3.6114	3.3340
PTACQ (from<50 to >=50)	6.4570	4.3542
TEXACQ (from1 to 2)	4.9212	3.6684
TEXACQ (from1 to 3)	3.6301	3.6301
TLC (from birth to growth)	1.0647	1.0050
TLC (from birth to Maturity)	2.7459	2.4841
TUNC (from 1 to 2)	0.1347	0.1649
TUNC (from 1 to 3)	2.3163	2.3150

In order to measure the relative goodness of fit of this model, we use both the Akaike information criterion (AIC) and the residual deviance. Since the AIC and residual deviance provide a means for comparison among models; we compare both the AIC and residual deviance of full model (model with all independent variables) and the present model. The AIC of the proposed model is 111.79 which is less than the AIC of the full model; 142.21. Residual deviance of our model is 91.79 and it is more than the residual deviance of full model; 59.45. Therefore our model is good enough.

Independent variables affect the propensity to acquire positively. These variables consist of past experiences in acquisition, technology life cycle and degree of technical uncertainty. As successful past experiences in acquisition increases, the propensity to acquire a technology increases too. The more the technology progresses in its life cycle, the propensity to acquire it increases. The higher technical uncertainty for a technology is estimated, the propensity to acquire it increases.

#### 5.4.3.2. Firm Specific Determinants of Acquisition

Relying on the same reasons of estimation PTCOOP (propensity to cooperate at technology level), we use a conversion function to formulate behavior of PFACQ (propensity to cooperate at firm level).

The conversion function is natural logarithm of dependent variable (Ln (PFCOOP)).

As other dependent variables at firm level, the effect of three control variables, namely; number of patents, rate of innovativeness and the age of firm, is studied. Using regression, amongst different models we select the best fitted model, which is presented below. The best model is the model with larger (or sometimes largest) amount of adjusted  $R^2$  and with Durbin- Watson Statistic near to 2. The results show the negative effect of patent on the dependent variable, which is shown in table 5.65 as Model 1.

Table 5.65- Determinants of Propensity to Acquire at Firm Level

Variables	Ln Propensity to Acquire (PFACQ)	Patents	past experiences in Acquisition	past experiences in Internal development	N	R	adjusted $R^2$	Durbin-Watson Statistic
Model 1	3.29 (.000)***	-.037 (.028)**	----	----	31	.407	.135	1.449
Model 2	3.52 (.000)***	-.030 (.066)*	.178 (.087)*	-.263 (.014)**	30	.699	.424	1.863
VIF	----	1.279	1.156	1.128	----	----	----	----

The regression equation regarding the dependent variable, Propensity to acquire is:

$$\text{Ln (PFACQ}_i\text{)} = 3.52 + 0.178 \cdot \text{FEXACQ}_i - 0.263 \cdot \text{FEXR\&D}_i - 0.03 \cdot \text{PATENT}_i + \epsilon_i \quad (5.11)$$

In where:  $i = 1, \dots, 63$  (is the  $i^{\text{th}}$  firm)

$\epsilon_i$  is the difference between the value of the dependent variable predicted by the model, and the true value of the dependent variable. One method of estimation is mean square method (MSE).



For this equation the MSE is 0.687 and less than the MSEs of other models; thus it is acceptable for our model.

Past experiences in acquisition has a positive effect on propensity to acquire. Two other variables that have a negative effect on propensity to acquire consist of the firm's past experiences in internal development and number of patents.

## **5.5. Conclusion**

In this chapter, the effect of various factors on three mode of technology sourcing was tested. Our findings confirm the effect of successful past experiences in R&D, firm's technological resources (including R&D capabilities, tacit know-how and ...), firm size, the stage of technology life cycle and technical and commercial degree of uncertainty on propensity to internal development. We found a positive relationship between successful past experiences in research and development and propensity to internal development. Moreover, strengths on technological resources motivate the firms to rely on internal development. Thus, firms which encompass weak technological resources compared with the industry leader firm should rely on other modes of technology sourcing, including; alliances or acquisitions. Firm size and its propensity to internal development have a negative relationship; i.e. the smaller firms are more likely to develop the technology internally. Amongst technology related factors, the stage of technology life cycle has a negative effect on internal development. In other words, the more a technology becomes mature, the less the firms rely on internal development. Technical and commercial uncertainties have a negative effect on propensity to internal development. It seems evident that in the case of technologies with a high degree of commercial and technical uncertainty, firms are more likely to share the risk and cost of gaining access to the technology with others. Thus, they are less likely to rely on internal development to gain access to the technology.

Regarding cooperation mode, our findings confirm the effects of three kinds of resources including; Physical, human and technological resources, as well as the level of firms' absorptive capacity and successful past experiences in cooperation. At technology level, technology life cycle and technical uncertainty have an impact on propensity to cooperate. Amongst three kinds of resources which have the effects on propensity to cooperate; physical and human resources have a positive effect and technological resources have a negative effect. In other words, firms with more strength on physical and human resources are more likely to cooperate while the weakness on technological resources increases firms' motivation to cooperate. Level of firms' absorptive capacity is also a factor affecting propensity to cooperate as higher level of absorptive capacity increases the propensity to cooperate. Firms with more successful past experiences in cooperation are more likely to rely on cooperation as a mode of gaining access to technology. The stage of life cycle in which the technology is situated

also affects the propensity to cooperate in the sense that the more a technology become mature, the fewer firms rely on cooperation. Degree of technical uncertainty in a technology affects the propensity to cooperate positively. Higher degree of technical uncertainty increases the propensity to cooperate.

Factors affecting propensity to acquisition include successful past experiences in acquisition, firm size, reputation and technological resources and differentiation objective amongst firm related factors and technology life cycle and technical uncertainty among technology related factors. Successful past experiences, firm size and the degree of strength on reputation resources have positive effects on propensity to acquire a technology. In other words, firms with more successful experiences, increasing level of reputation as well as the larger ones are more likely to acquire a technology. But, firms which select differentiation as their strategic objectives rely on acquisition to a lesser extent. Both the stage of technology life cycle and degree of technical uncertainty has positive effects on propensity to acquire. Acquisitions are more suitable for technologies that become mature or laggard as well as the technologies with higher level of technical uncertainty. Chapter 6 deals with these results and related literature.

## ***Chapter6***

### ***Discussion***

*In this chapter the research results are discussed in detail.*

This research investigates how, in technology intensive industries, the attributes of a technology and characteristics of a firm influence the degree to which a technology is developed internally, by cooperation or acquisition. As explained in chapter 5, while aiming to test the research hypotheses, two approaches were selected. Firstly, each hypothesis was tested and the effect of one independent variable on each of three dependent variables was studied. Secondly, using the regression model and discretization, the effect of a set of independent variables on each dependent variable was studied. The second approach was selected because the behavior of a variable may differ in presence of other variables. Although these two approaches are not mutually independent, some results may differentiate from one approach to another. Therefore, this chapter addresses a) the result of hypotheses testing in absence of other independent variables and b) the result of the effect of the same variable in the presence of other variables in regression model.

**Propensity to internal development:** The findings of this research support the negative effect of stage of technology life cycle<sup>16</sup> and degree of technical uncertainty on propensity to internal development. Moreover, our findings support the positive effect of successful past experiences and technological resources on internal development, as well as the negative effects of, reputation and size at the firm level analyses. Figure 6.1, represents the factors and their positive or negative effect on propensity to internal development.

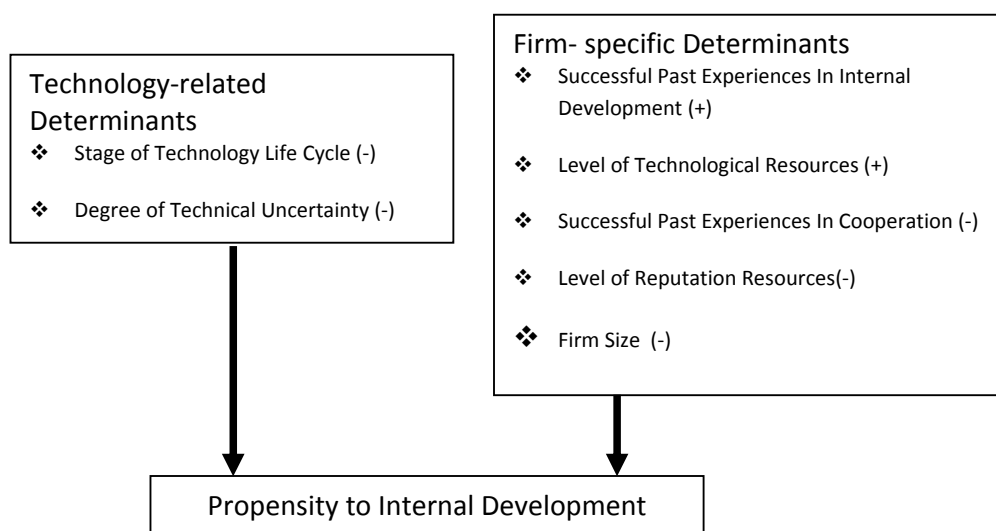


Figure 6.1- Determinants of Internal Development: Research Results

**Propensity to cooperate:** Our findings also support the negative effect of degree of commercial uncertainty and positive effect of degree of technical uncertainty on propensity to cooperate. At the firm level, our findings confirm the positive effect of successful past experiences in cooperation, level

<sup>16</sup> Negative effect of technology life cycle means that the more the technology advances in its life cycle; i.e. the more it becomes mature; the less firms have attention to develop the technology internally.

of absorptive capacity and level of human resources on propensity to cooperate. Level of technological resources is the factor that negatively affects propensity to cooperate (figure 6.2).

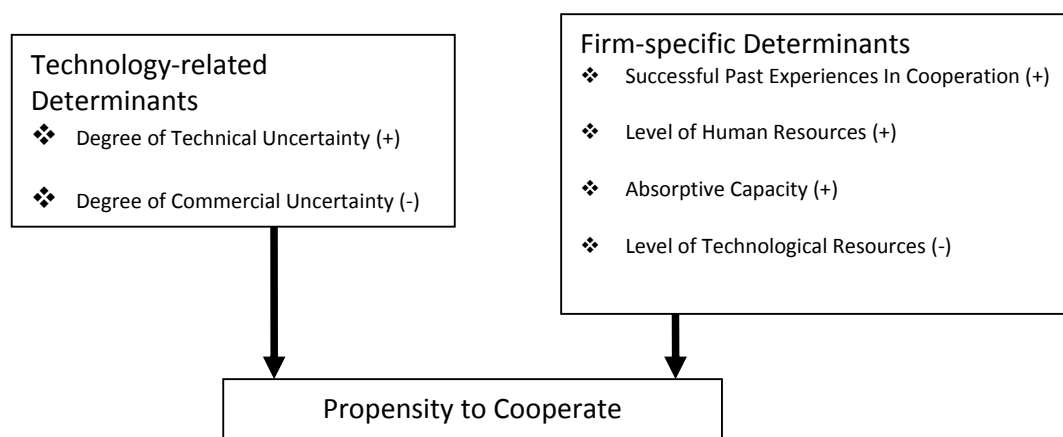


Figure 6.2- Determinants of Cooperation: Research Results

**Propensity to acquire:** As represented in figure 6.3, propensity to acquire is positively affected by stage of technology life cycle and degree of technical uncertainty. At the firm level, successful past experiences in acquisition positively affect propensity to acquire while successful past experiences in R&D and number of patents negatively affect propensity to acquire.

