International technology transfer and the dynamics of complementarity: A new approach

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ABSTRACT

Latecomer firm's catch-up through indigenous R&D and cross-border technology transfer embeds various influencing factors that are present simultaneously – beyond the will or power of managers and policy makers – and that have to be recognised, analysed and taken into account. Despite the increase in literature on substitution/complementary relationship, some ambiguity remains in understanding the complexity of complementing between indigenous and overseas technology sources. Unlike the majority studies on complementarity, this paper suggests the dynamic approach by which scholars are able to reach a deeper understanding of the dynamics, challenges and difficulties of these relationships. This study builds a theoretical framework to being operationalized in the context of Iranian latecomer firm located in gas turbine industry. This paper shows that taking the dynamic approach is able to reveal the strategies by which the latecomer firm deals with the difficulties of acquiring advanced technologies. Although complementary relationship exists, it is a strategic vision to understand how a latecomer firm complements its indigenous efforts with overseas technology sources. Different kinds of insights will be provided in terms of national-, industry- and firm-level factors and the strategies by which a latecomer firm can deal with these factors.

1. Introduction

Technological catch-up studies argue that both indigenous efforts and overseas technology transfer are the key elements of latecomer firms' catch-up. On one hand, the literature underlines the accessibility of foreign technology and international technology flows from leaders to followers as a significant part of the process. On the other, it emphasises indigenous innovation and learning systems and highlights the important role of institutions, organisations and interactions in enhancing domestic technological capabilities. In this view, a number of studies have tried to understand the relationship between indigenous and overseas technology sources. Some of them have shown that these two main technology channels are alternatives or substitutes, while others have argued that the channels are complementary. Regardless of the small number of such studies, especially in a developing country context, the majority of the existing literature has placed too much emphasis on the 'correctness' of one of these ideas. They have often examined the type of relationship and paid inadequate attention to its dynamics, challenges, and difficulties. Although some of the studies (Bell and Pavitt, 1993; Pack and Saggi, 1997; Radosevic, 1999) have criticised the static viewpoint of the existing literature and have posed interesting questions about the dynamics of technological development of latecomer firms, the issue has barely been touched upon. These studies have left unanswered the nature and the details of dynamics.

In this light, this paper, instead of examining only the type of relationship between indigenous technology development and overseas technology inflows, delves deeply into the dynamics. Based on a case study method and examining the Iranian Company — MAPNA, this research provides theoretical insights into the following questions: What have been the dynamics between indigenous technology development and overseas technology transfer for a latecomer firm intends to catch-up? How a latecomer firm can manage influencing factors in order to complement its indigenous technology development efforts with overseas technology inflows?

2. The conceptual framework

The first aspect of the technological catch-up concept is the important role of foreign technologies in enhancing domestic firms' technological capabilities. Radosevic (1999) argues that the catching-up literature builds upon the proposition that technology followers benefit from technology leaders (1999). Other important aspects which are highlighted in the literature on technological catch-up are the active role of domestic firms, the typology of their interactions, and the contributions of institutions, financial systems and infrastructure. Framed in this way, the technological catch-up process cannot be reduced to merely transferring technology from developed countries and imitating their routines among latecomers. Rather, indigenous capability building has become, and will continue to become, of ever greater value (Mazzoleni and Nelson, 2007).

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These kinds of discussions highlight an important theme in the literature. On one hand, the technological catch-up literature underlines the accessibility of foreign technology and international technology flows from leaders to followers. On the other hand, the literature highlights the important role of indigenous institutions, organisations and interactions in enhancing domestic technological capabilities.

Here, the question is how indigenous capabilities and foreign knowledge – as the two main sources of knowledge – interact with each other. What factors influence the dynamics of this process? And finally, the crucial question is whether these components are complementary or substitutes for one another. The extent of complementarity and substitution has become a focus for debate in the literature. Some researchers have argued that the two important technology sources work together in a substitutive way. In contrast, other researchers have argued that both means interact in a complementary way.

