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**Yoruk, E. and Yoruk, D**



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# Determinants of Innovation in Emerging Market SMEs: Thirty-Five Years' Evidence from Advanced Materials in Turkey

Esin Yoruk[1], Deniz Eylem Yoruk[2]

[1]*School of Slavonic and East European Studies-SSEES, University College London,16 Taviton Street, London, UK*

*e.yoruk@ssees.ucl.ac.uk*

[2]*Science and Technology Policy Research-SPRU, University of Sussex, Freeman Centre, Falmer, Brighton, UK*
*d.e.yoruk@sussex.ac.uk*

**Abstract**

This research investigates the dynamics of firm innovativeness in emerging markets. It explores how firms acquire knowledge externally, in what ways existing knowledge base and intensity of effort components of absorptive capacity contribute to the innovativeness of the firms. It also examines the complementarities arising from the favorable interaction of them in order to innovate. It addresses this question by examining change over a relatively long period of time - from 1967 onwards and comparing the trends in two different segments – 'science-based' and 'traditional' segments of the materials industry in Turkey. Multiple correspondence analyses and multinomial logistic regressions applied on a panel database with 408 observations suggest that while product/process improvement in science-based technology firms were achieved through knowledge acquisition via collaborative agreements during the period 1982-1996, their innovativeness shifted towards product/process development through firm-internal activities in the last period 1997-2001 and this shift was complemented by their aggressive approach to R&D and design, based on their dynamic managerial characteristics. Mature segment of the industry, on the other hand, followed a different route of first, during 1982-1996, conducting firm internal activities where they attempted reverse-engineering on the basis of arm's length technology purchases and then during 1997-2001 establishing collaborative agreements when their existing knowledge base has become insufficient. This shift was also accompanied by a lack of intensity of effort in areas other than design activities. Our findings suggest that while both existing knowledge base and intensity of effort in the firm are necessary conditions for innovativeness to complement the mode of technology acquisition, their mediating effect may cause differences according to the technological level of segments of a high tech industry.

**Keywords**

Technology acquisition, absorptive capacity, innovation, emerging market, Turkey.

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## 1 Introduction

This research is concerned with tracing the over time changes and the dynamics of firm innovativeness in emerging markets. In particular it asks how firms acquire knowledge, what internal factors contribute on the processing of this knowledge inside the firm and the complementarities arising from the favorable interaction of knowledge acquisition and internal knowledge processing in order to create new knowledge and innovate. It addresses this research question by using a combination of methods in order to achieve several substantial advances: (i) Examining change over a relatively long period of time - from 1967 onwards, analyzed in three periods, (ii) bringing quantitative methods to bear on both description and analysis, and (iii) comparing the trends and relationship in two different segments – 'science-based' and 'traditional' segments of the materials industry in Turkey.

It is widely recognized that at early stages of industrialization, innovation capabilities of firms in emerging markets have been typically weak. For the most part, acquisition of novel technologies from abroad served as the basis for capability assimilation and accumulation. An important part of the overall industrialization process involved firms making long-term transformation of these capabilities as they move from imitation to innovation (Dahlman *et al.*, 1987; Cohen and Levinthal, 1990; Lall, 1987, 1992; Hobday, 1995; Kim, 1997, 1997a, 1998, 1999). From this work we now understand quite a lot about, for example, micro-level learning processes that contribute to the accumulation and transformation of technological capabilities, the time paths that may be involved, and even about at least some of the factors that influence the rate of transition. Their innovativeness evolves and strengthens over time as firms accumulate higher levels of such capabilities and as their absorptive capacity rises (Cohen and Levinthal, 1990). Thus, firms improve their "ability to make effective use of the acquired technological knowledge in efforts to assimilate, use, adapt and change existing technologies" (Kim 1997a: 86; Bell and Pavitt, 1993). To build up and strengthen such capabilities firms need a *prior knowledge base,* which could be identified by the strength of human resources and capital resources in the firm and they also need an *intensity of commitment* to carry on building up such capabilities (Kim, 1998).

This research aims to look for the relationships between technology acquisition, the two major elements of the absorptive capacity concept (i.e. existing knowledge base and intensity of effort in the firm) and firm innovativeness in the materials industry in Turkey. While doing that, it demonstrates how firms' innovativeness increased over a time period of 35 years (as divided into three sub-periods) from no innovation to product/process improvement and then to development. It also demonstrates how patterns of this shift followed two different routes in the higher technology segment and the lower technology segment of the industry.

This research aims to contribute to the current literature by seeking answers for the complementarities between knowledge acquisition and the two elements of absorptive capacity concept (i.e. existing knowledge base and intensity of effort); comparing two technologically different segments of the materials industry (i.e. science-based vs. traditional) and most importantly introducing time dimension into the analysis by examining a period of 35 years. The use of a unique longitudinal database based on face-to-face surveys in 19 firms allows for generalizations for the industry.

The paper is organised as follows. Section 2 focuses on the theoretical background and investigates the role of technology acquisition modes and absorptive capacity in the firm on innovativeness, and presents the conceptual model of this research. Section 3 provides background information about the materials sector in Turkey. Section 4 describes the methodology. Section 5 presents the descriptive and the econometric results. Section 6 forms the discussion and conclusions as well as touching upon the limitations of this research and further research ideas.

## 2 Technology Acquisition and Absorptive Capacity: A Conceptual Framework

Several theories on the firm have been proposed to understand the underlying factors on how firms acquire knowledge and deal with it afterwards. Among them are the theory of the firm as joint team production [Alchian and Demsetz 1972], theory of the firm as a nexus of contracts between principals and agents [Jensen and Meckling 1976], Coase's [1937] approach to the firm and Williamson's [1975] transaction-cost theory with bounded rationality concentrating on transactions of knowledge base through market mechanisms. In an even more radical approach, known as the resource-based view of the firm in the economics literature, Nelson and Winter [1982], Chandler [1990], Barney [1991], Penrose [1995], Teece, et al. [1997], Nonaka, et al. [2000] and Teece [2007] focus on the 'firm' as a repository of specific knowledge and a knowledge-processing and creating entity.

Firms need access to external sources of knowledge in order to survive. For many firms in the developing countries, at least during the early stages of industrialisation, acquisition of novel technologies from abroad served and still serves as the basis for capability accumulation, catching-up with the technology frontier and further on resulting in attempts to produce new or improved products or production technologies. This process is always considered to be associated with two co-evolving stages: (i) The inflow of knowledge to the firm mainly from outside sources, and (ii) firm-internal efforts to assimilate and enhance the knowledge.

### 2.1 Technology acquisition modes

Knowledge inflow from outside sources occurs basically by means of differing modes of transfer of knowledge and technology from advanced country firms or other institutions either foreign or domestic. In the literature, the attempts to identify to dimensions of technology acquisition modes include direct and indirect [Cooper and Sercovitch 1970; Stewart 1985], vertical and horizontal [Mansfield 1975], formal and non-formal [Kim 1999], externalised and internalised [Lall, 2001], active or passive role of partner [Kim 1999], embodied and disembodied nature of knowledge [Teece 1977; Pavitt 1985; Kim 1997]. Particularly the distinctions between tacit and codified knowledge (i.e. type of knowledge) and vertical and horizontal acquisition of knowledge (i.e. direction of interaction) are among the most helpful tools for the purpose of this research.

The type of knowledge (*tacit / uncodified* vs. *codified* / *explicit*) acquired within the process of technology transfer[1] attracted much attention in the literature. The importance of uncodified knowledge in the transfer process has been highlighted [Teece 1977; Nelson and Winter 1982; Pavitt 1985; Kim 1997; Radosevic 1999]. According to Pavitt [1985: 6] "acquisition of technology is always involved when a firm moves from one vintage of production technique to another, or from one product group to another. Such acquisition involves not only written information (patents, blueprints, operating instructions), but also person-embodied skills and know-how." Kim [1997a: 87] points out that whereas "explicit knowledge may be acquired in the form of books, technical specifications, and designs or as embodied in machines, tacit knowledge can be acquired only through experience such as observation, imitation and practice; thus tacit knowledge can be transferred only through training or human transfer."

[1] In earlier studies scholars used the term "technology transfer". In this research technology transfer and technology acquisition terms will be used interchangeably.

In an earlier paper, Mansfield [1975] emphasizes the direction of interaction in making the classification. He therefore finds it important to distinguish between *vertical* technology transfer, which occurs when information is transmitted from basic research to applied research, from applied research to development, or from development to production, and *horizontal* technology transfer, which occurs when technology used in one place, organization or context is transferred and used in another place, organization or context. Horizontal technology transfer is mostly used in the international context in the literature, where inter-firm partnerships are explored [Hagedoorn and Schakenraad 1990]. Vertical technology transfer is important for assessing the knowledge flows from a research institute or university, where basic or applied research is conducted, to the industry, where development took place. The importance of university-industry linkages [Nelson and Rosenberg 1993], the influence of public research on industrial R&D [Senker and Faulkner 1992; Faulkner and Senker 1995; Cohen, et al. 2002] and universities as sources of innovation for industrial firms [Laursen and Salter 2004] have been highlighted as important issues and discussed. Vertical technology transfer can also take place between different units in a single firm, e.g. from the R&D unit, where applied research is conducted, to the production unit.