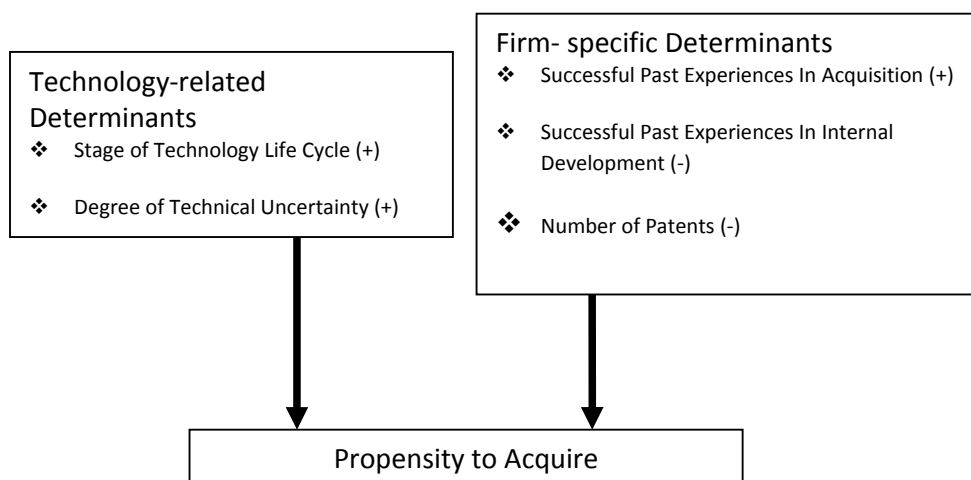


Figure 6.3- Determinants of Acquisition: Research Results

Regarding **technology life cycle**, the only supported hypothesis depends on the positive effect of technology life cycle (when a technology advances in its life cycle from birth to maturity) on propensity to acquire. Contrary to other researches, the present research addresses the movement of technology from each stages of life cycle to other stage separately. For example, we hypothesize that when technology advances in its life cycle from its birth to growth, propensity to cooperate and

acquisition increases, whilst advancing from maturity to laggard level decreases the propensity to acquire. One reason that our findings do not support the related hypotheses may be due to lack of sufficient data in each stage of technology life cycle- for example, only 14 out of 89 technologies are at the birth level and only 4 out 89 technologies are at the maturity stage of life cycle. Another reason may be related to how technology life cycle is determined in this research. We simply demand the managers to indicate the stage of life cycle of a certain technology, when they decide to gain access to the technology. Using supplementary questions around other specifications of different stage of technology life cycle may help managers to determine the stage more accurately. A third explication about the hypotheses related to propensity to internal development is the fact that internal development is a substitute mode of gaining access to the technology as Iranian firms use this mode whenever other modes; i.e. cooperation and acquisition, could not be applied. **Using regression model** for all the independent variables, our research findings support the influence of ***technology life cycle*** on propensity to internal development and acquisition. According to our findings, technology life cycle has a negative effect on propensity to internal development and a positive influence on propensity to acquisition. While our study supports this hypothesis with regard to Iranian technology- intensive firms, studies done by Jones et al, 2001 and Cho and Yu, 2000 do not find support this hypothesis neither in subsidiaries of multinational firms in USA nor for firms active in Korean telecommunication industry. Furthermore, Tyler and Steensma (1995) show the negative effect of progress in technology life cycle on propensity to cooperate in Manufacturing, utilities and software industry while our research does not support the effect of technology life cycle on propensity to cooperate. Such contrast between the findings of our research and studies done by Tyler and Steensma (ibid.) may be due to the low inclination of Iranian managers to cooperate with others (the fact that is explained later in detail in this chapter page: 159).

Two hypotheses that explain the effect of ***commercial uncertainty*** on propensity to cooperate and internal development are not supported by our study. In the regression model, our findings only support the negative effect of commercial uncertainty on propensity to cooperate and the effect of this variable on internal development and acquisition is not significant. Commercial uncertainty refers to the uncertainty associated with the commercial success of a technology or a technological innovation in the market. Lack of significant findings may be due to the ambiguity of commercial uncertainty for the respondents. Noting that there is a strong positive correlation between degree of technical and commercial uncertainty, it is probable that managers confuse these two concepts. Considering that Robertson and Gatignon (1998) do not find any evidence to support a positive relationship between *commercial* uncertainty and propensity to internal development, may confirm our reasoning.

Our findings support the hypotheses which describe the effect of **technical uncertainty** on propensity to internal development and cooperation. We found that technical uncertainty positively affects propensity to cooperate while it negatively influences propensity to internal development. Using regression model, **technical uncertainty** is also one of the factors which positively influence propensity to acquisition. Studies done by Tyler and Steensma (1995), and Bayona et al. (2001) also support the positive effect of technical uncertainty on propensity to cooperate.

The findings of this study do not support the effect of **strategic importance of technology** on the choice of technology sourcing modes. Tyler and Steensma (1995), however, found evidence which supports the effect of this factor on propensity to cooperate in the sense of an inverted U shape curve relation between strategic importance of technology and propensity to cooperate. As pointed out in section 5.1.3.1.3, the majority of investigated technologies is declared distinctive (76 from 89) and niche (6 from 89), therefore we may conclude that the results are valid for these kind of technologies. In other words, strategic importance of technology may be considered as a control variable in this research.

The effect of **technology urgency** on different modes of technology sourcing is supported neither in hypotheses testing process nor in the regression model. Related hypothesis states that the more urgent gaining access to a technology is, the fewer firms rely on internal development. In our analysis, urgency is not a factor influencing sourcing decision. As internal development is frequently a substitute for other modes; several internal and external restrictions<sup>17</sup> motivate managers to develop a technology internally in the firm, even if there is an urgent need to access to the technology. In such conditions, the effect of urgency in choice of a certain mode is not important.

At the firm level, we could not find a relation between firms' global **internal resources** and selection of technology sourcing modes neither in hypotheses testing nor in regression model. In the present research, level of firm's internal resource is evaluated as a function of six kinds of resources including technological, human, financial, physical, organizational and reputation. Although our study shows no relation between internal resources as a whole and each of three modes of technology sourcing, particular kinds of resources affect modes of technology sourcing.

Amongst different internal resources, **technological resources** affect propensity to internal development in a positive manner. Jones et al. (2000) show the positive effect of technological supports on internal development of technology in US-based multinationals. Contrary to our findings, Allerd and Swan (2004) could not find any evidence to support the effect of technological resources on propensity to internal development. The more the firm invests on its R&D resources, the more the

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<sup>17</sup> These conditions are described later in this chapter.

firm expects to be able generating additional technologies (for an accurate technology) and gain more profits from the technology (Davidson & McFetridge, 1985). So, firms with richer level of R&D resources are likely to develop technology internally.

According to our finding, **human resources** positively affect propensity to cooperate, without any influence on propensity to internal development and acquisition. Allerd and Swan (2004) find strong evidence which supports the effect of human resources on propensity to internal development.

Although we did not find any relation between **financial resources** and selection of technology sourcing modes, according to Allerd and Swan (2004), it positively influences propensity to internal development. Financial resources are mostly important factors to influence the choice of modes both directly (acquisition modes) and indirectly (internal development and cooperation). However, we did not find any relation between financial resources and selection of technology sourcing modes. One reason for this issue is that the respondents of our questionnaire underestimated the level of financial resources in the firms. This fact may become clearer when we consider the total number of respondents which provide financial information of the firms; (15 out of 63 firms). Thus, any judgment on financial resources is invalid.

Our results do not show any relation between other firms' resources; **organizational resources and reputation**, and choice of technology sourcing modes. Our literature review also did not reveal any such relation between these kinds of resource. Regarding the effect of **absorptive capacity**, three hypotheses are proposed. Hypotheses regarding the negative effect of absorptive capacity on internal development and its positive effect on cooperation are not amply supported. However, these hypotheses could not be rejected completely. The third hypothesis describes the negative effect of absorptive capacity on propensity to acquire. This hypothesis is not supported. In the regression model, our findings support the positive effect of absorptive capacity on propensity to cooperate, while Tyler and Steensma, (1995) could not find any evidence to support this effect. Such contrast between the findings of our research and the above-mentioned studies may be due to the fact that:

Firstly, we evaluate absorptive capacity in a specific manner. One part of Absorptive capacity is evaluated as the ability of firms to assimilate knowledge from external sources. Degree of knowledge leakage is widely different across the four studied industries, namely; telecommunications and microelectronics, Information technology, biotechnology and nanotechnology. Respondents may underestimate their real ability, for example, when the leakage of knowledge in their industry is weak, a manager may think the ability of assimilate the knowledge is feeble. In other words, the level of absorptive capacity is not being evaluated with an identical scale across different industries.

Additionally, our research contributes to define a more essential role for absorptive capacity as a determinant of technology sourcing mode. Most researches in this area introduce absorptive



capacity as a factor influencing the performance of an alliance or cooperation, or as a determinant of innovation activity within a firm.

Regarding **successful past experiences**, *our study supports* the positive effect of this variable on decision sourcing. Our findings confirm the theory that firms behave mostly according to their successful past experiences.

Regarding two main strategies; **differentiation** and **low-cost goal**, our results don't support the effect of them on choice of technology sourcing modes. However, the study done by Allerd and Swan (2004) supports the positive effect of differentiation and low-cost on propensity to internal development in subsidiaries of multinational companies in the United States. These contrasting finding may be accounted for by market differences.

Multinational firms compete in an international environment. Even if they act in a local market as national subsidiary, their pattern of innovation and their general strategies will be influenced by headquarter management or other units (Yip, 1989). Therefore, a competitive environment encourages MNCs to define their general strategies noticeably. Iranian technology-intensive firms are mostly active in a local market with low competition (mostly with overseas' productions). Market demand in technology-intensive productions /services is not saturated and general strategies are not well defined (Porter 1985). This fact explains why related hypotheses are not supported.

We found out that **firm size** has a negative effect on propensity to internal development and a relative positive effect on propensity to acquire. Kiyota and Okazaki (2005) and also Montalvo and Yafeh (1994) find the positive relation between firm size and number of licensing agreements in Japanese firms. While our study does not support the positive effect of size on propensity to cooperate, Shan (1990) reports the negative effect of size on propensity to cooperate, amongst a sample of American biotechnology firms which introduce new products to market. Boyle (1968), on the other hand, discovered persuasive evidence that larger firms engage more frequently in joint ventures than smaller firms. Hernan et al (2003) also report the positive effect of size on propensity to research joint ventures. In a multiple case study approach, Moenart *et al.* (1990) found that small firms with limited resources turned to alliances to achieve innovation, whereas large firms preferred to become innovative. Hagedoorn & Schakenraad (1994), by contrast, found a tendency towards greater strategic technology partnering as the size of firms rises. The discrepancy between the findings of Shan (1990) and Boyle (1968) and Hernan et al. (2003) and the lack of significant findings in this research may be due to the complexity of the issue itself. Clearly, arguments can be made for both propositions, that benefiting from high level of competencies (around all aspects of technology) in large firms may lead to less cooperation and more internal development and that lack of complementary competencies around the technology may lead large firm to cooperate. In this research, there is no distinction between firms with wholly-owned competencies and partly-owned

competencies in the area of technology. Therefore, a lack of significance finding is realized. Firm size may not be a determinant of technology sourcing decision on its own but it may be significant on certain context.

In the regression model, we find **Number of patent** as one of the determinants of propensity to acquire. The number of patents has a negative effect on propensity to acquire. In fact, it indirectly refers to the firm's past experiences. Firms with a large number of patents are more innovative and certainly have more experiences in internal development and cooperation rather than acquisition. Therefore, typically they rely less on acquisition.

Coefficient of regression equations at firm level shows a positive and high rate of Iranian firms' propensity to internal development (about 72%), a lower rate for acquisition (34%) and a negative propensity to cooperate with others (-14%). Interviewing managers in pilot phase of this research confirms high rate of propensity to internal development; managers of 13 firms amongst 40 studied firms declared using only internal development to gain access to the technology, and 22 firms reported of using other modes complementary to internal development. Amongst the studied firms, only 5 firms declared to rely on acquisition modes without any internal development efforts<sup>18</sup>. In contrast to our finding, in the pilot study the managers who declared using cooperative modes are also at the majority (17 out of 40 firms). Our findings show a negative tendency to cooperate at the firm level. This difference may be explained in terms of the time lag between pilot study (in 2004) and data collecting (in 2008).