2.1. Indigenous and overseas technology sources: substitute or complement?

In the literature on technology transfer Radosevic (1999) states the definition of "mutual complementarity as the process where the rise in one variable raises the payoff of increasing the other" (p 115). In contrast, a substitutive relationship between two variables reflects the decrease of one if the other increases. For example Braga and Willmore (1991, p 421) argue that "increased imports of technology imply a decrease in local R&D". Similarly, Radosevic (1999) defines substitution as "the more foreign technology was imported the less likely it was that domestic R&D would develop" (p 115). Complementary and substitutive relationships between indigenous technology development efforts and overseas technology transfers result in different policy implications, which have been highly controversial in the literature.

The substitutive view originates from import substitution policies, which were part of the mainstream development position of the 1960s and 1970s and were practised by the majority of developing countries such as India and Latin America (Radosevic, 1999, 2009). This view has been mainly articulated by Stewart (1977) and Mytelka (1978) in the literature. Stewart (1977, 1987) believed that developing countries should not copy advanced technologies developed in industrialised countries but rather should cooperate with each other to develop appropriate technologies and build a so-called South-to-South cooperation. Mytelka (1978) also studied two industries – metal-working and chemical firms – in the Andean Group of Latin American countries, and contends that by reducing the need to create indigenous technology, technology imports curtail domestic technological development and create a reliance on foreign technology. Both Mytelka (1978) and Pillai (1979) believe that imports reduce developing countries' need (or incentive) to undertake their own technological efforts: the developing country enterprises become 'dependent' on the imports.

The dependency idea has been criticised by Pack and Saggi (1997). They believe such policy thinking was the harmful long-term impact of technology capability building in Latin America. Despite these critiques, at that time Mytelka argued based on the circumstances of the 1960s and 1970s. She had observed unsuccessful technology transfer projects in Latin America and she was concerned with the traditional approach of technology flows from North to South, in which technology transfer regimes sufficed to import machines and equipment. These regimes often neglected the transfer of tacit elements of knowledge and did not include the engagement of indigenous people in learning-by-doing processes. Perez (2001) also interprets Latin American cases in a similar way. She argues that these countries, in contrast to the newly industrialised Asian countries, have passively engaged in technology transfer processes. Nevertheless, the substitutive idea, or the idea of import substitution, is no longer valid in the literature and the trade circumstances have been largely altered over the last three decades: this matter has also been argued by Perez (2008) in terms of changing conditions, changing strategies.

After Mytelka (1978) and Pillai (1979); Lall (1985) studied the interaction of both domestic and foreign technology sources. Lall (1985) argues that the relationship between technology transfer and domestic technological efforts is changeable, and at certain stages the two are substitutes while at others they are complementary. However, Lall (1985) believes that when the strategy of low technology import lasts so long, it may lead to technological stultification due to limited capabilities of developing country enterprises. The concept of the complementary relationship has been somewhat raised accordingly. Lall (1989), in his next piece of research, interpreted importing technology as a "building block" for domestic capabilities. His studies cast light upon the crucial role of foreign knowledge and interaction with domestic technology sources in building domestic capabilities. However, in Lall's studies this question remains unanswered: why does the relationship between these two technology sources change, and what factors influence this?

Bell and Pavitt (1993) and then Freeman and Hagedoorn (1994) had influential studies in which they show catching-up firms choose and use both of indigenous and overseas technology sources. Their studies also emphasise technology partnership with foreign technology owners, if not complemented with indigenous efforts, may even lead to falling behind. Although these studies confirm the complementary relationship, the details of this complementarity, its dynamics and influencing factors are still shrouded in mystery.

The studies discussed above are based in the general context of developing countries. Within the literature, scholars have identified the need to be more specific, and hence studies have begun to examine complementarity/substitutive ideas in specific contexts.

Braga and Willmore (1991) investigated the relationship between technological imports and technological efforts in Brazilian firms. Lee (1996) studied the relationship between technology imports and R&D efforts in the context of Korean manufacturing firms. Katrak (1997) implemented a similar study in the electrical and electronic industry in India. Kim (1998) studied Hyundai, the Korean automotive company, to interpret how both indigenous and foreign technology sources are coupled to upgrade the level of organisational knowledge. In the context of developed countries, Caloghirou et al. (2004) and recently Hagedoorn and Wang (2012) examined the type of relationship between firms' internal and external knowledge sources.