These two dimensions - type of knowledge and direction of interaction - offer a useful two-by-two matrix, as shown in Figure 1, to identify different modes of technology acquisition. Arm's length technology transfer mechanisms are associated with a horizontal flow of codified knowledge. Collaborative agreement kinds of technology transfer are associated with horizontal or vertical flows of tacit knowledge. Foreign direct investment is associated with a horizontal flow of codified and tacit knowledge. Firm-internal technology acquisition is identified with a vertical flow of tacit knowledge between differing units within the firm – i.e. from the R&D unit where basic or applied research takes place to the production unit. They are initiated within the firm using largely the firm's own resources.

| **Type of knowledge** | **Direction of interaction**: Horizontal | Vertical |
|---|---|---|
| Codified | Arm's length mechanisms<br>Foreign direct investment | - |
| Tacit | Collaborative agreements<br>Foreign direct investment | Firm internal activities<br>Collaborative agreements |

Figure 1: Technology acquisition modes by type of knowledge and direction of interaction

Due to the emphasis on the high dependence of developing country firms on foreign technology acquisition from developed country technology suppliers, major form of technology transfer in emerging market firms has focused on arm's length relations in the form of import of machinery and other capital goods; licence agreements, patents and know-how; turnkey agreements; exporting; subcontracting (outward processing); firm visits, fairs, exhibitions and conferences; and journals, patent disclosures, databases and internet [Contractor and Sagafi-Nejad 1981; Dahlman and Fonseca 1987; Bell and Pavitt 1993; Mowery and Oxley 1997; Contractor 1998].

These are considered to be the main channel of technology acquisition as embodied in tangibles, especially for the SMEs of developing countries. The significance of arm's length modes lies in the fact that the recipient gets into contact with recent technologies created elsewhere, however the amount of knowledge to be exploited from this activity totally depends on the existence and depth of the recipient's further interactions with the suppliers that it will form as a part of its informal networks. Moreover, the existence, depth and any possible satisfactory exploitation of knowledge spillovers from interactions is highly related to the skills and background of the people in the recipient. Beyond that, license agreements, for instance, may contain restrictive clauses in relation to the rights of the licensee to export, to conduct and/or use independent research, and tie-in clauses, whereby the licensee has to purchase inputs from the licensor and so on [Stewart 1985]. These restrictions are expected to have negative influences on the improvement of technological capabilities of the recipient firm.

As a response to the demands of the knowledge-based economy, firms have begun to search for new external knowledge through networking. Collaborative agreements between firms and among firms and other organisations have become means targeting the continuity of technological development within the firm and consisted of subcontracting (original equipment manufacturing), technical assistance and cooperation, strategic technology alliances [Contractor and Lorange 1988; Lorange and Roos 1993; Hagedoorn 1993; Mytelka 1991, 2001; Narula 1996; Inkpen 1998; Narula and Sadowski 2002].

Probably one of the most realized form of technology acquisition in the emerging markets is subcontracting. Yet, different types of subcontracting occurs at differing depths of interaction Radosevic [1999]. In its simplest form as *outward processing,* where the manufacture of (not the whole product but) parts, components, assemblies to be incorporated into a product [Radosevic 1999], has been one of the major modes of technology acquisition in the early stages of development in emerging market SMEs. We classify this under arm's length activities in this research. Other forms of subcontracting which involve collaboration with the foreign partner is *Original Equipment Manufacturing (OEM),* the production of whole finished products to the precise specification of the foreign contractor, and the contractor then sells the product under its own brand name and as Hobday [1995] observed in East Asian firms, OEM often involves the foreign partner in selection of the capital equipment and the training of managers, engineers and technicians, as well as advice on production, financing and management. Thus, OEM relations allow for horizontal flows of tacit knowledge as well as codified knowledge. *Own Design Manufacturing (ODM), a* step after OEM, involves design and manufacture of products with little or no assistance from the main firm showing the internalisation of sophisticated design skills of products, and sometimes complex production technologies, on the part of the subcontractor [Hobday 1995]. Particularly in the advanced materials industry in Turkey all three forms of subcontracting is realized under *Direct Offset Agreements*[2] *(DOA)* in relation with strategic industries such as defence, electronics and electric equipment, machinery and aerospace.

Technical assistance and co-operation is another widely used form of technology acquisition in the emerging market SMEs. It can be received from an organization – i.e. a university, research institute or another firm, on a formal contract basis, as well as from an individual person (i.e. a consultant). Its main difference from a strategic alliance is that the acquisition of knowledge is generally a one-way flow of knowledge from knowledge supplier to the firm. A strategic alliance is a rare form of technology acquisition particularly in SMEs since it necessitates great effort into

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[2]An *Offset Agreement* is a counter contract to a military export sale negotiated separately between the foreign purchaser, usually a foreign government, and the US exporter as a condition of the export sale. (DoC, downloaded in 2001b).

a strategic partnership as two-way relationships focused on joint knowledge production and sharing, as opposed to one-way knowledge transfer, putting the emphasis on technology and R&D alliances [Freeman and Hagedoorn 1994; Mytelka 2001; Narula and Sadowski 2002].

Foreign direct investment (FDI) has been investigated as a source of technology transfer and knowledge spillovers for developing country firms that are expected to induce modernisation of these firms by forcing them to keep pace with the competition imposed by the presence of foreign firms, to improve their innovative efforts and catch-up with the advanced countries. This form of technology transfer involves wholly-owned subsidiaries and majority joint ventures as well as brain gain (and brain re-gain). For instance when compared to turn-key technology acquisition projects, FDI facilitated catching-up in Latin American countries [von Tunzelmann 1995].The investor going through FDI has to decide on the entry mode choice, that is between a wholly-owned subsidiary and a majority joint venture; however the technological intensity of the industry in which FDI takes place has been said to discourage joint ventures in favour of wholly-owned subsidiaries [Mutinelli and Piscitello 1998], partly because the vast majority of foreign companies also prefer to bring in their own process technology and knowledge to their own subsidiaries under their total control, and thus the knowledge transfer takes a one-way shape. FDIs are mostly paired with multinational companies in the existing literature, since most of the traditional FDIs come from large companies in the form of a package of technology. Under the effects of financial globalization, FDI expanded much more rapidly than trade during the 1980s, and on balance followed a Myrdalian pattern of flowing much faster to the world's financial centres than to the needier parts, e.g. the USA was the major beneficiary of net inflows of capital during the 1980s [von Tunzelmann 1995]. However, until very recently Turkey did not enjoy the benefits of FDI. Therefore, during the time period studied in this research, FDI type of technology acquisition is very numbered.

Finally, there is an overlooked mode of technology acquisition that is relevant to developing country firm. Reverse-engineering and imitation facilitate catching-up through internalisation of technological knowledge as in the case of Korea and Taiwan when compared to turn-key technology acquisition projects [von Tunzelmann 1995]. We call these activities 'firm internal activities'. Reverse engineering is essentially imitation and adaptation of acquired technology without any formal agreement with the original innovator. It involves stripping down innovative products or processes and finding out how they work [Pavitt 1985]. It may involve either a considerable accumulation of technological capability in the recipient as a background or intense interactions with knowledgeable organizations to be able to further the activity. The latter have been largely observed in the Turkish materials SMEs. Especially reverse engineering on high technology production methods needs support beforehand or during the process. It has also been a common exercise that innovative firms start R&D projects of their own in the firm to produce new products or processes. Although earlier this concept was mostly associated with developed country firms, high and medium technology firms in the developing countries have also increasingly started on such activities. Launching an in-house R&D project certainly depends on the level of core capabilities in the firm, the key complementary asset being a skilled workforce that is able to carry on the task. It may involve intense interactions with other organizations to be able to further the activity, depending on the capability level of the firm and the disclosure of project details.

As a result, modes of technology acquisition based on collaborative interactions such as strategic alliances, R&D co-operations, etc. are always regarded to be more valuable than simple arm's length transfers such as import of machinery, since the former involves a considerable amount of tacit knowledge acquisition/exchange and transfer among the parties. Moreover, the effectiveness of external knowledge and technology acquisition depends, *ceteris paribus*, on the absorptive capacity of the recipient firm and the level of technological development of the industry and even the host country [Contractor and Sagafi-Nejad 1981, Contractor 1998].

## 2.2 Absorptive Capacity

The degree of catch-up and speed to innovativeness is largely a function of the rate of capability acquisition and accumulation [Zahra and Nielsen 2002; Lee and von Tunzelmann 2005; Mahmood, et al. 2011]. To complement the technology acquisition process, firms need to be able to absorb the externally acquired technology in order to make use of it. The successful exploitation of externally acquired technology requires some level of 'absorptive capacity' within the firm. Cohen and Levinthal [1990: 128] first defined absorptive capacity as "the ability of a firm to recognise the value of new, external information, assimilate it, and apply it to commercial ends". They stated that it is largely a function of the firm's level of prior related knowledge and characteristics of the firm's learning environment that influence the investments in R&D in the firm. Their outcome is supported by data from the high-tech sectors of pharmaceuticals and biotechnology in an advanced country, the USA. Cohen and Levinthal's [1990] seminal paper paved the way for further discussion, reconceptualization and contributions to the concept. Remaining in the context of advanced country industries Lane and Lubatkin [1998] stress the role of learning based on knowledge in the firm and organizational structure rather than purely focussing on R&D in operationalizing the construct. Zahra and George [2002] stressed on the multidimensional character of the concept and differentiated between the potential absorptive capacity to acquire and assimilate knowledge and realized absorptive capacity to transform and exploit knowledge. Thus, absorptive capacity concept mostly is associated and preceded with the conduct of R&D and learning in the advanced countries.