Conversely, on firm level results, coefficients at technology levels show a positive propensity to cooperate (1.8% for cooperation). These results may be explained according to strategic importance of technologies which is selected by managers. As explained in chapter 5, the majority of studied technologies could be classified as distinctive while only some rare technologies could be called niche. These technologies are those ones which are strategically crucial for the firms and even though the global firms' propensity are estimated negative for cooperation, for these technologies firms are more likely to cooperate rather than to acquire. For these technologies, propensity to internal development also increases compared to the firm level propensity of internal development; (about 130% at technology level compared to 73% at firm level). This findings show that, despite the critical importance of cooperation agreements high-tech industries (Mowery, 1988), Iranian firms in this industry are more likely to develop the technology internally. This fact could be explained in terms of two main reasons. Firstly, in Iran, legislations to support intellectual property rights are weakly developed. This factor discourages firm managers to enter in collaborative agreements with

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<sup>18</sup> Further information is represented in Appendix I.

compatriot companies. In our pilot study, chief technology officer of a telecommunication company with 150 employees pointed out:

*“In the country, collaborating with others is not a good solution. The legislations to protect IPs are less effective. For our technologies, we make some precautions to make the imitation difficult, if not impossible, for our competitors. In this situation, even outsourcing may give our competitors access to our technologies.”*

Also a CEO of an electronic company with more than 1000 employees describes the situation as following:

*“Legislations for protecting intellectual property rights are ineffective and time consuming in the country. Additionally, the amount of penalty devoted to abusers is not deterrent, thus in our company we prefer to obtain the technology through other modes rather than cooperation. We only enter in cooperation agreements with our sister companies”.*

Secondly, the international situation of Iran and limitations such as political restrictions- especially sanctions- prevents foreign companies to enter in collaboration agreements with their Iranian peers. In this situation, bargaining power of rare foreign would-be partners is increasingly high, and consequently it may not be easy to attain the aim of collaboration.

## **Chapter7**

### **Conclusion**

*In this chapter, a summary of research is presented. Moreover, we provide a general conclusion to this dissertation while pointing out the limitations of present research as well as the fields for further studies. The last section of this chapter proposes implications for managers and researchers.*

## **7.1. Summary and Conclusion**

This research aimed to investigate the determinants of technology sourcing modes (TSMs). Based on a conceptual framework, three group of modes were determined; namely, internal development, cooperation and acquisition. The literature review explored factors affecting different modes of technology sourcing while categorizing them into three categories; namely, Technology-related, Firm-specific and environmental factors. Amongst numerous factors supposed to influence TSMs, five of the most referred factors in each category were selected. A list consisting of thirty one hypotheses were proposed, argued and tested in Iranian high-tech firms. Data were gathered through a survey from CEOs, CTOs, R&D department chief, project managers and marketing projects in Iran. The study was confined to four technology intensive industry including; telecommunications and microelectronics, Information technologies, nanotechnologies and biotechnologies.

The results of hypothesis testing and regression model determine factors affecting each group of TSMs. Our findings showed negative effect of stage of technology life cycle and degree of technical uncertainty, on propensity to internal development. We also found evidence to support the positive effect of successful past experiences in internal development, and technological resources, and negative effect of successful past experiences in cooperation and level of reputation resources as well as firm size on propensity to internal development at the firm level analyses.

Moreover, our study revealed the positive effect of degree of technical uncertainty and negative effect of degree of commercial uncertainty on propensity to cooperate, at technology level. At the firm level, our findings confirm the positive effect of successful past experiences in cooperation, level of absorptive capacity and human resources on propensity to cooperate. Technological resource is the factor negatively affect propensity to cooperate.

Our results show that propensity to acquire, at the technology level, is positively affected by the stage of technology life cycle and degree of technical uncertainty. At the firm level, successful past experiences, positively affect propensity to acquire, number of patents and successful past experiences in R&D negatively affect propensity to acquire.

## **7.2. Limitations of Research**

The results of this research must be considered in the light of different limitations.

- Survey results can be used to describe the relationship between variables and not to explain the casualty (Kerlinger & Lee, 2000). To better understand the causal relationship between variables, the in depth case studies will be needed.

- The nature of some variables; e.g. dependent variables, were a single-item measure. This may raise the questions on reliability of the variable which may have explained why the present study revealed so little evidence.
- The data was gathering from one single respondent. If the number of respondents increases, the reliability of responses will augment.
- For classifying strategic importance of studied technologies into four groups, it may be possible to propose a more effective method which could consider the cases (3, 3).
- The stage of industry life cycle also influences decision on technology sourcing modes (Auster, 1992). While other industrial and environmental factors are approximately fixed in this research, the selected firms are drowning out of industries at different stage of life cycle. While electronic and telecommunication may shows maturity, Nano technology is at the growth stage. This factor is not considered in our study.

### **7.3. Research Implications**

Present research may help both practitioners and researchers in different ways. The results of this research suggest determinants affecting the selection of technology sourcing modes. Given that many firms now compete through their ability to choose one appropriate technology sourcing mode, an understanding of these determinants may assist the practitioners. Top executives involved in this type of decision making process can use these results to compare their decision making criteria with that of the sample of executives in this study. If they have not recognized the relevance of certain types of information, the theoretical arguments outlined in this research may help them shorten the selection process by eliminating factors not affecting selection of technology sourcing mode. According to Hamel (1991) the intent to learn should be a primary concern for a company wanting to develop and strengthen internal distinct competencies that can provide a competitive advantage. Top executives should ask themselves if they adequately consider the value of their firm's internal resources (e.g., skills, capacity to learn, tacit knowledge) and the potential for resource development when using an external sources of technology. They should evaluate their capacity to 'learn' from such a relationship.

The results of present study also may be advantageous for the researchers. It may provide the opportunity to compare the results of such study in different countries and industries. In this regard, the moderator variables are recognized and in the presence of such variables the effect of determinants are re-considered.

At national level of decision making, the results of the present study may help the authorities to provide appropriate legislations.

#### **7.4. Further Study**

The perspective of further study is suggested as follows:

- An important group of factors which is neglected in this research is “decision specific” factors. This group deals with the propensity, level of information and experience of firms’ managers in different level to select a mode. Further research may rely on this group of factors.
- Next research may focus on the hypothesis of background and marginal technologies with a valid data collection process.
- Our sample is limited to the private companies. Another study may be needed to concentrate on the public companies. Generally, public companies are benefited more financial resources and at the same time lower level of human resources and technological know-how.

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## **Appendix I**

### **Behavioural Patterns of Technology Sourcing: The Case of Iranian Hi-tech Companies**

#### **Abstract:**

This paper investigates different modes of technology sourcing which have been used by Iranian Hi-Tech companies. Technology sourcing is broadly defined as gaining access to a new technology and/or technological knowledge either from inside or outside of a firm. Different modes of technology sourcing are presented and briefly discussed. Thanks to an examination of a panel of selected examples, we infer a typology of Iranian Hi-Tech companies according to their behaviour regarding technology sourcing, and five behavioural patterns are identified: a) Technology implementer, b) Emphasis on In-house R&D, c) Cooperative, d) Conqueror and e) Full deployer. We also study the effect of size and business sector on the choice of technology sourcing mode.

**Key words:** Technology sourcing mode, behavioural pattern, Iranian Hi-Tech companies, exploratory research.

## Introduction

Technology is a source of competitive advantage. Firms are more likely to gain access to technology to survive. Focusing on internal research and development (R&D) and firms' own capability as the sole source of technology is not sufficient to survive in a speedy technological changing environment (Vanhaverbeke et al, 2002). Internal R&D is a costly and time consuming activity with high degree of technical and market risks, therefore firms are increasingly relying on external sources of technology.

Technology sourcing is broadly defined as gaining access to a new technology and/or technological knowledge either from inside or outside of a firm (Hemmert, 2004). Different modes of technology sourcing exist to gain access to a technology, for example In-house R&D, Non-equity joint venture (N.E.J.V.), Equity joint venture (E.J.V.), Equity R&D consortia, Sub-contracted R&D, License purchase, Patent purchase, License swap, Specialist recruitment, Firm take-over, Joint take-over and Complementary license purchase (Zahra and George, 2002; Jones et al., 2000; Veugelers and Cassiman, 1999; Jolly & Ramani, 1996; Spencer & Grindley, 1993; Werner, 1992; Hagedoorn, 1990; Evan & Olk, 1990; Roberts & Mizouchi, 1989; Ouchi & Bolton, 1988; Teece, 1986; McDonald & Leahey, 1984).

Selecting an appropriate technology sourcing mode is a big challenge for every firm. It is more critical for the firms situated in developing countries due to technological gaps existing between developed and developing countries, pressure to gain access to technology, and limited capacity to generate new technology internally (Lall, 2000). In addition, policies and regulations in developing countries promote certain modes of technology sourcing; for example Sino-foreign joint ventures in China (Jolly, 2004; Yan & Warner, 2002; Deng, 2001; Vanhonacker, 1997), cooperative agreements such as alliances and joint ventures with foreign counterparts in India (Von Zedwitz & Moitra, 2005; Mani, 2004) and hiring key personnel and alliances in Brazil (Balbinot, 2006; Vasconcellos et al., 1995), are a few cases studied in literature. Therefore, each country may follow its own behavioural pattern of technology sourcing according to the internal and external context. Furthermore, in the same country, this behavioural pattern may vary from one industry to another (Tidd et al., 2001, Zahra *et al.* 1997). Our research aims at revealing the attitude of Iranian Hi-Tech companies regarding technology sourcing.

Thanks to an examination of a panel of selected examples, we infer a typology of Iranian Hi-

Tech companies according to their behaviour regarding technology sourcing. It is to note that this paper is intended to be majorly descriptive and exploratory rather than analytic and normative.

The rest of the paper is structured as follows: Section 1 describes the research context, by briefly reviewing the economic and political conditions of Iran (as a developing country) and then analysing Hi-Tech industry in Iran. The second and third sections are devoted to literature review. Different modes of technology sourcing are discussed in section 2 and in section 3 decision models regarding technology sourcing in order to develop a conceptual model are reviewed. The fourth section describes the research methodology including the method of sampling and data analysis. The research findings (behavioural patterns of investigated companies) are presented and discussed section 5. Finally, the paper is concluded with managerial implications and recommendations for future research.

## 1. Research Context

Iran is certainly a unique market in the Middle East. It is populous, rich in natural resources and apt to technological progress and international developments. The country's natural resources (oil, gas, minerals) create significant, but mostly untapped wealth. The growth rate of the economy rose to 4.7 % in 2007 and Iran is the 17<sup>th</sup> country in the world<sup>19</sup>.

Iranian companies have engaged in technological relationships with foreign companies since 1972 (when the open-door policy of Iranian government was established). A period of revolution and war between 1978 and 1988 caused the country to lag in technological advancement. Nevertheless, about three decades of revolution, war and economic mismanagement have led to a very different reality.

After the war, Iranian companies started once again to make relationships with companies abroad to gain access to technology. At the same time they concentrated on internal R&D to enhance their absorptive capacity and make their technological relationships more effective and efficient. The government also promoted technological relationships with foreign companies, especially through foreign direct investment (FDI) particularly in energy sector.

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<sup>19</sup> World Bank report at <http://devdata.worldbank.org> and <http://siteresources.worldbank.org>, Retrieved February 2008

Still, there are some indications that Iranian officials have realized the extent of the damage caused by years of mismanagement and are trying to promote domestic and foreign private investment as well as economic and political liberalization in order to compensate via raising the rate of foreign direct investment in recent years (Figure1). However the FDI attraction rate is still classified as underperforming on its potential in corresponding period.

Figure 1 about here

According to the Constitution, the economy of the Islamic Republic of Iran consists of three sectors: state, cooperative, and private. Until 2006, the state sector included all large-scale industries, foreign trade, major minerals, media and transportation which were publicly owned and administered by the State. In recent years, the authorities pay more attention to the liberalization and therefore the shares of some large public companies are offered to private sector (Initial Public Offering). The cooperative companies concentrated on production, especially in agriculture sector and distribution in both urban and rural areas. Finally, the private sector consisted of those activities concerned with agriculture, animal husbandry, industry (including Hi-Tech), trade, and services.

Although Iran is the second producer of oil in the world, the government is issuing policies to diversify away from oil by investing in other areas of economy, including car manufacturing, aerospace industries, consumer electronics, petrochemicals, nuclear energy, and Nano-Technology. Also, Iran has a great potential for development in mining, tourism, and information and communication technology (ICT)<sup>20</sup>.