The abovementioned studies confirm the complementary relationship between indigenous and foreign technology sources. Furthermore, these studies showed that the complementary relationship exists apart from the size of firms.

Moreover, although a number of these studies operationalized in the context of developed countries, their scope overlaps with those conducted in developing countries. All these studies are built upon the strategic management of firms' knowledge sources (internal or external to firms). In fact, the complementary relationship, indeed, originates from the accepted concept of 'absorptive capacity' in cross-border technology transfer. Cohen and Levinthal (1989) coined the term 'absorptive capacity' and argue that the main function of R&D is to develop the firm's ability to identify, assimilate, and exploit knowledge from the environment. Subsequently, Cohen and Levinthal (1990) developed the concept of absorptive capacity, arguing that "the ease of learning, and thus technology adoption, is affected by the degree to which an innovation is related to the pre-existing knowledge base of prospective users" (pp 148–149). They divide the concept into two important elements, namely the "prior knowledge base" and "intensity of effort". The corollary of this argument is that foreign knowledge absorption needs prior indigenous capability building efforts as well as the extent to which latecomer firms makes the effort to acquire knowledge from leader companies.

Buildings on the notion of absorptive capacity, make-or-buy discussions (or substitution perspective) were cast aside in favour of complementarity between indigenous and overseas technology sources. The corollary of this position is that catching-up firms should not trap in the dichotomy of making or buying technologies; rather they should attempt complement their indigenous efforts with overseas technology sources. From this line of reasoning, firms may choose different collaborative methods with foreign partners. The appropriability of methods depends upon the level of absorptive capacity. When the level of absorptive capacity is low, a firm mostly relies on external sources of technology while in the case of high level absorptive capacity, a firm tries to satisfy its technological needs by internal-oriented technology sources. This argument is also mentioned by Lee (2005), who believes that Korean firms, in the late stages of catching-up, collaborated with foreign companies in the form of co-development (R&D collaboration) rather than OEM subcontracting. He argues that despite the lack of sufficient capability and a core knowledge base, the Korean firms had some complementary assets, which were created by indigenous R&D efforts. In fact, from the perspective of absorptive capacity, firms choose each of collaboration methods in order to fill their technological gaps while during collaboration they make efforts to learn from the foreign partner. However, in firms' decisions there are other influencing factors which will be discussed in the next sections. Fig. 1, indicates classical technology acquisition channels which are sorted based on internal (make) or external (buy) technology sources.

2.2. The dynamics of interactions: a new approach

The broad literature review above on the subject of substitution/complementarity reveals a number of important points. Firstly, the studies in both the contexts of developed and developing countries have paid much attention to exploring the ‘type’ of relationship between indigenous technological efforts and overseas technology transfer. The proponents of the substitution idea argue that technology accumulation in the countries of the global South may result in falling behind rather than technological catching-up. In contrast, the changing conditions in trade and technology development over the last three decades have led to the perception of overseas technology transfer as something working in combination with indigenous efforts. Thus, scholars since the 1980s, based on empirical observations, have criticised the substitutive view and argue in favour of the complementary relationship.

Secondly, the substitution/complementarity literature in the context of developing countries is confined to a small number of developing countries (India: Katrak, 1997 and Lall, 1985; Brazil: Braga and Willmore, 1991; South Korea: Lee, 1996, Kim, 1998). The majority of these studies aimed to find out the type of relationship and used quantitative methodologies.

Thirdly, all the studies that have been reviewed pay inadequate attention to the dynamics of interaction between indigenous technology development and overseas technology transfer. The majority of researchers have been preoccupied with assessing the correctness of one of the ideas of substitution or complementarity. In other words, they have tried to prove one view and reject the other, while a dynamic perspective on the analysis or interpretation is largely absent. The literature has paid inadequate attention to the complexity of the process, problematic situations, and the coexistence of influencing factors.