In advanced countries, the technology trajectory in that context tends to evolve and mature over time in roughly three subsequent stages: during the first stage the new product has been generated in a *fluid* phase during which product and market uncertainty prevails; this is followed by a *transition* stage where some standardization regarding the components, market needs takes place and finally in the last stage the product settles in the market and then matures whereby emphasis on production technology emerges [Utterback and Abernathy 1975; Afuah and Utterback 1997].

In the developing countries, on the other hand, it is argued that the trajectory exhibits a reversed structure to that of advanced countries. Kim's [1997a, 1998] observations from Korean firms suggest that the trajectory of an innovation flows the route from imitation to innovation, the imitated substance generally being a product brought onto the market in an advanced country which is then acquired by the catching-up firm mostly in the form of import of product/process.

In Kim's examples there exist considerable in-house effort inside the firm (i.e. reverse-engineering of the product acquired from abroad in an effort to rebuild it) supported by intensive in-house R&D activity and sometimes also supported by collaboration with the domestic research organizations that leads to assimilation of the externally acquired knowledge and further on extending to the introduction of other novel products onto the market. Hobday's [1995, 1995a] observations from other South East Asian firms (i.e. firms in the electronics industry in Taiwan, Singapore, Hong Kong and South Korea) suggest that the route to product improvement and development in the firm is generally associated with subcontracting types of relationships, the firm being the subsidiary of an advanced country firm. The deeper the degree of subcontracting (i.e. from outward processing to own brand manufacturing) the more the gains for the catching-up firm. Most of the time, these contractual types of relationships (i.e. subcontracting, licensing) co-exist with the internal efforts of the firm in the intermediate stage of assimilation [Amsden 1989; Hobday, et al. 2004; Ariffin and Figueiredo 2004]. At this stage, firms improve their "ability to make effective use of technological knowledge in efforts to assimilate, use, adapt and change existing technologies" [Kim 1997a: 86; Bell and Pavitt 1993]. To build up and strengthen such capabilities internally firms need a *prior/existing knowledge base* and they also need an *intensity of commitment* to carry on building up such capabilities with determination [Cohen and Levinthal 1990; Kim 1997, 1998, 1999]. Prior knowledge base of the firm could be identified by the strength of human resources and capital resources in the firm. Human resources are associated with researchers in the firm as well as the managerial capabilities [Rosenbloom 2000; Adner and Helfat 2003; Sirmon and Hitt 2009]. Intensity of effort (commitment) in the firm could be identified by continuously investing in R&D and design activities, conducting preparatory searches prior to technology acquisition and labour mobility [Cohen and Levinthal 1990; Kim 1997, 1998, 1999]. The complementarities between the external acquisition of technology and internal processing of knowledge help to create conditions conducive to innovation in the emerging market firm.

## 2.3 Conceptual Framework

Drawing on these earlier contributions, the pattern of relationships between external technology acquisition, absorptive capacity and innovation in an emerging market country firm is conceptualized as shown in Figure 2. We ask the research question "How does the mode of technology acquisition influence innovativeness in the materials industry in Turkey?"

The previous research suggests that the firm's absorptive capacity plays a critical role in the innovativeness of the firm. This research aims to contribute in advancing our understanding of the way(s) existing knowledge base and intensity of effort in the firm complement knowledge flow into the firm so that innovation occurs. The conceptual model of this research proposes to detail the role of the interaction between knowledge acquisition and absorptive capacity on firms' innovativeness. The main contribution of this conceptual model lies in its conduct of the mediating role of the elements of absorptive capacity on the relationship between technology acquisition modes and the innovativeness of the firm over time.

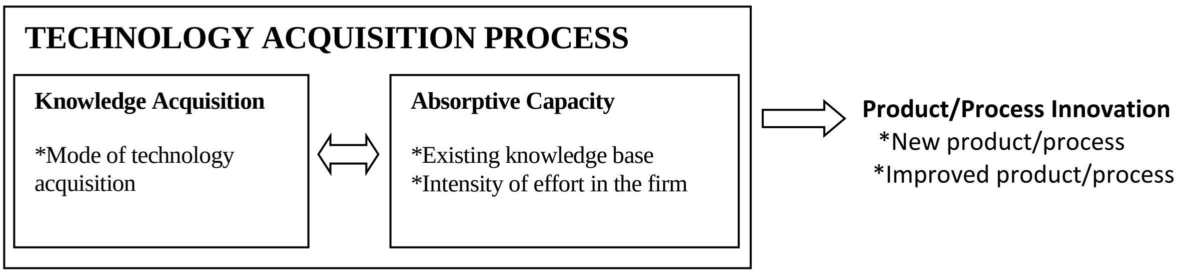


Figure 2: Conceptual framework of the research.

## 3 Advanced Materials Sector in Turkey[3]

The advanced materials sector involves manufacturing of metals, ceramics, composites and polymers.[4] Starting from the 1970s, there has been an accelerating increase in the study and applications of advanced materials in the universities and industry in the developed parts of the world. These materials started replacing the traditional materials (e.g., iron, standard steel, copper, aluminium, etc.) in mostly high technology applications. Today, it has evolved into a science-based, knowledge intensive and high value-added sector, which delivers products for almost all other industries, from automotive to aerospace, telecommunications, energy, electronics, chemicals, defence, biomedical, machinery and textiles. Thus, the sector distinguishes itself as a sector, which can connect its own dynamism to other related manufacturing sectors. This arises mainly due to the increasing cost-effectiveness and high-performance of advanced materials in comparison to traditional materials. Based on the kind of product, the materials production can be broadly classified into two:[5]

1. Products identified by their structural[6] properties (e.g., powder metallurgy parts and fiberglass, ceramic refractory) and by the use of medium technology processes in production (e.g., wet/dry/hydraulic pressing, sintering, casting, etc.); and by their application in medium technology sectors, such as ferrous and non-ferrous metal parts for the automotive sector, iron and steel, standard glass and ceramic sectors, standard electronics, etc.

2. High technology products (e.g., optical fiber, fiber-reinforced composites, technical ceramics such as piezoelectric, oxygen sensors, ultra-hard thin-film ceramic coatings), identified by their functional[7] properties and by the use of higher technology processes (e.g., injection moulding, resin transfer moulding, ion implantation, chemical vapour deposition, magnetron sputtering, plasma enhanced vapour deposition, etc.) and use of R&D; and by their application in high technology sectors such as telecommunications, complicated electronics, defense and aircraft, etc.

Turkey showed a steady change in its industrial specialisation patterns from resource-based to traditional products (from the beginning of the 1960s to the end of the 1980s) and then to medium technology products (from the 1980s to mid 2000s). The exports of structural materials have increased considerably from 2000 to 2005 due to favourable conditions in the automotive industry, which is the main buyer for iron and copper based powder metal parts. More than half of the exports of functional materials are of fibre optics. Technical ceramics

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[3] This section is taken from Yoruk [2011].

[4] It is not possible to classify these products directly within industrial classifications such as ISIC, NACE, etc. They are rather dispersed in different divisions and groups, creating a major obstacle for obtaining any kind of data on these products. A basic guideline on where these products may fit into ISIC Rev.4 may appear as below:
Small metal powder metallurgy parts in Division 25 – manufacture of fabricated metal products, except machinery and equipment under Class: 2591 – forging, pressing, stamping and roll-forming of metal; powder metallurgy.
Fibreglass, ceramic refractories and technical ceramics in Division 23 – manufacture of other non-metallic mineral products under Class: 2310 – manufacture of glass and glass products; Class 2391 – manufacture of refractory products and Class: 2393 – manufacture of other porcelain and ceramic products, electrical insulators and insulating fittings of ceramics, ceramic and ferrite magnets, ceramic laboratory, chemical and industrial products (i.e., ultrahard thin-film ceramic coatings).
Fibreopticcables in Division 27 – manufacture of electrical equipment under Class 2731 – manufacture of fibre optic cables.

[5] This classification also prepared the basis for studying and comparing two different segments namely mature technology firms and science-based technology firms, in the Turkish advanced materials sector.

[6] Structural properties of a material refer to mechanical properties such as high strength, high-temperature strength, wear resistance and lightweight.

[7] Functional properties of an advanced material refer to the physical, chemical and biological functions possessed by the material. These may relate to high thermal conductivity or insulation, high electrical conductivity or resistance, high chemical stability, piezoelectricity, corrosion resistance, biocompatibility, etc.

account for less than half. And among the technical ceramics, exported items fall into medium technology category products such as fuse insulators and aluminium oxide parts. Despite that, the materials sector in Turkey is more import-oriented than export-oriented. Demand for functional materials is mostly covered by imports and its domestic production meets internal demand with negligible rates of export.

# 4 Methodology

## 4.1 The Sample

The sample formation procedure involved several steps: (i) selection of firms of which the knowledge acquisition activities would be enquired, (ii) face-to-face questionnaire implementation at selected firms, (iii) data processing and formation of the dataset based on knowledge link, through which the knowledge has been acquired, being the unit of analysis.