Aforementioned policies are particularly opportune regarding the existing pool of highly qualified workforce, graduated from the best universities in the world and from Iranian universities. Iran is the 14<sup>th</sup> in the world for the number of students studying technical subjects, as well as for the quality of education in Iranian universities. It shows that Iranian universities are competent in number and quality to educate and prepare human resources to work in technology intensive industries. Iran has made the great improvement in

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<sup>20</sup> CIA Fact book/Iran at <https://www.cia.gov/library/publications/the-world-factbook/geos/ir.html#Econ>  
Retrieved February 2008.

published papers; from 768 in 1998 to 7000 in 2007<sup>21</sup>. Figure 2 and Table 1 indicate the increasing rate of Iranian publications especially in the Science and Technology fields from 1995 to 2005. Nevertheless only .41% of articles cite Iranian papers in 2007; Iran has made a four-fold growth from 0.1% since 1998 in share of citation. Iran is also listed 63<sup>rd</sup> on technology activity, weighted on research manpower, US patents and scientific journal articles, with a considerable growing rate.

Figure 2 & Table 1 about here

As mentioned earlier, this research is concerned with Hi-Tech companies. Hi-Tech companies are distinguished by the following characteristics (khalil, 2000):

- They employ highly educated people (normally more 60% of total employees hold BS degrees or above);
- Their industry is facing technological evolutions at a faster rate than other industries;
- They compete with technological innovation;
- They spend more than 10% of their revenue on R&D activities.

Taking into account the above mentioned characteristics, we can find very few truly Hi-Tech companies in Iran. Therefore we prefer to use the terms “Technology-Based” or “Technology Intensive” to refer to those companies which have built their businesses on technology but may not precisely possess all of the criteria stated above. In this research, we consider both “Hi-Tech” and “Technology Intensive” companies and the terms are used interchangeably throughout the article. Although Technology (either process or product technology) plays the main role in these companies’ competitive advantage (Kotabe et al., 2007), technology intensive companies tend to invest less than 10 percent of their revenue on technological innovation, and/or their number of knowledge workers may not exceed 60 percent of total employees.

The majority of Hi-Tech companies in Iran are Small and Medium private enterprises which

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<sup>21</sup> Department for Innovation, Universities and skill (DIUS), International comparative performance of the UK research base, UK government, July 2008



means their number of employees rarely reaches 500 and their revenue does not exceed 1 b\$<sup>22</sup>.

## 2. Technology Sourcing Modes

Decision on technology sourcing mode consists of internal R&D and a range of non-internal technology development methods (Narula, 2001). Various technology sourcing modes exist in literature. These modes are briefly described below<sup>23</sup>.

1. **In-house R&D:** This is the most common sourcing mode. It could be defined as the creative use of the firm's own resources (existing knowledge embodied in R&D staff as well as laboratories, tools and other equipment) to realize a technological innovation. The main difference between “in-house” and other modes is that the former is intra-mural while the latter are extra-mural.

2. **Internal transfers:** Such transfers occur when some technological knowledge is transferred from one SBU to another within a large company (a corporation). This means that the firm sees itself as a large reservoir of technology. The rationale behind this is that, if one technology was developed in a given SBU, it doesn't belong solely to that SBU but belongs also to the entire group. Consequently, other SBUs should be able to gain it (for a given internal transfer price).

Next three modes are positioned in cooperative R&D agreements which mostly carried out in the area of technological innovation. Noting that innovation is costly and uncertain, with special abilities being required in its management and with its results being difficult to appropriate, all this justifies the need for firms to cooperate in R&D (Bayona et al., 2001).

3. **Non-equity R&D joint venture (N.E.J.V.):** This mode covers co-operative agreements between at least two independent firms where one specific R&D project is co-coordinated, workload shared and results exchanged. The joint action is organized in the context of one contract without any equity link (i.e. without the creation of a common entity).

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<sup>22</sup> Definition of SMEs has been adopted from Acs & Audretsch, 1988.

<sup>23</sup> This part draws heavily on Humbert & Jolly (1997). In the contrary case, we have mentioned the related reference(s).

4. **Equity R&D joint venture (E.J.V.):** This is a joint structure set up by a small number of sovereign firms (usually two or three). They pool technological resources of their own to establish a new business. EJV might also be the result of a partial merger between two distinct companies that have decided, for example, to pool their respective R&D departments into one single body. Such entities are found in most Hi-Tech sectors.

5. **Equity R&D consortia:** This is quite similar to equity R&D joint ventures – except that the consortia usually bring together a large number of firms (Ouchi & Bolton, 1988). The role of a consortium may be focused on driving and co-coordinating the research conducted by members in-house, or on the contrary, on becoming a research centre distinct from its members (Evan & Olk, 1990). Several well-known examples, such as the Microelectronics and Computer Technology Corporation (Werner, 1992) or Sematech (Spencer & Grindley, 1993) in the semiconductor industry show that consortia usually target pre-competitive research.

6. **Sub-contracted R&D:** This is essentially funding another firm, under time and cost specifications, to conduct a specific R&D project whose results will be the property of the sponsoring firm(s). Unlike Roberts & Mizouchi (1989), we do not consider this approach to be a co-operative one, as there is no joint management, no common work and no reciprocity in the unilateral contract.

7. **Licensing:** It is the most commonly observed inter firm contractual agreements (Anand & Khanna, 2000). This is simply paying royalties (or some other form of compensation) to an innovator for the right to use the knowledge he or she developed. The license contract ends when the two parties (buyer and seller) decide to cancel their agreement.

8. **Patent purchase:** This mode involves much more commitment than license purchase because it is a definitive move. Property is transferred from the innovator to the acquiring firm. It is a way of internalizing knowledge that has been produced outside the firm.

Both licensing and patent purchasing are usually far from being situations of co-operation as these unilateral commercial transactions take place between a seller and a buyer in the knowledge market (Hagedoorn, 1990).

9. **License swap:** While some authors use this term (e.g. Zahra et al., 2005), others use the term “cross-licensing” (Anand & Khanna, 2000; Telsio, 1979) to describe an agreement

where two firms agree to barter (without disbursement) their licenses. Such deals occur very frequently in industries with more intensive competition such as the semiconductor or pharmaceutical industry.

10. **Specialist recruitment:** This is a quick way to internalize some expertise into the firm's set of resources.

11. **Firm take-over:** This might be a full take-over (100%), an acquisition (in order to gain financial control) or an absorption (where  $A+B=A$ ). All these moves allow the company to gain access to an existing technological asset or R&D capabilities of the firm taken over that are otherwise not possible to efficiently redeploy (Anand & Delios, 2002).

12. **Joint take-over:** This involves two firms agreeing to buy a third one to gain a technological base. This mode is not frequent. Most of the time, it ends in splitting the targeted entity between the two buyers.

13. **Complementary license purchase:** This involves a two party agreement. The first one is a firm requiring technological knowledge and the second one is a research centre or university (rarely another firm). The buyer sends its qualified labour to learn a certain technological knowledge, and pays for this to the second party. The responsibility of preparing the equipment belongs to the firm and the second party (research centre or university) acts as consultant.

The above mentioned technology sourcing modes are not exclusive. In addition, at a corporate or even at a SBU, one project may be based entirely on In-house R&D as another project may be run through a technology acquisition. Furthermore, for a single project, a combination of different modes could be applied, for example the project may start with In-house R&D and continue with alliance or acquisition.

Decision on technology sourcing modes is one of the main questions that should be answered when a firm technology strategy is being formulated (Chiesa, 2001; Burgelman et al., 2001; Hax & Majluf 1996). Answering such an important question, which may affect the firm position in competitive market and/or its financial perspective and profitability, needs taking into account corporate and sectoral diversity (Tidd et al., 2001).

There are different typologies which might explain the diversity of companies, such as Large

vs. Small or Medium size, Hi-Tech vs. Low or Medium Tech, Start-up vs. Well-established. Concerning sectoral diversity, there are several taxonomies, such as Pavitt taxonomy (Pavitt, 1984), Niosi taxonomy (Niosi, 2000), Marsili taxonomy (Marsili, 2002) and OECD taxonomy (Acha & Tunzellman, 2005). These taxonomies help to elaborate, analyze, describe or explain “Inter-sectoral differences” based on two parameters: structure (complexity) of industries and patterns of industrial dynamics (Dosi, et al., 1997). Almost all authors believe that the source of innovation and/or technology differs from one category of firms to another.

### 3. Theoretical Framework

To classify the modes of technology sourcing, different models are developed (Chiesa, 2001; Jolly, 1995; Ford, 1988); Single-dimension models which classify technology sourcing modes in a spectrum between internal R&D and Turn-key (Chiesa, 2001; Ford, 1988), and double-dimension models which consider two basic questions that managers normally face in selecting technology sourcing modes; firstly, whether to develop the technology internally or externally, and secondly, if the firm should act solo or with collaboration (Jolly, 1995).

Chiesa (2001), in his single-dimension model, classifies different modes of technology sourcing according to the following factors:

- The impact of each mode on the *firm’s resources*,
- The needed *time* to gain access to technology in each mode,
- The degree of *control* which the firm has *over activities* in each mode,
- The degree of *control* which the firm has *over results* obtained by each mode,
- The degree of (financial) *risks* which the firm accepts,
- *Reversibility*: the extent to which the characteristics of the modes can be modified,
- *Start up time and costs* necessary to start each mode.

Figure3 represents how these factors help managers to decide on appropriate mode(s).

Figure 3 about here

Ford (1988) suggests five other factors including “Technology-related” factors such as technology life cycle and strategic impact of technology (Figure 4).

Figure 4 about here

In his double-dimensions models (Figure 5) Jolly distinguishes between the “access mode” (internal versus external development) and the “action mode” (collaborative versus autonomous).

Figure 5 about here

Amesse and Cohendet (2005) describe different modes of technology transfer using a similar model. Shilling (2005, pp. 143-145) defines two modes of action; going solo and collaborating. She considers some acquisition modes such as licensing and outsourcing to be collaborative while Jolly positions these modes in “autonomous action” category.

We distinguish “collaborative actions” from acquisition by defining a collaborative action to comprise a provisional relationship in which two (or more) “allies” (so-called “partners”), pool their resources in order to achieve a predefined shared objective. The results of this relationship benefit every part. Out of this relationship, allies stay independent (Jolly, 1995). Alternatively an acquisition agreement typically involves two parts; buyer and seller that do not necessarily share an objective, benefit from its results bilaterally, or stay independent outside the relationship. Therefore, acquisition cannot be considered as a collaborative action.

Deciding on technology sourcing modes is simpler by using double-dimensions models comparing to one dimension ones. In former, decision making is divided into two stages: managers should first focus on the zone (among four zones of matrix) and then select the appropriate mode(s) from the focused zone. It decreases the complexity and facilitates the decision making.

Taking into account two dimensions model, we have based our theoretical framework on Jolly's model to determine how Iranian companies behave according to technology sourcing modes.

#### 4. Methodology

##### Sample

Initial data were drawn from a sample of Iranian Hi-Tech companies, which were selected through the two following steps. In the first step, from a list published by the Hi-Tech Industries Centre of Iran (HTICI)<sup>24</sup>, companies were extracted by eliminating those companies which had been active for under six months or were active in activities other than manufacturing (such as consulting).

Interviews were conducted with managers, C.T.O or R&D managers of selected companies (persons who seemed to be more informed about the modes of Technology sourcing)<sup>25</sup>, and the aim of the research was clearly described.

Since there still remained companies that hadn't subscribed in the HITCI, in the second step, the interviewees were asked to introduce other Hi-Tech companies<sup>26</sup> including their partners, rivals, suppliers, customers; etc.

Amongst 52 identified companies, managers of 44 companies agreed to participate in the interview. Four questionnaires were excluded from the analysis due to their paradoxical input. The majority of 40 remaining companies were active in four main sectors; electronics and microelectronics, telecommunications, information technologies and biotechnology.

##### Data Collection and Analysis

A semi-structured questionnaire was designed and used for data collection. The questionnaire was split into three parts. In the first part, the managers were asked to give some general information about the company such as: year of establishment, number of

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<sup>24</sup> Hi-Tech Industries Centre of Iran (HTICI) is a governmental organization for support of Iranian Hi-Tech companies. For more information please visit [www.hitech.ir](http://www.hitech.ir).

<sup>25</sup> purposeful sampling method

<sup>26</sup> snowball sampling method

staff, number of engineers working for the R&D department (including the engineers who work either inside or outside the R&D department), and annual R&D budget. The second part consisted of questions about different modes of technology sourcing used by the company, by the time of interview. We also asked about the companies' partners and their nationalities. In the third part the managers were invited to express their comments including problems they confronted within technology sourcing process and their experiences in relationships with technology suppliers or partners. Among all cases of technology sourcing, we encountered some cases that had happened before the period of interviewees' responsibility, or the manager simply did not remember the case in enough detail, leaving the researcher uncertain about the modes applied. These cases have been therefore eliminated.