A closer look at the findings of the substitution/complementary studies and the successful technological catch-up cases reveals that despite the complementarities between indigenous technology development efforts and overseas technology transfer (based on the absorptive capacity concept), they have an interchangeable role. The studies show that firms tend to choose both of the two knowledge sources (Bell and Pavitt, 1993) but ‘partially’, because the firm, due to its prior knowledge base and its contemporary efforts, not only is able to absorb the transferred technology but also is able to actively involve itself in the transfer process. This argument was discussed by Lee (2005) in the Korean catching-up cases. Furthermore, at some stages the need for foreign knowledge is much higher than at others (Lall, 1985). Therefore, although foreign knowledge and domestic efforts complement each other and the importance of both sides is emphasised in the literature, the evidence shows that firms often dynamically change the contribution of both knowledge sources in terms of resource allocation (financial and human resources). In some circumstances they may invest more in indigenous capability building than in foreign knowledge sources, and vice versa. The extent of the contribution depends on the dynamics of the process and associated influences. However, this cannot be reduced to a static trade-off between these two knowledge sources (Pack and Saggi, 1997). Radosevic (1999) argues that “the optimal trade-off between imported and domestic technological effort cannot be answered in general for any country. It is very much an industry-specific relationship” (p 120). Thus, the extent to which domestic and overseas technology sources contribute to the technological catch-up process depends not only on national level but also on sector and firm level influences. Furthermore, as technological catch-up is a long and dynamic process, the extent of these influences may change. Hence, the dominance of foreign or indigenous knowledge may change depending on influencing factors.

This paper approaches this issue from a different perspective than that of the traditional literature. It argues that a ‘dynamic approach’ is needed to study the interaction processes between these two main knowledge sources. This is because technological catch-up is an extraordinarily complex process within which the interaction processes between indigenous and overseas knowledge sources are influenced by various national, industry and firm level factors, and thus it is often necessary to view the issue from different angles for different industries as well as for different countries. These influences may present simultaneously – beyond the will or power of managers and policy makers – and that has to be recognised, analysed and dealt with. Therefore, understanding the interaction processes between indigenous efforts and overseas technology transfer cannot be reduced to examining only the type of relationship. Instead, far more attention needs to be

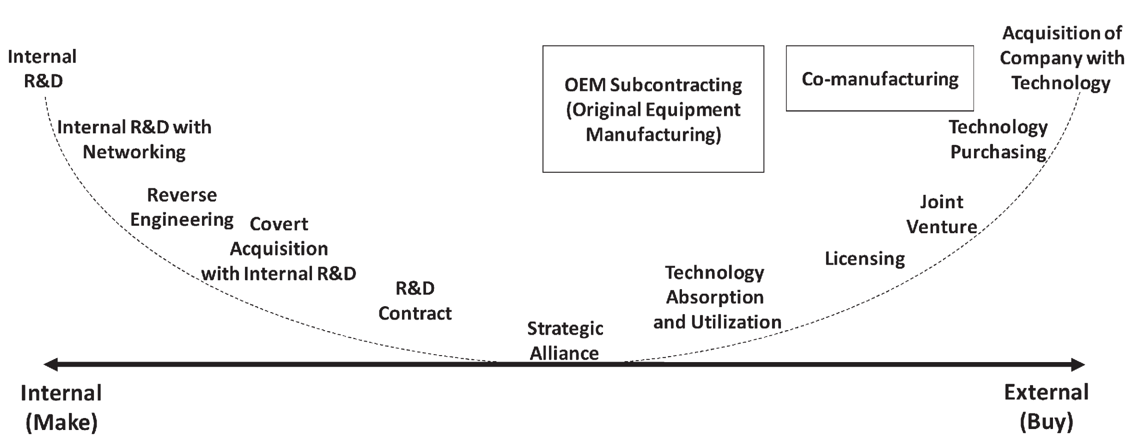

Fig. 1. Classical technology acquisition channels.

devoted to identifying the influencing factors and understanding how they affect the technological catch-up processes.

The dynamic approach shares the perspective with the dynamic capability concept. The dynamic capability concept highlights the development and exploitation of technological capabilities that are changing on an ongoing base and are conceived as routines/activities/competencies embedded in firms (Teece et al., 1997; Eisenhardt and Martin, 2000; Cetindamar et al., 2009). However, the dynamic capability concept, mainly, focuses on innovation in firms rather than latecomer firm's growth.

Therefore, the dynamic approach in this paper refers to a synthesis of indigenous expertise and imported knowledge in the complex and changing context of the technological catching-up processes. It aims focusing on challenges, difficulties and influencing factors rather than examining the type of relationship between indigenous and overseas technology sources.