The firms were selected using several means of information channels: Consultations with TTGV[8], TUBITAK-TIDEB[9] and other key experts at research institutes in Turkey. One-page pilot questionnaire was implemented, enquiring about firm activities and process technologies. 19 firms out of 75 responded. The results from this survey highlighted that the sample could be grouped into two as (i) 10 science-based firms producing high-complexity novel products with high-technology processes,[10] and (ii) 9 traditional firms producing relatively conventional products with mature technology processes.[11] Also, science-based technology firms were distinguished from the others, with their percentages of researchers and engineers in total employees being above 20%. On the other hand, to put the comparison on an acceptable basis and to be able to interpret the collected data, commonalities between them are concerned only with privately owned, small and medium scale family firms from the materials sector. All firms have employees under 500 as fits the definition of an SME from the employment point of view. The data were collected through face-to-face semi-structured interviews in June 2001 with key informants such as managers, chief engineers of production and especially R&D units in the firms.

In processing the data, to start with, the 'technology project' concept was brought into the analysis as an intermediate tool to dig into the knowledge links of firms associated with each project. The questionnaire was purposefully arranged to seek information in that context. Technology project is defined as any type of firm activity that the firm undertakes for acquiring technology, as well as the specific production and research activities with knowledge flows. Therefore, within each firm, the acquired information was listed with respect to each of a sequence of 'technology projects' through the lifetime of the firm. This provided a total of 289 technology projects spreading over 35 years, with the earliest establishment of a firm in 1967.12

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[8] TTGV (Turkish Technology Development Foundation) is a World Bank sponsored NGO in Turkey.

[9] Turkish Institute of Science and Technology branch giving support to SMEs.

[10] For instance, the use of the physical or chemical vapour deposition technique for production of ultra thin film ceramic coatings on metal or glass surfaces; production of optical fibre; production of small intricate technical functional ceramic parts by injection moulding methods for use in electronics, biomedical, steel industries; production of polymer matrix composites for use in defence and aerospace industries, etc.

[11] For instance, a hydraulic press for production of metal powder composite parts produced especially for the automotive and manufacturing cutting tool industries; production of fibreglass, etc.

[12] To eliminate as much as possible the recall problem with regard to earlier acquaintances of firms, predominantly family-run enterprises with unbroken institutional memories have been selected. Vast majority of the managers in the sample firms have been managing the firm since its establishment. In a few older firms, the son or daughter of the owner took over the managerial position,

Further on, within each technology project information about the knowledge links has been enquired. The data were processed into a panel data structure where each observation was associated with a 'knowledge link'. A 'knowledge link' is defined as kind of interaction between the firm and any one of the external partners of the firm through which primarily knowledge is transferred to the firm by any means of technology transfer within a particular technology project. The domestic or foreign partner may be another firm or an institute in the form of a knowledge supplier. Knowledge links are attributes of technology projects; and there may be more than one knowledge link attached to a technology project, simply because in one project there may be different kinds of links with different types of partners. For instance, production of a new product in the firm might be conducted in a way that involved knowledge links with (i) a university department, (ii) a customer firm, and along with (iii) contributions from the firm's own R&D unit. In that particular case, there would be three knowledge links associated with the-one technology project. Therefore, within each technology project, information was sought about what technology was acquired and how through each of several 'knowledge links' involving different sources. There were between one and five actively performed links per project, and the total of 289 technology projects provided a total of 408 observations of knowledge links (which formed the panel dataset). In proposing the 'knowledge link' concept, there was one objective in mind. It would increase the number of observations and indeed allow for the data to be configured in the way that they could be used in econometric analyses. It is useful in finding and highlighting the details about each single interaction of firms and studying them in quantitative analyses, which would not be possible if the 'firm' were to be used as the unit of analysis.

### 4.2 Measures

**Dependent variable.** We use the type of innovation (INNOVATION) the firm has conducted as the dependent variable, which indicates whether the firm developed new products/process, improved its existing products/process, or conducted no innovation. Approximately, one fifth of the links in the sample improved and developed products/process in the firms for the period examined (23% and 24% respectively). The industrial segments differ with respect to newly developed products/processes (30% in science-based segment of the industry, 17% in the mature-based segment).

**Explanatory variables**. Three elements are used for analysing the technology acquisition process in accordance with the conceptual model in Figure 2. These are the mode of technology acquisition, the existing knowledge base in the firm, and the intensity of effort by the firm. In this research, three variables are used to explain the existing knowledge base in the firm is operationalised through three variables, while to explain the intensity of effort by the firm four variables are used. Technology acquisition modes are operationalized by one variable. All variables are categorical variables.

***Existing knowledge base in the firm*** is defined, in this research, as the already acquired stock capabilities held by the firm. As the first element of absorptive capacity of the firm, they refer to the level of its prior related knowledge [Cohen and Levinthal 1990]. In this research, as largely drawn from Kim [1998] and as explained in section 2.2, they aim to explain mainly the tacit component of capabilities embodied in human capital. They are identified as *manager*

but in such cases it was possible to meet and interview the first generation manager as well. Additionally, frequent opportunities to meet chief engineers of production and especially R&D units, who in some cases worked in the firm since its establishment, were always taken.

*qualifications related to education and academic research experience* (MANACD) and *manager qualifications related to industrial experience* (MANIND). They intend to capture the importance of managerial influence on creating a knowledge base for the firm. Entrepreneurial leadership is an important factor that creates organizational conditions favourable for learning in the firm. Issues related to learning in the firm, such as the selection of technology to be acquired, gaining expertise in the technology already being used in the firm and the ability to solve existing problems with the technology used, are much related to the managerial knowledge base, especially in SMEs. *Percentage of researchers and engineers in total employees* (PRES) is used to measure the amount of skilled labour in the firm where the tacit knowledge is embodied.

***Intensity of effort by the firm*** is defined as the firm's efforts towards internalisation of knowledge acquired from the technology acquisition process. It is the second major element of the absorptive capacity of a firm. It aims to explain the commitments of the firm towards continuous knowledge acquisition and creation as explained in Cohen and Levinthal [1990]. Such commitment needs concrete acts to prove to be successful. As explained in section 2.2 above and drawn from Kim [1998], these may include issues related to preparatory measures prior to acquisition of technology, labour mobility, R&D and design. Four variables are used to explain intensity of effort by the firm. *Search into contributor* (SECONT) and *Search into technology to be acquired from the contributor* (SETECH) are pre-project activities in the form of preparatory efforts undertaken by the firm to find out what kind of product or process technology they will transfer from domestic or foreign contributors and what kind of domestic or foreign contributor they will deal with. *Search into contributor* is considered as simple when the knowledge gathered about the contributor is mostly via Internet search or via activities such as attendance in conferences, fairs and exhibitions, where the level of knowledge needed is relatively lower. It is considered to be experience-based if the firm gathered the information about the contributor from other parties that had collaborations with this particular contributor in the past or if the firm contacted a continuously knowledge-seeking institution such as a university or research institute to get information about the contributor. Similarly, s*earch into technology* is considered as simple search when the information gathered is mostly via Internet search, journals and product leaflets, visits to the technology supplier firm, or only a price comparison with substitutes for the technology. It is considered to be knowledge-based and deep if the firm contacted especially the provider of the technology or another knowledge holding body about this particular technology to get information about the technology to be acquired. *R&D activities* (RND) stand for the firm's efforts put into research activities with regard to each link. Such activities differ in application. For instance, a firm may have its own R&D unit on its premises and be primarily engaged in research activities related to the project. Or, it may take active part in research activities related to the project by using one of the partner's laboratories. Or, R&D conducted elsewhere (mostly in the headquarters of a foreign firm) may find application on the firm's premises. Therefore, R&D conducted primarily by the firm in its own R&D unit is categorised as 'primary' R&D; R&D conducted at the partner's premises where the firm takes an active role is categorised as 'active' R&D; and finally if there is no R&D conducted in the project, category 'none' applies. Finally, d*esign activities* (DESIGN) stand for the firm's efforts put into design activities with regard to each link. These activities differ in content and level. The firm's design activities may solely rely on a customer's recipe. Or, the firm may be creative and achieved the level of capability to originate its own designs. The former is categorised as 'trivial and none', denoting the low level of significance in the firm's design capabilities. The latter is categorised as 'non-trivial', pointing a high level of significance in design capabilities.

The variables for existing knowledge base and intensity of effort by the firm and their categories are shown in Table 1.

| Component | Indicator | Description of the indicator | Categories of the indicator |
|---|---|---|---|
| **DEPENDENT VARIABLE** | | | |
| | INNOVATION | Type of innovation | New product/process<br>Improved product/process<br>No innovation (base category) |
| **EXPLANATORY VARIABLES** | | | |
| | TECHACQN | Mode of technology acquisition | Collaborative agreements<br>Firm-endogenous activity<br>Arm's length mechanisms<br>Foreign direct investment |
| Existing knowledge base in the firm | MANACD | Manager qualifications related to education and academic research experience | Degree from a national university<br>Degree from a university abroad<br>No academic degree |
| | MANIND | Manager qualifications related to industrial experience | Work experience at a domestic firm<br>Work experience at a firm abroad<br>No work experience in the field |
| | PRES | Percentage of researchers and engineers | equal to or more than 50%<br>less than 50% |
| Intensity of effort in the firm | SECONT | Search into knowledge supplier | experience-based search<br>simple or none |
| | SETECH | Search into technology to be acquired from the supplier | knowledge-based search<br>simple or none |
| | RND | Intensity of R&D activities | Primary<br>active<br>none |
| | DESIGN | Intensity of design activities | non-trivial<br>trivial or none |

Table 1: Indicators used in the research.