Questionnaires were reviewed and analyzed putting all information together, and comparing companies according to their characteristics and technology sourcing modes they employed. Also additional remarks pointed out by managers during the interviews were considered.

In order to classify the companies, the procedure presented in Figure 6 has been followed. According to this procedure, starting from Jolly's model which distinguishes four different patterns (Figure 5), each company is put into the appropriate category (zone). There were some overlaps (i.e. one company fitted into two or more categories), or companies in the same category experienced different patterns of technology sourcing, which resulted in the category being divided into two or more subcategories. Thus, the categories were reviewed and reorganized to the point where the final classification was accomplished.

Then, some simple statistical calculations were carried out based on the collected data in order to associate firms' characteristics (such as their size, the industry they belong to, the number of staff and their R&D budget) with the pattern of technology sourcing they followed.

## 5. Results and Discussion

### 5.1. Behavioural Patterns

Three main behaviours were identified among surveyed companies according to Jolly's model; the first group are companies which emphasize internal resources and rarely

participate in collaborative activities, even in joint R&D projects, referred to as “R&D Emphasizers” in this article. The second group which are an opposite extreme of the first are “Technology Implementer” companies that make no effort in their R&D department; they only implement the acquired technologies. In other words, they prefer to gain access to technology rapidly by purchasing licenses or other sorts of technology acquisition. Three other categories can be distinguished between these two extremes: “Cooperative” “Conqueror” and “Full Deployer”. “Cooperative” companies are very open to the outside world through alliance, JV, consortium, etc., “Conquerors” are under time pressure, they want to gain access to technology quickly and put their efforts into firm take-over rather than collaboration. And finally, “Full Deployers” benefit from all modes of technology sourcing; from internal R&D to alliances and licensing-in. The five-identified categories are mapped on Jolly’s model (Figure 7).

Figure 7 about here

Table 2 illustrates the companies in each category. As shown, among the five categories, the “Cooperative” holds the major portion of investigated companies (17 of 40). In other words, they gain access to technology by cooperating as well as by putting their efforts on R&D. The second largest category encompasses “R&D Emphasizers”. It is implied that the majority of Iranian Hi-Tech companies do perform R&D activities to sustain a certain level of technological capabilities. These companies enable themselves to enter cooperative modes in order to gain access to technology faster and less costly by improving their absorptive capacity through internal R&D.

Many researches confirm the positive impact of internal R&D activities on firms’ absorptive capacity (Cohen & Livintal 1990, Zahra & George,2002). Many references also elaborate the relationship between absorptive capacity and technology or knowledge transfer effectiveness (Liao et al. 2007, Chen,2004, George et al. 2001, Lane et al., 2001, Lane and Lubatkin, 1998; Lyles and Salk, 1996). In a recent publication, Hongwu (2008) explores the determinants of firms' external technology sourcing modes. His research is focused on firms' absorptive capacity and examines how a firm matches sourcing modes with its absorptive



capacity to enrich knowledge transfer in technology sourcing. He has shown positive relations between firms' absorptive capacity and interactive technology sourcing modes.

On the other hand, both "R&D Emphasizers" and "Cooperatives" companies studied stuck to "Develop/Make" versus "Acquire/Buy" Strategy (Figure 7). It may be because of political situation of the country and the sanctions which have provoked some restrictions on Iranian Hi-Tech companies' access to required technologies.

## 6.2. Effect of industry

As mentioned earlier, in this research we investigated companies from four sectors of Hi-Tech; electronics and microelectronics, telecommunications, information technologies and biotechnology. It seems that companies in a particular sector use common ways to access to technology.

Bio-Tech companies use licence purchasing and/or complementary licence purchase; modes which allow rapid access to technology, along their internal R&D. There are few companies, such as PZT, who focus only on internal R&D.

Companies which are active in microelectronics, electronics and telecommunications, put more emphasis on internal R&D. They also try to have some kind of collaboration (technological alliances, joint ventures, etc.) with foreign partners. These companies benefit from very high qualified knowledge workers, which enables them to establish technological relationships and learn from world-class partners.

IT companies also have access to high qualified knowledge workers, invest in R&D, and make relationships with foreign companies. However, their purpose of collaboration is different from aforementioned groups; it is to gain access to marketing expertises rather than technological capabilities.

Differences in behavioural pattern of companies in different sectors may be interpreted by the assumption of influence of sector on technology sourcing modes. Some researches discuss the effect of business sector on technology sourcing modes (Tidd et al., 2001, Zahra *et al.* 1997; Gersony, 1996; Galbraith & De Noble, 1988). Firms in different sectors are committed to particular modes of technology sourcing depending on the characteristics of the sector/industry they belong to.

### 6.3. Effect of Size and R&D Investment

Many researches confirm the impact of size on technology sourcing strategies (Moeller et al., 2002; Vasconcellos et al., 1995); some investigated the relationship between internal R&D and firm size (Munier, 2004, Acs & Audertsch, 1998, Rosen, 1991), and some others studied the effect of firm size on collaborative modes such as alliance, joint venture, etc. (Casaroni, 2004; Moeller et al., 2002; Kusewitt, 1985).

Different criteria are used to measure the size of companies, including the annual turnover (Moeller *et al.*, 2002) and the number of employees (Casaroni, 2004; Munier, 2004; Cohen & Klepper, 1996). In this work the revenue and budget of R&D department was declared by a small number of investigated companies, therefore the number of staff and the ratio of R&D engineers (per total employees) have been chosen as indicators of company's size and its R&D investment respectively (Table 3).

On average, "cooperatives" are larger than "R&D Emphasizers" in size which may explain the relationship between firm size and cooperative behavioural of companies. A firm's motivation to cooperate with others will increase as its size increases, since larger firms risk less in cooperation than do smaller ones (Narula, 2004; Cassiman & Veugelers, 1998). However, the average ratio of R&D engineers in "R&D Emphasizers" is higher than in "Cooperatives" which is probably because "R&D Emphasizers" focus more on internal R&D activities than "Cooperatives".

Propositions for "Technology implementers", "Conquerors" and "Full deployers" might not be as strong as those for the two aforesaid categories due to the limited number of companies under these categories within the sample. However, based on a small number of studied companies, we can draw some interpretations. Amongst the five categories, "Technology implementers" are the smallest in size and average number of R&D engineers. This is probably because "Technology implementers" do not have any internal R&D. R&D activities require considerable investments and risk taking abilities which small companies are not often likely to hold. "Conquerors" are large vis-à-vis "R&D Emphasizers" and "Cooperatives" but, their R&D engineers are fewer. It means that they put less effort on R&D activities than "R&D Emphasizers". In fact, R&D engineers in these companies are required

mostly to monitor technological evolutions.

Table 3 about here
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## 6. Contribution and Concluding Remarks

This study sheds light on different modes of technology sourcing employed by Iranian Hi-Tech companies. We distinguished five behavioural patterns regarding technology sourcing: “R&D Emphasizers” who rely only on their internal resources and capabilities for technology development; “Cooperatives” who perform R&D activities but are very open to the outside world as well through cooperation, JV, consortium, etc.; “Conquerors” are companies under time pressure to gain access to technology quickly. They do not have enough time to go through R&D or to put their resources in collaboration and normally try to acquire the needed technology through firm take-overs; “Technology implementer” refers to the companies which allocate no funds to R&D and normally gain access to required technology by license purchasing; and finally, “Full deployers” are those companies which use different kinds of technology sourcing (including in-house R&D, any kind of collaboration, licensing-in, firm take over, etc.). Thanks to an examination of a panel of 40 selected examples, the effect of industry and size in the choice of different modes of technology sourcing was investigated.

Our results show:

- The majority of investigated companies have an acceptable level of R&D activities which enables them to improve their absorptive capacity. Their higher level of absorptive capacity provides better conditions for learning from external sources of knowledge. Thus, they have performed many joint R&D projects successfully, with domestic as well as foreign partners.
- In cases of buying the technology or license purchase, the companies prefer to deal with foreign partners in order to gain access to new technologies as well as to decrease their technological gap with other countries.
- In the case of internal technological collaboration, the companies prefer to collaborate with their sister companies (who share their board of directors) rather than with their domestic competitors. This is due to the lack of legislations to protect intellectual property rights.
- R&D units established by foreign companies in developing countries are important sources of locally developed technology. Given the highly qualified labour and high

R&D quality level of Iranian companies, they are able to attract multinational companies to establish their R&D units in Iran. This could also be a new source of technology. However, there is a lower rate of joint ventures, alliances and other kind of technological collaboration with foreign partners compared to Hi-Tech companies in other developing countries such as Brazil, India or China. It may be because of political situation of the country and the sanctions which restrict the relationship with other countries, especially with western countries.

- Although the majority of the company top managers and senior researchers are, at the same time, university faculties, there is a low rate of official relationships with the universities and research centres (8 companies from a total of 40 investigated companies). It may also be due to the lack of intellectual property rights protection.

## 7. Managerial Implications

The implications of this research work can be divided into two groups with regard to their significance to managers and policy makers of Hi-Tech companies.

### 7.1. Implications for Managers

Focusing on internal research and development (R&D), and firms' capabilities as the sole source of technology is not sufficient to survive in a rapidly changing technological environment. This study demonstrates that in order to fully benefit from their technology sourcing, Hi-Tech companies, especially those performing in developing countries, should concomitantly develop both their learning process and their absorptive capacity. Managers of Hi-Tech companies should be aware of the fact that a learning attitude shared throughout the firm together with a developed absorptive capacity may facilitate expanding their range of technology sourcing modes more efficiently. The majority of investigated companies in this work consist of "R&D Emphasizers" and "Cooperatives" which have an acceptable level of R&D activities which shows Iranian Hi-Tech top managers notice to this issue.

### 7.2. Implications for Policy Makers

Considering Iranian government's recent interest in promotion of knowledge-based firms,

policy makers may consider focusing on and supporting technological innovation within newly established SMEs especially those founded by university graduates or people with brilliant technical backgrounds. Hi-Tech companies in every country cannot be isolated from global market. They need to collaborate with companies from other countries in order to gain access to new technologies. Iranian companies have been developing their absorptive capacity and are potentially able to enter collaborative activities with companies overseas. However, since the political situation of the country may limit their relationships policy makers may also consider Hi-Tech companies' challenges in related decision making.

Furthermore, the government may initiate a research program with the help and contribution of Hi-Tech companies' managers, with the aim of determining the appropriate mode(s) of technology sourcing for each group of companies according to specific characteristics of the industry they belong to.

## 8. Limitations and Further Research

Extending the results of this research to all Iranian Hi-Tech companies is not allowed due to the limited number of investigated companies, especially in the case of "Technology implementers", "Conquerors" and "Full deployers" within the sample. In fact, the research is intended to be mostly descriptive and exploratory rather than analytic and normative.

Another important point is the kind of company in terms of public or private, as this might affect the choice of technology sourcing modes. Our study was limited to private companies and therefore does not suggest that public companies follow the same behavioural pattern.

Considering at least three different important periods in Iran; the years of war between Iran and Iraq, the post-war period of reconstruction, and the period of stability, possible relationships between different modes of technology sourcing and the characteristics of the mentioned periods might be investigated. In the survey, all cases of technology sourcing during the history of investigated companies are studied regardless of the period they occurred in.

Only the effects of size and sector on technology sourcing modes have been examined in this work, while, many other factors such as technology related factors, affecting this decision, are yet to be investigated.

For further research, we propose the following topics:

- Examination of other important factors affecting the decision regarding technology sourcing, such as technology life cycle, firms' absorptive capacity, cultural and geographical distance, intellectual property rights, etc.
- Comparison between the behaviour patterns of Iranian companies and other developing countries. In this context the research may be narrowed down by comparing behaviour patterns of companies situated in a specific industry among developing countries. Comparing behavioural patterns of companies in different countries can reveal the effect of macro environment on selection of technology sourcing modes.
- Exploration of the difference between behavioural patterns of public and private companies regarding to technology sourcing modes. The same study can be realized by comparing the behaviour of Hi-Tech and Low and/or Medium Tech companies.