In the research framework, both indigenous and overseas knowledge sources are synthesised in a dynamic and changing context in which several kinds of influencing factors exist. However, before any attempt to operationalize this perspective in a specific context is made, it is necessary to scrutinise the literature to discover the findings of previous studies. Table 1 summarises and categorises the influencing factors discussed, explicitly or implicitly, in the technological catch-up literature. It should be noted that this paper, as discussed in the above sections, perceives substitution/complementarity literature as one of the main elements of the technological catch-up concept. Furthermore, as argued in the above sections, complementary perspective in this context, builds upon the absorptive capacity concept. Thus, in order to explore the influencing factors in the area of substitution/complementarity, the possible candidates for influencing factors should be identified. These factors might not be relevant to the substitution/complementary literature; however, they should be taken into account before examining issues of dynamics in the case of this paper.

Table 1 provides a preliminary framework by which this research is operationalized. Through this framework, this paper will examine the possibility of engaging these factors in the Iranian context and will explore other possible engaged factors. The matrix categorises the influencing factors based on a latecomer firm perspective. From this perspective, the technological acquisition process of a latecomer firm is influenced by intra-firm factors as well as by other external influencing factors. The external factors are on a broad range of industry, national and global levels and a clear distinction between them is not always possible. For instance, gas turbine technologies are highly advanced and sophisticated and the international market for these products has an oligopolistic structure (Islas, 1997; Watson, 2004; Magnusson et al., 2005; Bergek et al., 2008; Majidpour, 2012). In these circumstances, the type of technology is a global level factor. It means that acquiring gas turbine technologies is a challenging process around the globe. Furthermore, the IPR regimes are industry-, country- and also global-level factors. Thus, any exclusion of these issues in the categorisation of the factors will be an ad hoc view. With respect to this, the matrix above categorises all industry-, national- and global-level factors as factors external to the firm.

3. Empirical analysis

3.1. Introduction

As explained in the conceptual framework, in contrast to previous studies which were often based on quantitative analysis, mostly survey analysis, this study is interested in exploring the dynamics and gaining an in-depth understanding of the influences. The case study method, by going into great depth in a single case, enables the researcher to understand the dynamics present within one setting (Eisenhardt, 1989). This method also enables the researcher to investigate important topics not easily covered by other methods, and can illuminate a particular situation, to get a close (that is to say, in-depth and first-hand) understanding of it (Yin, 2006).

Iran's gas turbine industry is often defined by MAPNA Group. It is now a conglomeration of a parent enterprise and 30 subsidiaries of which three subsidiaries are primarily involved in the gas turbine industry, namely TUGA (MAPNA Turbine Engineering and Manufacturing Co.), PARTO (MAPNA Turbine Blade Engineering and Manufacturing Co.) and MECO (MAPNA Electric and Control Engineering and Manufacturing Co.). Since 2007, MAPNA and its subsidiaries have expanded their markets to Middle Eastern and African countries. The evidence suggests that the company is the only latecomer firm in a

Table 1
Influencing factors that affect technological catching-up.