***Mode of technology acquisition*** is used in this research to examine whether the acquisition mode has any direct impacts on the innovation types. In the interview questions, the firms were asked about the means of acquisition of current and previous core production technology. The means of collaboration with partners in a particular technology project were also identified. The observed technology acquisition modes are shown in Table 2 as classified according to their organizational context.

| Categories of the variable 'Mode of Technology Transfer' | Elaborations to the categories of the variable |
|---|---|
| External: Arm's length activities | import of machinery and capital goods<br>licence agreement with import of machinery<br>licence agreement with import of machinery & know-how<br>know-how transfer<br>journals, databases, patent disclosures, internet search<br>firm visit, conferences, fairs and exhibitions<br>inter-firm marketing alliance<br>exporting<br>turnkey agreements<br>subcontracting: outward processing |
| External: Collaborative agreements | inter-firm marketing alliance with knowledge inflow from technology supplier<br>subcontracting: original equipment manufacturing and direct offset<br>consultancy<br>external problem-solving activity<br>technical assistance and co-operation<br>customer-oriented product development<br>inter-firm strategic technology alliances<br>firm-research institute technology partnering<br>firm-university technology partnering |
| External: Foreign Direct Investment | joint ventures<br>subsidiaries<br>brain gain and re-gain |
| Internal: Firm-endogenous activities | in-house problem-solving activity<br>reverse engineering<br>in-house R&D project |

Table 2. The variable Mode of Technology Acquisition (TECHACQN) and its categories

Modes of technology acquisition are categorized as external and internal. Technology projects with external acquisition modes always required involvement of a partner in the project, such as a university, research institute, and another firm or technology supplier. In line with the existing literature, external modes of technology transfer are further divided into three: (i) Arm's length activities, where the knowledge acquired is mostly codified and uni-directional from the supplier to the firm; (ii) Collaborative agreements, where the knowledge acquired is mostly from person (team) to person (team), having a bi-directional character between the partners; and (iii) Foreign Direct Investment, where knowledge is acquired via equity-based interactions and brain gain.

In addition, an invaluable observation of the fieldwork was about internal technology acquisition modes. These are related to 'technology projects' that were originated mostly by the initiative of the manager/engineer of the firm, with the firm's engineers taking the leading role, although accompanied by external partners in most of the cases. The frequency of firm-internal activities amounted to such a considerable number that they could not be neglected in this research. Being endogenous to the firm, these modes of technology acquisition were expected to shed light to the unknowns of innovation activities of emerging market firms. This internal mode of technology acquisition also paves the way for understanding the significance of the firm's own knowledge endowments to pursue technology projects and to create new knowledge. Activities classified under this heading are in-house problem-solving activity, reverse-engineering and in-house R&D projects. These firm-internal activities should be well differentiated from the variable *R&D activities.*[13] Regarding the former, R&D is not necessarily a part of these activities, even though in-house R&D projects are a part of it. Also, R&D generally is a part of the collaborative agreement type of activities as well. Therefore, these two R&D related components do not overlap with each other.

**Control variable.** Industry is used as control variable and measured with two different segments of materials industry, as science-based and mature technology segments (please see section3).

**Time** is operationalised as periods. When determining the sub-periods for analysis in this research, two approaches have been considered:

1) Allocation of knowledge links between sub-periods as representative and explanatory as possible, and

2) Periods taking historical events in Turkish economy into account (i.e. drastic liberalisation policies as of 24 January 1980 and switch from import-substitution to export-orientation development policies, deregulation of money and capital markets, and so on. Therefore, allowing Sub-period I from 1967 to 1981 and sub-period II from 1982 to 1996 draws a line between two completely different economic policies applied in Turkey and captures this radical shift in the economy. Impacts of the application of export-orientation policies in the industry after 1980, however, were felt with a time lag of approximately 10-15 years, which acted as a transition period. The final sub-period from 1997 to July 2001 is characterised by an obvious emergence and progression of a larger number of firms and technology projects in this period.

## 4.3 Estimation Methods

This research employs multinomial logistic regressions [Hosmer and Lemeshow 2000; Borooah 2002]. As explained above, the dependent variable 'innovation' is nominal with three categories – i.e. new product/process or improved product/process or no innovation. The measurement scale is important when a regression model for a discrete dependent variable with more than two responses is considered [Hosmer and Lemeshow 2000: 261]. The log risk-ratio equations were specified. A *risk-ratio* is the ratio of the probability of outcome *m* to that of outcome *k*, or [Prob($Y_i$=*m*)/ Prob($Y_i$=*k*)]. For the models set up in this research, the first risk-ratio is the ratio of the probability of an improved product or process to the probability of no innovation. The second risk-ratio is the ratio of the probability of a newly developed product or process to the probability of no innovation. In the models, 'no innovation' category of INNOVATION indicator is referred to as the 'base category' for the dependent variable. Therefore, the coefficients of this category are set to zero and the risk-ratios of the other categories are defined with respect to the probability of this base category. Similar to that, in multinomial logistic regression analyses, the last category of each independent variable is also set to zero as the base category and the findings for the categories of the indicators are always interpreted with respect to the base category.

[13] We have run crosstabulation analyses to see that firm internal activities do not fully overlap with the indicators we use as proxies for intensity of effort, namely primary R&D, active R&D, design, search into contributor and search into technology.

As with any fitted model, before making inferences, the overall fit of the model should be assessed; however in multinomial logistic regression this is a difficult problem since there are multiple outcome categories and the integrated assessment of fit for the two logits need to be considered [Hosmer and Lemeshow 2000: 281]. The ‘goodness-of-fit’ measures for the models are shown in Tables 4 and 5. These include the log-likelihood measure as a minimum measure to be stated as suggested by Greene [2000: 831-833], Chi-square measure, significance value of the Chi-square measure and McFadden’s Pseudo $R^2$ value. As Borooah [2002: 57] points out the Pseudo $R^2$ is due to McFadden [1973] and is bounded from below by 0 and from above by 1. A value of 1 corresponds to perfect prediction of the model. However, as Greene [2000] notes that the values between 0 and 1 have no natural interpretation, though it has been suggested that the Pseudo $R^2$ value increases as the fit of the model improves.

## 5 Results

We first utilised multiple correspondence analysis (MCA)[14] to explore the relationship between technology acquisition modes and firm innovativeness over time. A joint category plot, in Figure 3, shows that there may be some association between innovation types, technology acquisition modes and periods analysed in this research. Dimension 1 clearly discriminates development and improvement of product/process from no innovation; firm internal activities and collaborative agreements from arm’s length activities and FDI; and the period 1997-2001 from earlier periods. The plot suggests that new product/process development is associated with firm internal activities and that improved product/process is associated with collaborative agreement types of technology acquisition modes. Moreover, these are associated more with period 1997-2001 than with period 1982-1996 and period 1967 to 1981that seem to associate with arm’s length activity type of technology acquisition modes and virtually no innovation. FDI stands on its own suggesting Turkey’s deficiency in attracting foreign investment before mid-1990s.

[14] In MCA, it is not possible to tell whether there is a causal relationship between these variables or not and also not possible to “say anything about the *magnitude* of their interaction in an absolute sense” [Bartholomew, et al. 2002: 92]. Hence, it is important to note that the level of (dis)association is in *relative* terms, and not absolute terms. In other words, the categories that are close to each other are more strongly associated than (or compared to) the categories that are far apart from each other.

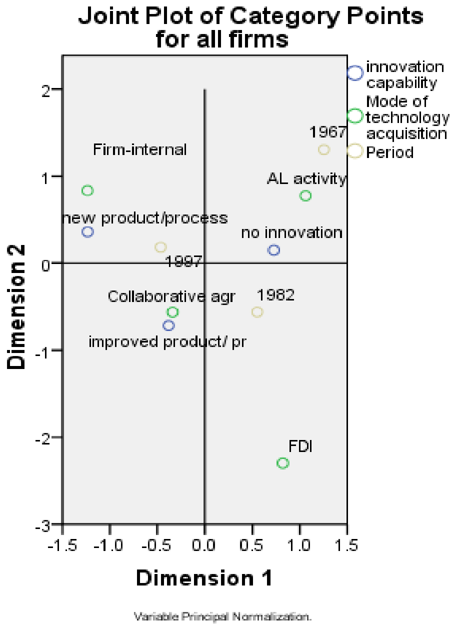


Figure 3: Multiple correspondence analysis plot for innovation, mode of technology acquisition and period for all firms links (N=408).

Figure 4 allows us to understand the dynamics of these relationships in two different segments of material industry. It highlights not only the major differences between science-based and mature technology firms but also the outliers in each segment. It suggests that in both segments of the sector, the development of new product/process is more strongly associated with the period 1997-2001 than 1982-1996. However, the mode of technology acquisition differs considerably between these two segments. New product/process development in science-based technology firms is more strongly associated with firm-internal activity kind of technology acquisition modes than improved product/process that associates with collaborative agreements. The opposite is observed in the mature segment of the sector; new product/process development in science-based technology firms is more strongly associated with collaborative agreements.