### **Acknowledgement**

The authors gratefully acknowledge the managers of companies, in particular Professor Ali Fotowat Ahmadi, for the time they devoted to the interviews, as well as for sharing their knowledge and experiences. This research would not have achieved its results without their collaboration. The authors would also like to acknowledge Mr. Pardiss for his help and precious advice during this research.

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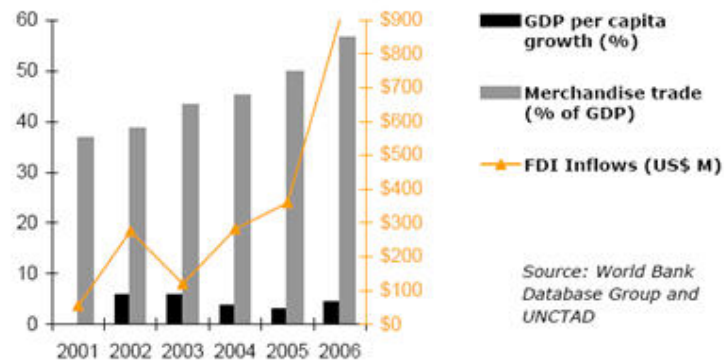
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## 1- Figures



Source: World Bank Database Group and UNCTAD

Figure 1- The rate of GDP and FDI growth in Iran

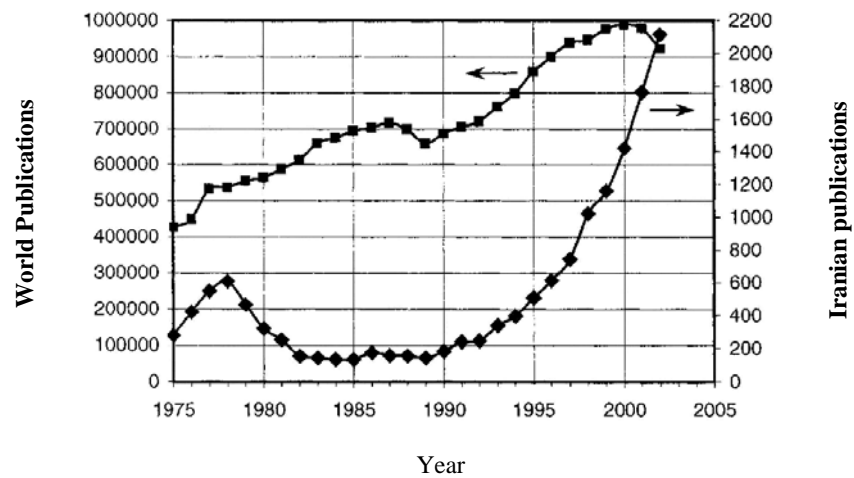


Figure 2 - World and Iranian publications indexed in SCI

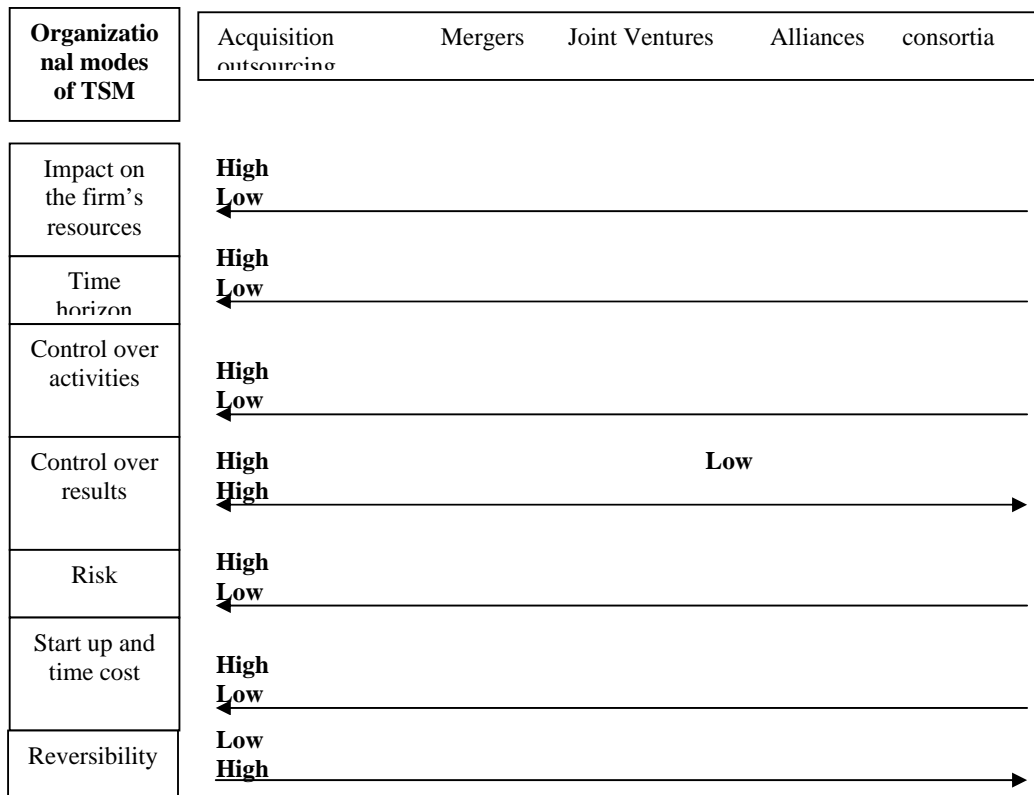


Figure 3 – Characteristics of organizational modes Source: Chiesa (2001)

Acquisition modes	Company Relative Standing	Urgency of Acquisition	Commitment / investment involved	Technology Life Cycle position	Categories of Technology
Internal R&D	High	Lowest	Highest	Earliest	Most Distinctive or Critical
Joint Venture		lower		Early	Distinctive or Basic
R&D Outsourcing		Low		Early	Distinctive or Basic
License Purchase		High	Lowest	Later	Distinctive or Basic
Turn-Key Agreements	Low	High	No Commitment/Investment	All Stages	External

Figure 4 - Ford Model (source: Ford, 1988)

<div> <div>Action Mode</div> <div>Access Mode Mode</div> </div>	Autonomous Approach	Collaborative Approach
<b>Develop the technology internally</b>  <b>(Make)</b>	In-house R&D	All kinds of technological alliance such as:  - Equity R&D joint venture - Non-equity R&D joint venture - Equity R&D Consortium - Joint Venture
<b>Develop the technology externally</b>  <b>(Buy)</b>	- License purchase - Complementary License Purchase - Patent purchase - Firm take-over - Acquiring one part of an innovative firm - Sub-contracted R&D	-Joint take-over

Figure 5- Classification of Technology Sourcing Mode (Source: Adapted from Jolly, 1995)



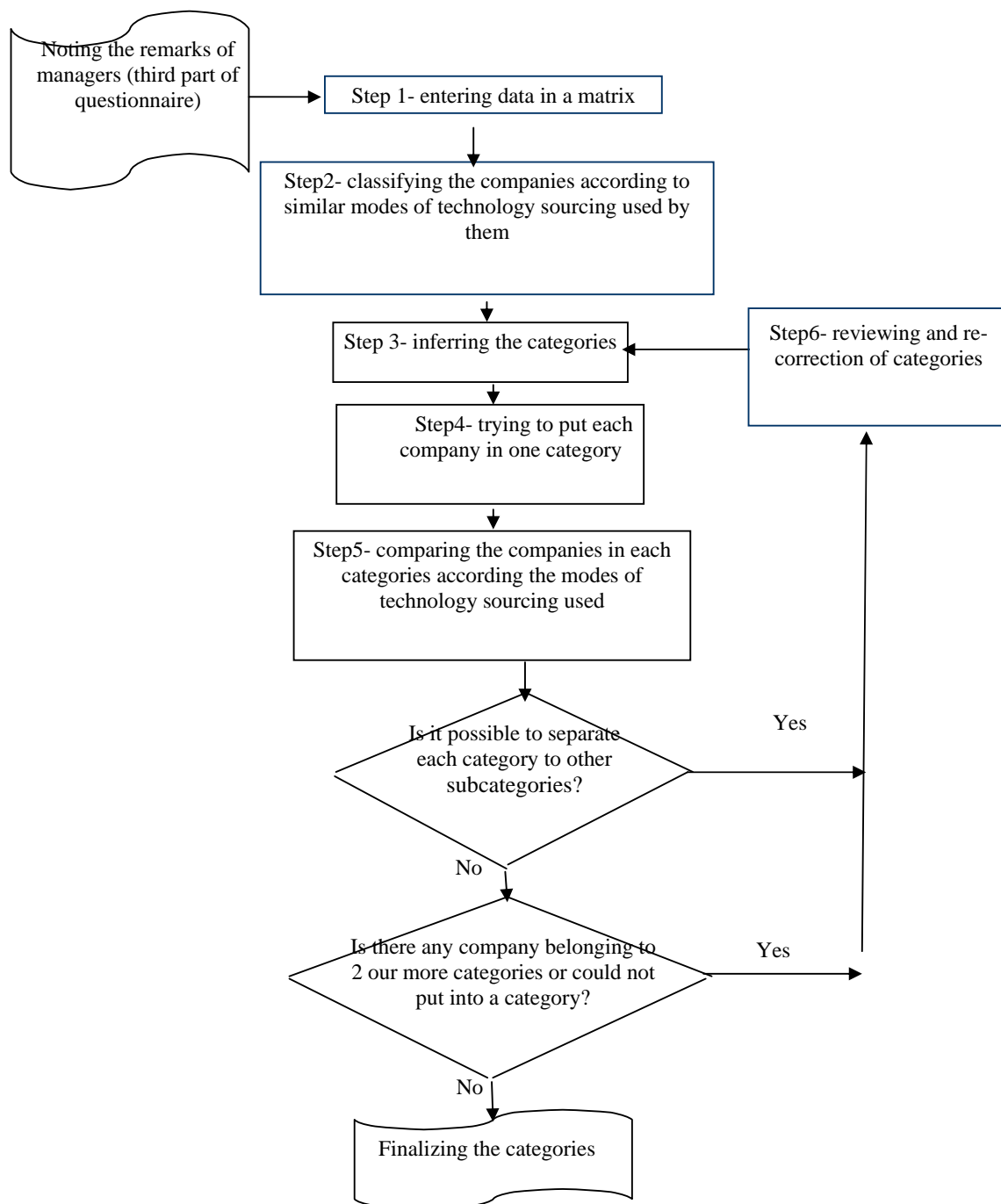


Figure 6- procedure of inferring five categories of behavioural pattern of Iranian companies

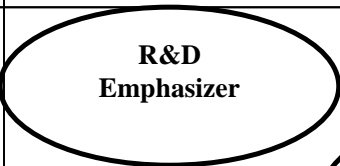


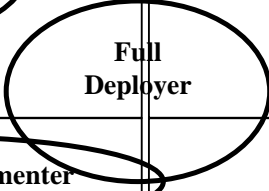

<div> <div>Action Mode</div> <div>Access Mode</div> </div>	Autonomous Approach	Co-Operative Approach
Develop the technology (Make)	 <b>R&amp;D Emphasizer</b>	 <b>Cooperative</b>
Acquire the technology (Buy)	 <b>Technology Implementer</b>	 <b>Full Deployer</b>  <b>Technology Conqueror</b>

Figure 7- Five behavioural patterns of investigated companies

## Tables

Table 1 – Distribution of Iran's scientific publications, 1975–2002, across Library of Congress subject headings (LCSHs)  
(Source: Wilson & Osareh (2003))

<b>LCSH</b>	<b>1975–81</b>	<b>1982–88</b>	<b>1989–95</b>	<b>1996–2002</b>
<b>Basic sciences</b>	1098 (35·2)	472 (42·3)	1230 (41·5)	6091 (46·3)
<b>Medical sciences</b>	1053 (33·7)	428 (38·3)	767 (25·9)	3191 (24·2)
<b>Technology</b>	476 (15·2)	117 (10·5)	610 (20·6)	2367 (18·0)
<b>Agricultural sciences</b>	396 (12·7)	88 (7·9)	326 (11·0)	1111 (8·4)
<b>Social sciences</b>	100 (3·2)	12 (1·1)	33 (1·1)	410 (3·1)