	Factors	Literature
Internal factors (Firm Level)	Technological capability and absorptive capacity	▪ Initial technological development (Freeman and Hagedoorn, 1994; Pack and Saggi, 1997; Radosevic, 1999) ▪ Existence of skilled local entrepreneurs (Hobday, 1994) ▪ Absorptive capacity (Cohen and Levinthal, 1989; Kim, 1998; Lee, 2005; Lee, 2009), Technological capability (Joo and Lee, 2009; Lee and Kim, 2009). ▪ Production experience (Katrak, 1997)
	Continuous interactions with foreign players	▪ Cross-border flows of knowledge (Bell and Pavitt, 1993; Freeman and Hagedoorn, 1994; Pack and Saggi, 1997; Radosevic, 1999; Lee, 2005; Malerba and Nelson, 2011; Mazzoleni and Nelson, 2007) ▪ R&D openness and absorptive capabilities in Chinese firms (Wang et al., 2014).
	Type of contract	▪ This factor discussed in the Korean case studies in which the government formulated an effective consortium in order to enhance the possibility of technology acquisition from the US companies (Lee (2005; 2013).
External factors (industry, national, and global level)	Government policies	▪ Investing in learning and education (Bell and Pavitt, 1993; Hobday, 1994; Malerba and Nelson, 2011). ▪ Tax privileges, tariff reduction, public procurement (Lee, 1996; Lee, 2005) ▪ Substitution policies (Pack and Saggi, 1997; Katrak, 1997) ▪ Financing, tax reduction, protection of the local market (Kim, 1998) ▪ Creation of conditions for brain gain and circulation of strategic human capital (Lin and Rasiah, 2014).
	Size and orientation of market	▪ The size of domestic market can be a driver of growth e.g. China and Brazil (Malerba and Nelson, 2011; Mu and Lee, 2005) ▪ Export-led growth (Hobday, 1994). ▪ Domestic market as a test bed (Whang and Hobday, 2011)
	Geographical agglomeration	▪ Clustered geographically (local externalities) (Pack and Saggi, 1997; Lee, 2005)
	Type of technology	▪ Type of technology – connections with scientific knowledge (Mazzoleni and Nelson, 2007) ▪ Technological Regimes (Lee and Lim, 2001; Breschi et al., 2000).
	Universities and public research institutes	▪ Coupling of the education system with industry needs (Hobday, 1994; Lee, 2005; Lee and Kang, 2010) ▪ Universities and public research institutions (Mazzoleni and Nelson, 2007; Malerba and Nelson, 2011).
	Intellectual property rights regimes' status	▪ Loose IPR regimes (Mazzoleni and Nelson, 2007) ▪ IPR may have different effects on different sectors (Malerba and Nelson, 2011)

developing country that has fully localised gas turbines and has built essential capabilities (Majidpour, 2012).

The author has been technology management and R&D consultant for PARTO Co. for three years and tried to integrate this research into his carrier. A rich access to MAPNA's data – through participating in meetings, seminars, conferences and other events – was possible. Thus, action research method was in this research agenda. However, in order to gather complementary data, this study planned to conduct multi-level interviews and document collection. The interviews were classified and conducted at the three levels of government, industry and firm. In total, 28 interviews were conducted. Further to the interviews, many documents have been gathered. A number of these documents had been documented by the author and his colleagues during several projects. These supporting documents can provide detailed information about technological development processes.

3.2. Government policies

Government policies have been continually discussed as an important influencing factor in technological catch-up and in latecomer firms' growth processes (Bell and Pavitt, 1993; Hobday, 1994; Lee, 1996, 2005; Pack and Saggi, 1997; Katrak, 1997; Kim, 1998; Radosevic, 1999; Mu and Lee, 2005; Malerba and Nelson, 2011; Lin and Rasiah, 2014). The role has been highlighted particularly at the early stages of development (Fagerberg and Godinho, 2005). However, recent studies have revealed that the type of government policies and the methods of government interventions in the processes differ significantly from one country to another (Fagerberg and Godinho, 2005; Lee, 2005; Malerba and Nelson, 2011).

In the case of MAPNA, government policies have contributed in technological development in three different ways. Firstly, the government in Iran has granted the majority of power plant construction projects to MAPNA in order to offer an opportunity of learning-by-doing to the domestic company. Furthermore, domestic utility companies have been obliged to order power plant projects from MAPNA. I want to suggest that such a governmental support not only, of course, in tandem with successful catch-up cases policy, but as a matter of the strategic vision built on the industry structure. Gas turbines are categorised as complex products systems (CoPS) which its market is concentrated with few suppliers and few buyers (Miller et al., 1995; Davies, 1997; Hobday, 1998; Magnusson et al., 2005). In addition, CoPS customers in many countries are managed and regulated by the state and 'hence, it is not unusual for CoPS markets to have evolved into monopsonies, where government agencies act as sole customers' (Magnusson et al., 2005). The strategic vision here is the status of developing countries in gas turbine industry where only three countries engaged (Majidpour, 2012). In order to deal with these challenging circumstances, the Iranian government designated a new model of technology transfer contract from foreign companies.