Period 1982-1996 is associated with product/process improvement and no innovation. Improved product/process is more associated with the use of collaborative agreements and FDI kinds of acquisition modes in the science-based segment of the industry; whereas in the mature segment it seems to be associated with the use of firm-internal activities. In addition to collaborative agreements, FDI is more strongly associated with improvement of product/process in science-based technology firms than development of product/process. In both segments of the industry, the period 1967-1981 seems to be associated with no innovation and arm's length relations.

Finally, regarding the outliers, the period 1967-1982 appears to be a time period during which only two science-based technology firms were present (see Table 3). In the mature technology firms, the lack of importance of FDI as a technology acquisition mode becomes clear, probably the interest of foreign investors in high technology sectors in the country. These will be kept in mind during the interpretations of the regression results below.

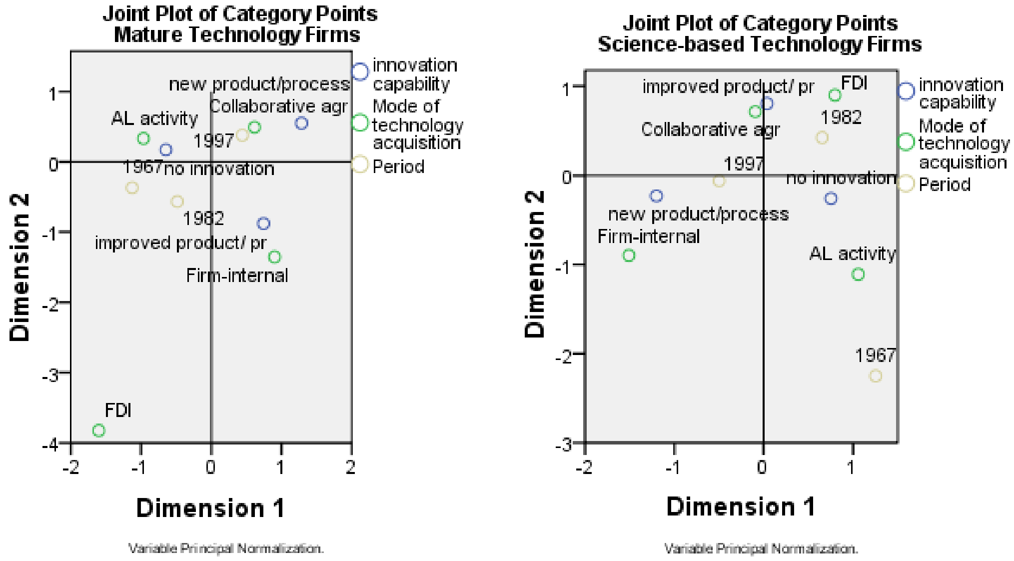


Figure 4: Multiple correspondence analysis plot for innovation, mode of technology acquisition and period for science-based firms' links (n=217) and mature technology firms' links (n=191).

Second, an over time crosstabulation analysis of both kinds of firms' links by types of innovation and period shows that materials firms in Turkey have been introducing more new products/processes onto the market over the periods from 1967 to 2001. The 'all links (count)' row in Table 3 shows the rising frequency of links during the three periods. The table also shows that over time for firms in the sector, proportion of links which resulted in newly developed product or process increased from nil during 1967–1981 to more than one-third of all links in 1997–2001, and the proportion of links with outcome of no innovation were more than halved from 1967–1981 to 1997–2001. This pattern was more emphasised in the science-based segment of the sector.

| | **Science-based technology firms (n=217)** | | | **Mature technology firms (n=191)** | | |
|---|---|---|---|---|---|---|
| | 1967-81 | 1982-96 | 1997-01 | 1967-81 | 1982-96 | 1997-01 |
| **No innovation** | 100.0 | 61.0 | 33.3 | 93.8 | 73.4 | 47.4 |
| **Improved product or process technology** | 0.0 | 27.3 | 23.3 | 6.3 | 26.6 | 22.5 |
| **Newly developed product or process technology** | 0.0 | 11.7 | 43.4 | 0.0 | 0.0 | 29.7 |
| **All links (%)** | 100 | 100 | 100 | 100 | 100 | 100 |
| **All links** (count total 408) | 11 | 77 | 129 | 16 | 64 | 111 |
| **Firms** (count) | 2 | 9 | 10 | 5 | 9 | 9 |
| **Pearson Chi-square Tests** | **(asymp. sig. 2-sided)** | | | **(asymp. sig. 2-sided)** | | |
| **PERIOD vs. INNOVATION** | 0.000 | | | 0.000 | | |

Table 3: Distribution of links by types of innovation, period and industry categories (in percentage of links) *Source:* Author's interviews.

In the light of these initial descriptive findings, we present results from the further econometric analyses. We used multinomial logistic regression to estimate the effects of technology acquisition mode (Model1), existing knowledge base (Model 2) and intensity of effort (Model 3) on innovativeness as separate from each other. We also looked at the effects of all three in a full model (Model 6). Tables 4 and 5 contain the results of the estimation. All the models are statistically significant.

The results of first three models are consistent with the MCA results with respect to association between modes of technology acquisition and firms' innovativeness. The full model clarifies the role of interaction between technology acquisition modes and absorptive capacity on the changes in the innovativeness of the firms.

Models 1a and 1b were used to assess the effect of technology acquisition mode on innovativeness.[15] In line with MCA results above, the estimation results, displayed in Tables 4 and 5, identify two characteristics as being important for improving a link's risk-ratio of yielding innovations particularly in development of a product or process:

- Engaging in firm-internal activity and collaborative agreement modes of technology transfer regarding both kinds of firms; and also
- Being a science-based technology firm.

The risk-ratio of firms having improvement and development of a product or process from links with the firm-internal activity and collaborative agreement modes of technology transfer was *ceteris paribus* higher than that of links with foreign direct investment (FDI).[16] The risk-ratio of a link resulting in improvement and development of technology was greatest for the firm-internal mode of technology transfer (3.221and 1.520 >0 in Model 1a and Model 1b). Also, a link based on firm-internal activity could result in more innovativeness in favour of the development of product or process compared to that for the improvement of product or process (3.221 >1.520). This we suspect because firm-internal activity associates with improvement of product/process in mature technology firms. However, the risk-ratio of firms having product/process improvement and development from links with the arm's length modes of technology transfer was *ceteris paribus* lower than that of links with FDI (-1. 224 and -1.310<0 in Model 1a and Model 1b). As complementary to the kinds of technology transfer, the type of firm also matters for capability increments in product or process development. The probability of having development of product/process to that of no innovation was *ceteris paribus* higher in science-based technology firms than in mature technology firms (0.811 > 0 in Model 1b).

Models 2a and 2b were used to assess the effect of existing knowledge base on innovativeness. The estimation results, displayed in Tables 4 and 5, identify two characteristics as being important for improving a link's risk-ratio of yielding innovations both in the form of improvement and development of a product or process:

- Being endowed with researchers and engineers in the firm as more than 50 per cent of the total employees and with managers holding academic degrees related to the activity field of the firm regarding both kinds of firms; and also

[15] Model 1a assesses the risk-ratio of product/process improvement to that of no innovation. Model 1b assesses the risk-ratio of product/process development to that of no innovation, and this will be the same for all models.

[16] Except for the links with the collaborative agreement mode of technology transfer and their effect on capability increments particularly on the improvement of a product or process. In this case, the variable is statistically not significant.

- Being a science-based technology firm.

The risk-ratio of firms having development of technology from links at the time when the firm had a ratio of researchers and engineers of more than 50% in total employees was *ceteris paribus* higher than when the firm's ratio of researchers and engineers was under 49%. However, this relationship was not significant for product/process improvement. Therefore, considerably high rates of researchers in the firm mattered for product/process development, but not for improvement.

The risk-ratio of firms having improvement and development of technology from links conducted by managers with academic degrees related to the field of activity of the firm was *ceteris paribus* higher than that of links conducted by managers with no academic degrees related to the firm's field of activity. A university degree obtained abroad raised the risk-ratio of achieving product/process improvement more than a degree obtained from the home country (1.847>1.262 in Model 2a). Managers with degrees from abroad were mostly specific to science-based technology firms. Although it has been anticipated that these kinds of managerial qualifications would add largely to firms' innovative capabilities, it did not happen so in the science-based segment of the Turkish materials industry. Instead, their influence was almost the same on technology improvement capabilities mostly associated with imitation and small-scale developments as on technology development capabilities associated with innovation. This may be mainly because science-based firms had been dealing with significantly complex and novel processes and products and these technologies need precise and deep knowledge for radical innovations to occur.[17] These kinds of innovations rarely take place in a catching-up country.