Table 2 - Technology sourcing modes in different business sector

Category of company	ABB	Electronic & Micro Electronic	Telecommunication	Biotechnology	IT	Diverse
Technology Implementer (5 from 40)	JEL	√				
	POD			√		
	BIZ			√		
	LED			√		
	INS			√		
R&D Emphasizer (13 from 40)	MC		√			
	PAR		√			
	BOR				√	
	AFA	√				
	FAR				√	
	PZT			√		
	IRL			√		
	BAF			√		
	PAT			√		
	TAT					√
	FRN					√
	PAD	√				
	PRM		√			
cooperative (17 from 40)	RAY				√	
	HAS				√	
	IRS		√			
	ARK				√	
	REL	√				
	RAS		√			
	IRR				√	
	AAG		√			
	YSY				√	
	BES		√			
	BAN		√			
	CIN			√		
	NAF		√			
	SAR		√			
	SYG				√	
	PAS		√			
	PER					√
conquerer (2 from 40)	MIC		√			
	RAS		√			
full deployer (3 from 40)	KAC	√				
	KIL		√			
	PIT			√		



Table 3 - Relationship between company size (No. of R&D engineer /No. of staff) and (No. of Staff) and its category

Technology Implementer			R&D Emphasizer			cooperative			conquerer			Full Deployer		
Firm ABB	Percentage of R&D engineers	No. of Staff	Firm ABB	Percentage of R&D engineers	No. of Staff	Firm ABB	Percentage of R&D engineers	No. of Staff	Firm ABB	Percentage of R&D engineers	No. of Staff	Firm ABB	Percentage of R&D engineers	No. of Staff
BIZ	na	5	AFA	14	140	AAG	na	na	RAS	na	na	PIT	18	57
JEL	6	80	PAR	15	300	BES	na	na	MIC	40	100	KAC	20	251
LED	20	15	BOR	20	12	SYG	3	400				KIL	21	70
INS	25	40	IRL	25	12	RAY	12	100						
POD	53	15	BAF	30	60	PER	12	45						
			FAR	33	200	REL	20	90						
			PAT	42	12	ARK	21	38						
			FRN	50	26	IRR	25	40						
			PAD	55	18	CIN	27	26						
			TAT	75	20	NAF	29	70						
			MCT	80	100	YSY	33	60						
			PRM	88	25	RAS	40	80						
			PZT	89	18	IRS	41	200						
						HAS	50	na						
						SAR	67	45						
						BAN	70	50						
						PAS	80	75						
Average of R&D engineers		26	Average of R&D engineers		47	Average of R&D engineers		35	Average of R&D engineers		40	Average of R&D engineers		20
Average of staff		38	Average of staff		73	Average of staff		94	Average of staff		100	Average of staff		126

## Appendix II

Mailing 1 of 2

Dear Mrs. /Sir

I am writing to ask for your help in a study of technology sourcing in Iranian High-tech industries. As I explained in our conversation by telephone before, this study is a part of a doctoral research in “institute nationale polytechnique de Lorraine” about determinants of technology sourcing modes.

As a chief executive officer you are the most informants to assist with this study. For some parts of questionnaire you may consider other person in your firm as the key informant; in such a case please don't hesitate to ask this person to fill out this part of questionnaire.

Results from this study will be used to better understand how and why technologies are sourced.

The enclosed questionnaire asks only for general information about technology sourcing in your firm and is not seeking any proprietary information about your firm or its technologies. Additionally your answers are confidential and results will be aggregated to assure anonymity. You can help us very much by taking a few minutes to share your knowledge of technology sourcing decision at your firm.

Please contact me at 09126308188 or e-mail me at akaramipour@yahoo.com should you have any questions or comments about the questionnaire. We would be happy to hear from you.

We sincerely appreciate your collaboration.

Sincerely

Azita Karamipour  
Doctoral candidate  
INPL-ENSGSI  
8, rue Bastien Lepage  
54010 NANCY Cedex  
France

Mailing 2 of 2

Dear Madame /Sir

Thank you for filling out and returning the questionnaire. Please let me keep you posted on the results.

Sincerely yours



## Questionnaire

### **“Determinants of technology sourcing modes”**

Dear Madam/ Sir

This questionnaire is designed in order to study the effects of Technological and firm specific factors on selection of technology sourcing modes.

It consists of three parts. The first part is dedicated to firm related questions. Second part is about general information of your company, and finally, the third part is designed for technology related questions. The last part should be filled out for each technology acquisition project. This is why we enclose several copies in the questionnaire. Each part of questionnaire could be filled out by different persons.

Should you have any question or comments, please do not hesitate to contact Mrs. Azita Karamipour at 09126308188.

Your response to this survey is strictly confidential and will be reported only in summary form.

We appreciate your time and participation.

## Part 1-Firm Related Questions

- How is your firm able to gain access to and assimilate external knowledge from ...?

1. Suppliers? *Weakly capable*

1	2	3	4	5
---	---	---	---	---

*Very capable*

2. Clients? *Weakly capable*

1	2	3	4	5
---	---	---	---	---

*Very capable*

3. Competitors? *Weakly capable*

1	2	3	4	5
---	---	---	---	---

*Very capable*

4. Universities? *Weakly capable*

1	2	3	4	5
---	---	---	---	---

*Very capable*

5. Other research institutions? *Weakly capable*

1	2	3	4	5
---	---	---	---	---

*Very capable*

6. Conferences, meetings and specialized journals? *Weakly capable*

1	2	3	4	5
---	---	---	---	---

*Very capable*

7. Exhibitions and showrooms? *Weakly capable*

1	2	3	4	5
---	---	---	---	---

*Very capable*

8. To what extent your firm has been able to enhance its performance of processes, using aforementioned external sources? *Very Weak*

1	2	3	4	5
---	---	---	---	---

*Very High*

9. To what extent your firm has been able to enhance its performance of products /services, using aforementioned external sources?

<i>Very Weak</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>Very High</i>
------------------	----------	----------	----------	----------	----------	------------------

10. To what extent your firm has been able to create new products /services, processes, knowledge, systems and organizational forms using aforementioned external sources?

<i>Very Weak</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>Very High</i>
------------------	----------	----------	----------	----------	----------	------------------

11. How do you evaluate the **intensity of firm's efforts** to identify and gather knowledge from aforementioned external sources?

<i>Very Weak</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>Very High</i>
------------------	----------	----------	----------	----------	----------	------------------

12. How do you evaluate the **speed of firm** to identify and gather knowledge from aforementioned external sources?

<i>Very Weak</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>Very High</i>
------------------	----------	----------	----------	----------	----------	------------------

13. Do you have the routines for analyzing, interpretation and understanding information obtained from external sources, in your firm?

Yes ☐

No ☐

14. If yes, how do you evaluate the effectiveness of these routines?

<i>Very Weak</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>Very High</i>
------------------	----------	----------	----------	----------	----------	------------------

15. Do you have the routines for adding, deleting new knowledge or interpreting previous knowledge in new manner, in your firm?

Yes ☐

No ☐

16. If yes, how do you evaluate the effectiveness of these routines?

<i>Very Weak</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>Very High</i>
------------------	----------	----------	----------	----------	----------	------------------

17. Do you have the routines to harvest and incorporate knowledge into its operations, in your firm?

Yes ☐

No ☐

18. If yes, how do you evaluate the effectiveness of these routines?

<i>Very Weak</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>Very High</i>
------------------	----------	----------	----------	----------	----------	------------------

- Please rate the strengths of your firm comparing to the leader in the industry, regarding the following aspects?

19. Financial Resources?

<i>Very Weak</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>Very High</i>
------------------	----------	----------	----------	----------	----------	------------------

20. Human Resources (including knowledge, experience, judgment, intelligence, relationships, and insight of managers and workers)?

<i>Very Weak</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>Very High</i>
------------------	----------	----------	----------	----------	----------	------------------

21. Technological assets (including R&D capabilities and tacit know-How)?

<i>Very Weak</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>Very High</i>
------------------	----------	----------	----------	----------	----------	------------------

22. Physical resources (including Plants and equipments)?

<i>Very Weak</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>Very High</i>
------------------	----------	----------	----------	----------	----------	------------------

23. Organizational assets (including corporate culture, inter-service teams, forecasting groups, new product development department, venture group)?

<i>Very Weak</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>Very High</i>
------------------	----------	----------	----------	----------	----------	------------------

24. Reputation assets (Brands, well-known products/services,...)?

<b>Very Weak</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>Very High</b>
------------------	----------	----------	----------	----------	----------	------------------

25. Please indicate the degree to which differentiation in your products/services is important for your customers' choice.

<b>Last Important</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>Most Important</b>
-----------------------	----------	----------	----------	----------	----------	-----------------------

26. Please indicate the degree to which low cost of your products/services is important for your customers' choice.

<b>Last Important</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>Most Important</b>
-----------------------	----------	----------	----------	----------	----------	-----------------------

- Please complete the following table.

27	The percentage of firm's technologies that are developed internally?	
28	The percentage of firm's technologies that you develop with a partner?	
29	The percentage of firm's technologies that you acquired externally (license purchase, firm take over, outsource) solely or with others?	
	Total	100

Name of completer:  
Position:

**Part2-General Information**

30. Company's Name:

31. Web site Address:

32. Main Fields of Activity:

33. Your firm is: producer                      service-developper

34. Kind of company:              Public                      Private

35. Year of establishment :

36. Number of staff (Totally):

37. Number of R&D researchers:

38. Would you like to complete the table below for your firm's registered patents until now?

Number of registered patents	Country in which the patents is registered

39. Number of patents that your company has/had been able to register but for some reasons it does/did not:

Please complete the following table.

No.	years	2005	2006	2007	2008
40.	Annual revenue of the Company				
41.	Annual budget of R&D department/ firm's total revenue				
42.	Total payment of R&D personnel (per month)?				

43. Please indicate the percentage of firm's annual revenue that you earn by new products.

0%-25%	26%-50%	51%-75%	76%-100%
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**Name of completer:**

**Position:**

**Part3- Questions about the Technology (please duplicate this section for multiple case)**

**Technology is defined as “practical implementation of knowledge” including information, knowledge, skills and equipment. Some technologies may not include the equipment.**

44. Technology (name or code):

45. How long do you have this technology in your portfolio (years)?

46. Please indicate the percent of modes which is used to gain access to this technology?

The mode used to gain access to the technology	Percent of technology gained by this mode
Internal development	
Cooperation	
Acquisition(license purchase, firm take over, outsource)	
Total	100

- Please note that technology could be gained by only one mode (100 %)

47. Please describe the major factors you take into account to select this mode.

- Technology –related factors:
  - Technology life cycle
  - Importance strategic of technology
  - Degree of urgency to gain access to the technology
- Environmental factors:
  - Legislations
  - Political conditions
  - Intellectual property rights
  - Bargaining power of partners
- Firm related factors
  - Financial resources
  - Other resources
  - Firm’s learning capacity
  - Degree of independence of the firm
- Others (please indicate the factor)



48. Before selecting above mode(s), Have you ever had successful past experiences using this mode(s)?(please complete the rows correspond with question 46)

Internal development	<i>No successful experience</i>	1	2	3	4	5	<i>A lot of successful experiences</i>
Cooperation	<i>No successful experience</i>	1	2	3	4	5	<i>A lot of successful experiences</i>
Acquisition(license purchase, firm take over, outsource)	<i>No successful experience</i>	1	2	3	4	5	<i>A lot of successful experiences</i>

- **Notification:** in order to answer the following questions, please consider the situation your company was confronted when deciding to gain access to the technology.

49. At which stage was it, when it came into your portfolio: birth, growth, maturity or laggard?

50. How did you evaluate the degree of possibility of Commercial success for this technology?

**Very Weak**

1	2	3	4	5
---	---	---	---	---

**Very High**

51. How did you evaluate the degree of possibility of Technical success for this technology?

**Very Weak**

1	2	3	4	5
---	---	---	---	---

**Very High**

52. How did you assess the impact of this technology on your competitiveness?

**Very Weak**

1	2	3	4	5
---	---	---	---	---

**Very High**

53. How did you evaluate the potential market share (application-field) gained by this technology?

<i>Very Weak</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>Very High</i>
------------------	----------	----------	----------	----------	----------	------------------

54. To what extent your firm was under time pressure for gaining access to this technology?

<i>Very</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>Very High</i>	<i>Weak</i>
-------------	----------	----------	----------	----------	----------	------------------	-------------

- In the case of cooperation, please answer the questions from 55 to 58.
  - 55. Number of your partners:
  - 56. Name of your partner(s):
  - 57. Time of establishment the cooperation:
  - 58. Time of dissolution of cooperation:
- In the case of acquisition, please answer the questions 59 and 60.
  - 59. Your equity sharing:
  - 60. Number of partner:
  - 61. Noting above conditions about the technology, please indicate the percentage of your preference way to gaining access to the technology.