Secondly, due to the strategic importance of gas-fired power plants and subsequently the gas turbine industry in Iran's energy policy (Majidpour, 2012), the managers in the Ministry of Energy have constantly supported many education and learning activities. The government has supported the establishment of any kind of research centre to make close interactions and connections with MAPNA and its subsidiaries. These institutes play an intermediary role between universities and industry to foster applied research. In analysing the Iranian case, it can be argued that government education policies can foster and stimulate the learning of domestic firms. These policies can provide required finance in education and research. The outcomes are the formation and development of human capital and the close interaction between firms and universities and research centres.

3.2.1. Type of contract

Unlike in other Asian contexts, tax privileges and R&D subsidies were not core aspects of the government's policies in Iran. Rather, by following 'public procurement policies', the government has secured a market for MAPNA's products. Furthermore, MAPNA, with the support of government's procurement policies, put together a number of projects and proposed a fleet of power projects which are designed to be attractive to foreign companies. Such a 'type of contract' has enhanced MAPNA's bargaining power by aggregating domestic power projects and has facilitated the interactions between indigenous and overseas knowledge sources. Such a state-led demand provided an opportunity, particularly in its early phases, for MAPNA, in which the company and its subsidiaries were able to engage in technology transfer projects.

The contract between MAPNA and foreign company was designed based on project-based learning in a co-manufacturing scheme. The contract of delivering 30 gas turbines, which is a large project, designed and implemented in 5 phases. The foreign company was also obliged to supply from at least 51% of equipment from MAPNA's subsidiaries. In this contract, foreign company bought localised equipments from MAPNA's subsidiaries and sold to MAPNA. The quality assurance and the progress of localisation were reported by foreign company to MAPNA. As Table 2 indicates, the proportion of localisation increased from one phase to another.

By deepening into the dynamics of interactions between technology owner and technology recipient and examining the particular sequence of contracts, one can extract insights into the technology acquisition processes — knowledge of a kind that cannot be deduced from some merely theoretical taxonomy of technology transfer channels such as those discussed in Fig. 1. Therefore, I want to argue that serious problems arise as a matter of the potential explanatory usefulness of an analysis built on such classical premises. It is vital to deepen into empirical cases and understand the dynamics of interactions between engaged parties.

3.2.2. State-owned company and political destabilisation

MAPNA, since its inception, has been a state-owned company. Although it is governed not as a state entity but as a private company in terms of its rules and regulations, since the majority of its shares belong to the state, it still counts as a state-owned company. One of the consequences of being a state-owned company could be management instability as managers and boards might change from one administration to another. Consequently, not only may government policies change, but the firm's strategies might turn in other directions. Furthermore, transferral of experience and knowledge from a group of managers to another group is an issue. Such instabilities may incur negative consequences for the firm's technological development. However, MAPNA has been excluded from these instabilities. In order to respond to increasing domestic electricity demands, infrastructural development such as electricity network development has been a top priority for all governing parties. In fact, power plant construction has been a common thread in governments' energy and industrial policies. Furthermore, satisfactory performance of MAPNA Group has widely been accepted among several Iranian political parties. One the subsidiaries' CEO commented that:

"MAPNA has not been destabilised as a result of the change of governments. However, if the change of government had resulted in a change of management, this influence would have definitely destabilised MAPNA, because the group who established MAPNA and managed its initial technological developments were well aware of MAPNA's objectives and understood the workings of the wider group. Their removal from the company would have become a barrier to MAPNA achieving its aims."

3.3. The dynamic approach in the context

After MAPNA's establishment in 1992, the company was the focus of policy makers in terms of economic and technological growth. In the early phases of MAPNA's establishment, all design and manufacturing of power plants and the main pieces of power equipment were

Table 2
Technology transfer phases in MAPNA's contract with foreign company.
Source: adapted from Siavoshani (2008) and Zargarpour (2008).

Technology transfer phases	Number of units	Start	End	Localisation (%)
1	6	2000 (Dec)	2002 (Jan)	11.34
2	4	2002 (Jan)	2003 (Jan)	27.49
3	6	2003 (Jan)	2003 (Aug)	37.05
4	6	2003 (Jul)	2004 (May)	55.39
5	8	2004 (Mar)	2005 (Mar)	70.52

procured through outsourcing, but MAPNA initiated its learning phase through cross-border technology transfer contracts. The company assimilated repairing and assembling knowledge through cooperation with foreign suppliers in both the repair of damaged power plants and the construction of new power plants.