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[17] Process development activities have taken place in some of the science-based technology firms at the start of their lifetime regarding sophisticated processes such as slightly different versions of Physical Vapour Deposition (PVD) and ion implantation and their related ultra-thin film ceramic coating products such as titanium nitride, titanium carbonitride, zirconium nitride, chromium nitride, titanium zirconium nitride, etc. Some other sophisticated processes such as injection moulding for the production of small technical ceramic parts like insulators, honeycomb strainers for metal casting, catalytic convertors, ceramic ferrites and piezoelectrics used in electric electronic industry, oxygen sensors for the steel industry and resin transfer moulding (RTM) for production of polymer matrix composites that are used in aircraft and defence industries have often been subject to incremental improvements.

| | Improvement of a product or process | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Indicators** | **Model 1a. Technology acquisition** | | **Model 2a. existing knowledge base (EKB)** | | **Model 3a. intensity of effort (IoE)** | | **Model 4a. Mediating effect of EKB** | | **Model 5a. Mediating effect of IoE** | | **Model 6a. Full model** | |
| | **Coef.** | **z (sig.)** | **Coef.** | **z (sig.)** | **Coef.** | **z (sig.)** | **Coef.** | **z (sig.)** | **Coef.** | **z (sig.)** | **Coef.** | **z (sig.)** |
| **TECHACQN= Arm's length activity** | -1.224 | 4.233** | | | | | -1.152 | -2.07** | -1.13 | -2.01** | -1.175 | -2.05** |
| **TECHACQN=Collaborative agreements** | 0.444 | 0.805 | | | | | 0.426 | 0.83 | 0.202 | 0.39 | 0.207 | 0.39 |
| **TECHACQN= Firm internal activity** | 1.520 | 6.659*** | | | | | 1.52 | 2.52*** | 0.935 | 1.44 | 0.965 | 1.47 |
| **PRES= Researchers more than 49%** | | | 0.452 | 0.89 | | | 0.188 | 0.34 | | | 0.065 | 0.11 |
| **MANACD=Manager holds degree from university abroad** | | | 1.847 | 2.58** | | | 1.992 | 2.69*** | | | 1.551 | 2.05** |
| **MANACD= Manager has degree from national university** | | | 1.262 | 1.92* | | | 1.482 | 2.18** | | | 1.275 | 1.86* |
| **MANIND= Manager has work experience abroad** | | | 12.976 | 0.02 | | | 13.900 | 0.01 | | | 14.061 | 0.01 |
| **MANIND= Manager has work experience at home country** | | | 14.019 | 0.02 | | | 14.673 | 0.01 | | | 14.689 | 0.01 |
| **RND= Primary (at firm's premises)** | | | | | 1.772 | 1.44† | | | 0.584 | 0.47 | 0.632 | 0.50 |
| **RND= Active (at knowledge supplier's premises)** | | | | | 0.746 | 1.55† | | | 0.367 | 0.75 | 0.338 | 0.66 |
| **DESIGN= Non-trivial** | | | | | 2.128 | 5.61*** | | | 1.759 | 4.44*** | 1.595 | 3.93*** |
| **SECONT= Experience-based prior search into knowledge supplier** | | | | | 0.623 | 1.59† | | | 0.412 | 0.93 | 0.354 | 0.79 |
| **SETECH= Knowledge-based prior search into technology to be acquired** | | | | | -0.052 | -0.11 | | | -0.002 | -0.000 | -0.012 | -0.02 |
| **FIRM= Science-based** | 0.217 | 0.639 | 0.494 | 1.81* | 0.303 | 1.13 | 0.432 | 1.45 | 0.275 | 0.96 | 0.476 | 1.54 |
| **Constant** | -1.009 | 3.941** | -16.340 | -0.02 | -1.908 | -3.66*** | -17.203 | -0.002 | -1.528 | -1.99** | -17.411 | -0.01 |
| **Log-likelihood** | -348.03 | | -395.78 | | -320.08 | | -336.57 | | -298.65 | | -290.80 | |
| **df** | 8 | | 12 | | 12 | | 18 | | 18 | | 28 | |
| **LRchi2** | 134.21 | | 38.72 | | 190.12 | | 157.15 | | 232.97 | | 248.68 | |
| **Sig.(chi2)** | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | |
| **PseudoR²** | 0.16 | | 0.05 | | 0.23 | | 0.19 | | 0.28 | | 0.30 | |

***significant at 0.001, **significant at 0.01, *significant at 0.05, †significant at 0.1.

Table 4: Results of multinomial logistic regressions for dependent variable: Prob (Improved product or process) / Prob (no innovation). (N=408).

| | Development of a product or process | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Indicators** | **Model 1b. Technology acquisition** | | **Model 2b. Existing knowledge base (EKB)** | | **Model 3b. Intensity of effort (IoE)** | | **Model 4b. Mediating effect of EKB** | | **Model 5b. Mediating effect of IoE** | | **Model 6b. Full model** | |
| | **Coef.** | **z (sig.)** | **Coef.** | **z (sig.)** | **Coef.** | **z (sig.)** | **Coef.** | **z (sig.)** | **Coef.** | **z (sig.)** | **Coef.** | **z (sig.)** |
| **TECHACQN= Arm's length activity** | -1.310 | 2.571† | | | | | -1.273 | -1.54 | -1.372 | -1.57 | -1.155 | -1.73* |
| **TECHACQN=Collaborative agreements** | 1.405 | 4.503** | | | | | 0.520 | 2.24** | 0.573 | 0.79 | 0.576 | 0.77 |
| **TECHACQN= Firm internal activity** | 3.221 | 19.829*** | | | | | 3.236 | 4.40*** | 1.903 | 2.29** | 1.730 | 2.03** |
| **PRES= Researchers more than 50%** | | | 1.163 | 2.41** | | | 0.813 | 1.44 | | | 1.723 | 0.25 |
| **MANACD=Manager holds degree from university abroad** | | | 1.200 | 2.37** | | | 2.223 | 2.49** | | | 0.990 | 1.02 |
| **MANACD= Manager has degree from national university** | | | 2.014 | 2.61*** | | | 2.247 | 2.74*** | | | 1.450 | 1.67* |
| **MANIND= Manager has work experience abroad** | | | 13.345 | 0.02 | | | 14.105 | 0.01 | | | 13.047 | 0.01 |
| **MANIND= Manager has work experience at home country** | | | 14.337 | 0.02 | | | 14.730 | 0.01 | | | 14.266 | 0.01 |
| **RND= Primary (at firm's premises)** | | | | | 3.799 | 3.25*** | | | 2.338 | 2.02** | 2.776 | 2.32** |
| **RND= Active (at knowledge supplier's premises)** | | | | | 0.862 | 1.67* | | | 0.347 | 0.65 | 0.398 | 0.73 |
| **DESIGN= Non-trivial** | | | | | 3.437 | 8.5*** | | | 2.951 | 7.01*** | 2.960 | 6.68*** |
| **SECONT= Experience-based prior search into partner** | | | | | 1.267 | 2.44** | | | 1.278 | 2.13** | 1.248 | 1.98* |
| **SETECH= Knowledge-based prior search into technology to be acquired** | | | | | 1.927 | 1.74* | | | 2.12 | 1.82* | 2.122 | 1.81* |
| **FIRM= Science-based** | 0.811 | 7.387*** | 1.134 | 4.03*** | 0.405 | 1.23 | 1.155 | 3.47*** | 0.448 | 1.25 | 0.882 | 2.26** |
| **Constant** | -2.384 | 12.087*** | -17.691 | -0.02 | -5.297 | -4.65*** | -19.516 | -0.002 | -5.672 | -4.03*** | -21.230 | -0.002 |
| **Log-likelihood** | -348.035 | | -395.781 | | -320.082 | | -336.57 | | -298.65 | | -290.80 | |
| **df** | 8 | | 12 | | 12 | | 18 | | 18 | | 28 | |
| **LRchi2** | 134.21 | | 38.72 | | 190.12 | | 157.15 | | 232.97 | | 248.68 | |
| **Sig.(chi2)** | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | |
| **PseudoR²** | 0.16 | | 0.05 | | 0.23 | | 0.19 | | 0.28 | | 0.30 | |

***significant at 0.001, **significant at 0.01, *significant at 0.05, †significant at 0.1.

Table 5: Results of multinomial logistic regressions for dependent variable: Prob (Newly developed product or process) / Prob (no innovation) (N=408).

A degree for managers obtained at home raised the risk-ratio of achieving technology development more than a degree obtained abroad (1.200<2.014 in Model 2b). Almost 75% of all links are directed by managers with academic degrees from national universities. The majority of these managers seemed quite enthusiastic about the work they did. Their activities were largely concentrated on low and medium level mature technologies. Since these kinds of processes and products have been on the market for a long time, it is rather easier to imitate and improve such technologies in the form of development for many firms.[18]

The type of firm mattered for capability increments in both improvement and development of technology. The risk-ratios of having improvement and development of technology were *ceteris paribus* higher in science-based technology firms than in mature technology firms (0.494>0 in Model 2a and 1.134>0 in Model 2b).

Models 3a and 3b were used to assess the effect of intensity of effort on innovativeness. The estimation results, displayed in Tables 4 and 5, identify one characteristic as being important for improving a link's risk-ratio of yielding development of a product or process:

- Being involved in primary and active R&D activities, non-trivial design activities and search efforts into partner to be collaborated and technology to be acquired, regarding both kinds of firms.

The risk-ratio of firms having particularly development of technology from links with primary and active R&D was *ceteris paribus* higher than for links without any R&D activity. Primary R&D and active R&D were statistically significant for technology improvement only at the level of 10%.

Similarly, the risk-ratio of firms having both improvement and development of technology from links with non-trivial design activities was *ceteris paribus* higher than for links with trivial design or no design activity. This was particularly the case for product/process development, design being only the second important indicator after primary R&D (3.437 >0 and 3.437 > 0.862, 1.267, 1.927 in Model 3b). Moreover, it is the only statistically significant indicator for improvement of product/process at 1% level. In the materials sector, new designs pave the way for new products and product improvements. Therefore, design capability is substantial.