Develop internally	
cooperation	
Buying the technology/ firm take over/outsource/...	
Total	100

62. To what extent the technology could be codified?

<i>Weak potential</i>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<i>High potential</i>
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Name of completer:

Position:

*Thank you for your participation*

## ***Appendix III***

### ***Consistency of English and Persian version of questionnaire***

In our research, the original questionnaire is designed in English. In the procedure of data gathering some managers desired the English version of the questionnaire while some others preferred the Persian one. In order to have a higher response rate, we prepared both versions of questionnaire while performing a back translation process to guarantee the consistency of the two versions. Normally a back translation process is performed only to translate a questionnaire distributed in another language, i.e. once a back translation is performed; all the distributed questionnaires are in second language. Our research is different because we distributed the questionnaire in two languages according to the managers' requests. Therefore, after finishing the data collection, we tested the consistency of two versions of questionnaire. The aim of this test was to answer the following question: Are there any differences between the responses given to these two versions of questionnaire?

We used two different method to answer this question; firstly, we categorized the completed questionnaires into two groups, namely; those which were completed in Persian and those which were completed in English (18 questionnaires). Then, we compared the variances and means of each group for each question and verified if there was significant difference between the answers given to the two groups. Secondly, using a clustering method, we clustered the questionnaire into two groups. If questionnaire in Persian and English were clustered in two separate groups, we could conclude there were significant differences between the two versions of questionnaire which is not the case.

#### **1- Comparing variances and means**

Amongst 63 returned questionnaires, only 18 questionnaires have been completed in English. We arrange English questionnaire in one group and the Persian one in another one. Variances and means of each question in each group has been calculated and shown in table 1.

**Table1- Group Statistics**

Question	Group	N	Mean	Std. Deviation	Std. Error Mean	Question	group	N	Mean	Std. Deviation	Std. Error Mean
Q1	.00	41	3.34	1.334	.208	Q20	.00	45	3.78	.974	.145
	1.00	18	3.39	.979	.231		1.00	18	3.72	.669	.158
Q2	.00	43	3.30	1.282	.196	Q21	.00	45	4.18	.806	.120
	1.00	18	3.11	1.323	.312		1.00	18	3.33	1.029	.243
Q3	.00	42	3.17	1.286	.198	Q22	.00	45	3.44	1.035	.154
	1.00	18	2.44	.984	.232		1.00	18	2.83	1.043	.246
Q4	.00	45	3.31	1.276	.190	Q23	.00	45	3.51	1.141	.170
	1.00	18	2.00	1.138	.268		1.00	18	3.22	.808	.191
Q5	.00	45	3.07	1.405	.209	Q24	.00	44	4.02	.876	.132
	1.00	17	1.94	1.029	.250		1.00	18	3.56	1.294	.305
Q6	.00	45	3.42	1.076	.160	Q25	.00	45	4.20	.726	.108
	1.00	17	3.12	1.364	.331		1.00	17	3.82	.883	.214
Q7	.00	44	3.57	1.021	.154	Q26	.00	45	3.18	1.403	.209
	1.00	18	3.06	1.056	.249		1.00	18	3.61	1.145	.270
Q8	.00	45	3.47	.919	.137	Q27	.00	45	71.76	25.705	3.832
	1.00	18	3.11	1.023	.241		1.00	18	63.33	30.534	7.197
Q9	.00	45	3.71	.843	.126	Q28	.00	45	16.82	17.655	2.632
	1.00	18	3.39	1.037	.244		1.00	18	16.94	24.979	5.888
Q10	.00	45	3.78	.902	.134	Q29	.00	45	11.42	19.033	2.837
	1.00	18	3.50	.985	.232		1.00	18	19.72	24.463	5.766
Q11	.00	45	3.71	1.121	.167	Q33	.00	45	1.07	.539	.080
	1.00	18	3.33	.970	.229		1.00	18	.78	.647	.152
Q12	.00	45	3.38	.886	.132	Q34	.00	45	24.96	42.592	6.349
	1.00	18	3.06	.998	.235		1.00	18	1.00	.000	.000
Q13	.00	45	.53	.505	.075	Q35	.00	45	1998.42	9.857	1.469
	1.00	18	.61	.502	.118		1.00	18	1995.00	8.905	2.099
Q14	.00	24	3.63	.711	.145	Q36	.00	43	90.72	196.706	29.997
	1.00	11	3.09	.539	.163		1.00	18	102.67	192.478	45.367
Q15	.00	45	.56	.503	.075	Q37	.00	36	9.00	9.274	1.546
	1.00	18	.61	.502	.118		1.00	16	16.31	16.243	4.061
Q16	.00	25	3.64	.757	.151	Q38	.00	43	2.84	5.644	.861
	1.00	11	3.09	.831	.251		1.00	14	1.14	2.033	.543
Q17	.00	45	.69	.468	.070	Q39	.00	43	5.35	9.844	1.501
	1.00	18	.44	.511	.121		1.00	14	.93	1.774	.474
Q18	.00	30	3.70	1.088	.199	Q43	.00	39	2.38	1.206	.193
	1.00	7	3.00	.577	.218		1.00	15	1.80	.775	.200
Q19	.00	45	3.04	1.296	.193	Q45	.00	43	56.84	52.344	7.982
	1.00	18	2.44	1.338	.315		1.00	16	99.38	102.668	25.667

For each question, equality of variances and means of questions in the two groups were tested. Table2 provides a list of questions that resemble significant differences of variance or/and means between two groups.

**Table2- Test of Homogeneity of Variances**

Questions	Levene Statistic	df1	df2	Sig.
Q3	.462	3	56	.710
Q4	1.070	3	59	.369
Q5	1.525	3	58	.218
Q14	1.662	3	31	.195
Q16	.450	3	32	.719
Q18	.254	3	33	.858
Q21	.350	3	59	.789
Q22	.229	3	59	.876
Q34	23.716	3	59	.000
Q37	5.868	3	48	.002
Q45	15.696	3	55	.000

These differences may occur because of differences in language or other reasons such as differences in industry characteristics. Using ANOVA amongst these questions, we excluded the questions which did not show significant differences in the two groups. Therefore, questions 4, 5 and 16 were excluded from the list of questions that show differences between the two versions of questionnaire (table 3).

**Table3- Statistical Data of Questions**

	Filter	N	Mean	Std. Deviation	Std. Error Mean
Q3	.00	14	3.29	1.383	.370
	1.00	7	2.43	.535	.202
Q14	.00	7	3.43	.535	.202
	1.00	6	3.17	.408	.167
Q18	.00	9	3.89	1.167	.389
	1.00	2	3.00	.000	.000
Q21	.00	14	4.43	.756	.202
	1.00	7	3.71	.951	.360
Q22	.00	14	3.64	.842	.225
	1.00	7	3.00	1.155	.436
Q34	.00	14	1.00	.000(a)	.000
	1.00	7	1.00	.000(a)	.000
Q38	.00	13	1.31	3.401	.943
	1.00	6	.17	.408	.167
Q39	.00	13	6.38	13.985	3.879
	1.00	6	.33	.816	.333
Q43	.00	13	2.46	1.127	.312
	1.00	6	2.17	.753	.307

For other questions we retested the equality of variances and means separately for four kind of industry. The results are shown in table 4 to 7, and briefly described as follow;

- In telecommunication industry, the only significant differences between the two groups (versions) were observed with regard to answers given to question number 3.
- In IT industry the differences are significant for questions number 34.
- In Bio industry no differences exist in any questions.
- In Nano industry the differences are significant for questions number 21, 22 and 43.

Noting that the questions are not similar in different industries, we can conclude that the differences may be resulted from other factors than language. To have a valid conclusion, we use the second analysis which is a kind of clustering.

**Table4- Test of homogeneity in telecommunication industry**

	Filter	N	Mean	Std. Deviation	Std. Error Mean
Q3	.00	14	3.29	1.383	.370
	1.00	7	2.43	.535	.202
Q14	.00	7	3.43	.535	.202
	1.00	6	3.17	.408	.167
Q18	.00	9	3.89	1.167	.389
	1.00	2	3.00	.000	.000
Q21	.00	14	4.43	.756	.202
	1.00	7	3.71	.951	.360
Q22	.00	14	3.64	.842	.225
	1.00	7	3.00	1.155	.436
Q34	.00	14	1.00	.000(a)	.000
	1.00	7	1.00	.000(a)	.000
Q38	.00	13	1.31	3.401	.943
	1.00	6	.17	.408	.167
Q39	.00	13	6.38	13.985	3.879
	1.00	6	.33	.816	.333
Q43	.00	13	2.46	1.127	.312
	1.00	6	2.17	.753	.307

**Table5- test of homogeneity in IT industry**

	Filter	N	Mean	Std. Deviation	Std. Error Mean
Q3	.00	7	3.29	.756	.286
	1.00	7	2.29	1.113	.421
Q14	.00	3	3.33	1.528	.882
	1.00	2	2.50	.707	.500
Q18	.00	6	3.17	1.169	.477
	1.00	2	2.50	.707	.500
Q21	.00	8	3.63	.744	.263
	1.00	7	3.29	1.254	.474
Q22	.00	8	3.38	1.188	.420
	1.00	7	3.00	1.155	.436
Q34	.00	8	62.25	50.720	17.932
	1.00	7	1.00	.000	.000
Q38	.00	8	.38	.744	.263
	1.00	4	1.25	2.500	1.250
Q39	.00	8	7.50	9.914	3.505
	1.00	4	.75	1.500	.750
Q43	.00	8	2.25	1.165	.412
	1.00	5	1.40	.548	.245

**Table6- test of homogeneity in Biotechnology industry**

	Filter	N	Mean	Std. Deviation	Std. Error Mean
Q3	.00	5	3.20	1.483	.663
	1.00	2	2.50	2.121	1.500
Q14	.00	3	4.00	.000	.000
	1.00	2	3.50	.707	.500
Q18	.00	3	4.00	1.000	.577
	1.00	2	3.50	.707	.500
Q21	.00	5	4.00	.707	.316
	1.00	2	3.00	.000	.000
Q22	.00	5	3.80	1.095	.490
	1.00	2	2.50	.707	.500
Q34	.00	5	40.20	53.677	24.005
	1.00	2	1.00	.000	.000
Q38	.00	4	3.75	6.185	3.092
	1.00	2	3.00	4.243	3.000
Q39	.00	4	.75	.957	.479
	1.00	2	.00	.000	.000
Q43	.00	4	1.75	1.500	.750
	1.00	2	2.50	.707	.500

**Table7- test of homogeneity in Nanotechnology industry**

	Filter	N	Mean	Std. Deviation	Std. Error Mean
Q3	.00	16	3.00	1.414	.354
	1.00	2	3.00	1.414	1.000
Q14	.00	11	3.73	.647	.195
	1.00	1	3.00	.	.
Q18	.00	12	3.75	1.055	.305
	1.00	1	3.00	.	.
Q21	.00	18	4.28	.826	.195
	1.00	2	2.50	.707	.500
Q22	.00	18	3.22	1.114	.263
	1.00	2	2.00	.000	.000
Q34	.00	18	22.78	41.924	9.882
	1.00	2	1.00	.000	.000
Q38	.00	18	4.83	7.382	1.740
	1.00	2	2.00	1.414	1.000
Q39	.00	18	4.67	7.227	1.704
	1.00	2	4.00	2.828	2.000
Q43	.00	14	2.57	1.284	.343
	1.00	2	1.00	.000	.000

## 2- Clustering

Using clustering method, the questionnaires were clustered into two groups. Results show that both questionnaires (i.e. English and Persian versions) are classified in two clusters. In other words, using clustering method the questionnaires of two versions are not separated, therefore we can conclude that there is no significant difference between the two groups.