The risk-ratio of firms having product/process development from links with prior search activities into the partner whom they will cooperate and into the technology that they will acquire was *ceteris paribus* higher than for links without these prior search efforts. These indicators were not found to be statistically significant for process/product improvement. This suggests that firms put more prior search effort into product/process development than improvement.

[18] These processes mainly were relatively simple cold or hot pressing, isostatic pressing methods and the thermal treatment processes such as sintering by which small particles of material are bonded together in solid state diffusion. These are used for the production of small metal parts by pressing metal powders to produce low, medium and high density products mainly for the automotive industry such as filters, bearings, shock absorber pistons, gears, seal parts, alternators, friction discs, etc. Many mature technology firms were able to reproduce such kind of technologies and even add improvements on the new machines compared to the existing machines.

The ‘firm type effect’ is not found to be statistically significant in either of the sub-models, suggesting that the intensity of effort is not bound by the firm type.

The full model (Models 6a and 6b) was used to assess the mediating effects of existing knowledge base and intensity of effort components of absorptive capacity on the relationship between technology acquisition modes and firms’ innovativeness. By controlling for the mediating effect of absorptive capacity, we examine whether the effects of technology acquisition modes on firm’s innovativeness are mediated by various transformation processes internal to the firm; because the mediators will tell us how or why certain effects occur [Baron and Kenney 1986: 1176].

The estimation results of the full model show that the effect of significant technology acquisition modes (in Models 1 a and 1b) on a link’s risk-ratio of yielding innovations both in the form of improvement and development of a product or process *reduces* when the variables of existing knowledge base and intensity of effort were introduced and tested as mediators. These reductions are particularly significant in both improvement and development of a product or process, especially because the effect of firm-internal activity in improvement of a product or process and the effect of collaborative agreements in development of a product or process has disappeared.

In order to find out the major mediator (s), models 4 and 5 were estimated using technology transfer mode and one of the components of absorptive capacity. Their estimation results indicate that intensity of effort (models 5a and 5b) is a mediator in the relationship between technology acquisition modes and firms’ innovativeness. Because, when the variables of existing knowledge base were controlled for, the impact of technology acquisition modes on firms’ innovativeness did not change (models 4a and 4b). The results for the development of a product or process indicate that having existing knowledge base is important for science-based technology firms when compared to mature technology firms (Model 4b). However, when the variables of intensity of effort were controlled for, the effect of firm-internal activity in improvement of a product or process and the effect of collaborative agreements in development of a product or process has disappeared. This means that intensity of effort (particularly through design activities and primary R&D and to some extent search into partner and technology within the firm) is a condition for these technology acquisition modes to effect the improvement and development of a product or process in the firm. Consistent with the MCA results in Figure 4, these associations represent both kinds of firms.

## 6 Discussion and Concluding Remarks

This research contributes to the current debate and findings about the relationship between technology acquisition modes and innovativeness of firms in emerging markets. Our findings suggest that firms’ innovativeness significantly increased over time from 1967 to 2001 in the materials industry in Turkey. Particularly in the last period 1997-2001, we observe a shift from improvement to development of a product or process. Period 1982-1996 seems to be a transition period for both segments of the sector, when firms were gradually gaining innovative capabilities for improvements in a product or a process.

Our findings also suggest that innovativeness was strongly influenced by the mode of technology acquisition chosen by the firm over the years. While the improvements of a product or process by science-based technology firms were achieved through knowledge acquisition in collaborative agreements and FDI during the period 1982-1996, their innovativeness shifted towards development of a product or process through firm-internal activities in the last period 1997-2001. Having given emphasis on firm-internal activities for improvement of a product or process during the period 1982-1996, mature technology firms, on the other hand, turned to other external sources for development of a product or process by means of collaborative activities in the last period 1997-2001.

These findings suggest that science-based firms have progressively built their innovativeness on a strong existing base of knowledge with the use of high percentage of researchers in the firm as well as the reliance on mostly the academic experiences of their engineer-managers. They complemented their strong existing knowledge base with high commitment to firm-internal activities, i.e. in-house problem-solving activities, in-house R&D project and reverse-engineering. Hence, having greater numbers of researchers and engineers in the firm and managers with academic degrees in the activity field of the firm and conducting primary or active R&D and non-trivial design activities facilitated transfer of tacit knowledge and training [Kim 1997a] for improving a link's risk-ratio of yielding an improved and developed product or process. Moreover, the probability of this resulting in new product/process was greater than that of resulting in product/process improvement if the firms had high levels of the intensity of effort, as they invested heavily in primary and active R&D and non-trivial design activities, designs originating from inside the firm, similar to Kim's [1998] findings in the case of Hyundai Motor in Korea which is based on the success and efficiency of reverse-engineering processes.

Mature technology firms, on the other hand, followed the route of first firm internal activities where they attempted reverse-engineering on the basis of arm's length technology purchases and then establishing collaborative agreements when their existing knowledge base has become meagre / insufficient. They approached domestic universities to complement their lack of knowledge in process operation and troubleshooting. These kinds of assistance paved the way for joint technology projects for process imitation in many firms and even towards cost-cutting minor and major novel improvements in already existing processes. However, our results also suggest that they but failed to exert sufficient commitment to product/process development as strong as science-based technology firms despite engaging in collaborative agreements; in other words, the elements of intensity of effort other than design activities become a condition for collaborative agreements to turn into higher level of innovativeness in mature technology firms. This result indicates that, although firm-internal activities may seem very similar to intensity of effort within the firm, the latter's existence is directly related to the process of knowledge internalisation or catch up while the former's existence certainly speeds up this process.

Therefore, our results confirm the findings of Kim [1998, 1999], Hobday [1995,1995a], Ariffin and Figueiredo [2004], Ariffin [2010], Figueiredo [2001, 2010] on the one hand, and on the other, by drawing attention to differences between science-based and mature technology firms in a high-tech industry, they extend our understanding of the determinants and the pattern/trajectory of firm innovativeness. As firms increased their existing knowledge base and exerted more intensity of effort in their research activities, their innovativeness tended to increase. In this respect, the science-based segment of the industry appeared to be better endowed than the mature segment of the industry in skilled workforce and managerial experience. Following from these, the strong base of existing knowledge in these firms allowed the science-based technology segment to behave more aggressively in R&D and design activities and conduct their intra-firm technology projects with support from knowledgeable outside partners, especially within the last five years studied in this research. In Kim's (1997: 97) words, 'one of the important elements of effective knowledge conversions leading to productive learning in the firm, the existing knowledge base, of course mostly tacit knowledge', appeared to be playing a more crucial role in the science-based technology firms.

Despite arm's length relations are mostly considered as the major mode of technology acquisition in emerging markets, we find the impact of arms' length relations on firms' innovativeness is statistically significant but negative. This is in a way similar to Koc and Ceylan [2007] who found that technology acquisitions and exploitation are significant predictors of innovative capacity in large Turkish manufacturing firms. Most of the research on technology acquisition in emerging markets, including theirs, focuses on the technology acquisition packages in the manufacturing and large firms that are technologically dependent on technology suppliers [Contractor and Sagafi-Nejad 1981, Contractor 1998]. Moreover, Koc and Ceylan [2007] define technology acquisitions and exploitation as monitoring, selection and acquisition of technologies; the development of new and improved technologies through R&D or external acquisition, and the exploitation of technical knowledge. These may explain some of the differences in our results, which indicate that arm's length relations do not improve or develop a product or process, as the level of absorptive capacity increases. Our research contributes by examining SMEs and a high-tech sector which is largely under-researched, as the impact of arm's length relations on firms' innovativeness might be different in high-tech sectors. In addition, there is a possibility that our findings reflect a deeper explanation to the relationship between technology acquisition and firms' innovativeness by defining which other technology acquisition modes other than arm's length relations are important for firms' innovativeness.

Finally, our results on the mediating effect of intensity of effort component of absorptive capacity on the relationship between technology acquisition modes and innovativeness of Turkish SMEs in materials industry are in line with the findings of Chudnovsky, et al. [2006] and Tsai and Wang [2008]. In their work on Argentine manufacturing firms during 1992-2001 period, Chudnovsky, et al. [2006] found that technology acquisition alongside in-house R&D expenditures have positive payoffs in terms of enhanced probability of introducing new products and/or processes to the market. Similarly, examining large Taiwanese electronics firms, Tsai and Wang [2008] found that external technology acquisition does not provide a significant contribution to firm performance *per se*; however, the positive impact of external technology acquisition on firm performance increases with the level of internal R&D efforts.

Finally, although our findings contribute to the current literature, we acknowledge the limitations of this research. When dealing with the technology acquisition concept this paper only dealt with the kind/type of technology transfer. It follows the implicit assumption that interactive/collaborative modes of transfer allow for tacit knowledge flow and thus more important implications on innovativeness than arm's length modes. Yet, what kind of knowledge comes is also an important factor as how the knowledge comes. Lee and Von Tunzelmann (2005) state that it is rather the former that determines the degree of catch-up and speed to innovativeness (in a scale from basic to advanced). Further research in this area has potential to make significant contributions also to the understanding of which kind of acquisition modes could be associated with which kind of knowledge content.

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