In 1999, when MAPNA embarked on manufacturing, the first idea was to benchmark Siemens's manufacturing lines and establish a similar plant in Iran. A trade-off emerged once the managers recognised that a few of the Siemens manufacturing processes as well as their machining lines were relatively old. MAPNA hired local experts and university researchers to advise on plant construction. These consultants advised the managers to use new manufacturing machines and procedures. On one hand, some of the managers were keen to start manufacturing activities at the earliest possible time simply by directly copying Siemens machines and procedures in Iran. On the other, the consultants advised the installation of new techniques and the establishment of a modern plant. MAPNA finally decided to establish an advanced plant based on its own needs.

MAPNA envisioned mastering gas turbine manufacturing technologies not only based on one specific model, but also wanted to be capable of manufacturing other types of gas turbines. The interview data show that the managers did not wish to establish a manufacturing plant for one specific model of gas turbine, preferring to master manufacturing technologies instead. Therefore, they were not concerned with technical specifications; instead, they returned to the question of what kinds of capabilities and knowledge they needed and then tried to acquire them. However, the realisation of such thinking needed the engagement of domestic universities, experts and intra-firm capabilities in the process, as explained above. Therefore, MAPNA's plant establishment has been complemented by indigenous technology development efforts.

A similar challenge has been the case of gas turbine blade manufacturing. When PARTO started to transfer blade manufacturing technologies, a number of problematic situations emerged. The first challenge was in adapting casting technologies. Although the machines and techniques were adapted from foreign suppliers, techniques and procedures had to be improved for Iran's climatic conditions, since temperature and humidity are influential factors in casting. The second challenge was in the development of machining procedures. Siemens provided the final machining drawings and technical specifications for PARTO, but PARTO developed its own manufacturing techniques. In a few cases, updated techniques were developed and deployed by PARTO.[1] These changes were partly because of the advent of new manufacturing techniques at the time of PARTO's establishment, and partly because of the indigenous efforts of PARTO to adapt and localise manufacturing technologies. Transferred machining technologies were synthesised with indigenous technology development efforts.

The third problematic situation for PARTO was in transferring coating technologies. The companies collaborating with Siemens in the coating of blades were American companies, and thus collaboration between these companies and Iranian firms was not possible. Siemens could only provide the final specifications; that is to say the 'acceptance criteria'. However, reverse engineering activities enhanced the technological coating capabilities of PARTO. The company decided to activate both indigenous technology development efforts and possible foreign technology consultants, drawing on both these knowledge sources. PARTO dynamically interacted with indigenous and foreign knowledge sources and thus acquired coating technologies.

The efforts described above have all aimed to acquire technological knowledge through a synthesis of domestic and foreign sources in a dynamic context. However, while multiple sources of technological knowledge gave PARTO a broad scope for spillovers, the issue was the integration of the knowledge, and in particular its codification. Technical documents were given to PARTO in a diverse range of languages and for a variety of standards. Therefore, the next step was to codify and standardise these documents in accordance with domestic routines. These efforts resulted in serious indigenous efforts to codify, standardise and localise technical knowledge for PARTO.

The PARTO case clearly demonstrates a dynamic progression of capabilities; that is to say, constant interactions with indigenous and foreign knowledge sources and the evolution of capabilities.

MAPNA's approach can be seen in its other subsidiaries. MECO has tried to acquire capabilities related to power plants' electrical and control systems. However, MECO has relied heavily on licencing know-how, and subsequently activated indigenous technology development to internalise these technologies. It is worth mentioning that repairing and assembling knowledge, during the early phases of MAPNA's evolution, helped MECO absorb technologies in its licencing contracts. MECO has gradually increased the localisation of gas turbine control and electrical system manufacturing. MECO decoded the existing software and mastered its know-how. Furthermore, MECO has entered into technology upgrading contracts with Siemens and other European companies in order to renew its know-how. In the case of MECO, indigenous technology development efforts have been progressively enhanced. These efforts have synthesised with licencing technologies and have recently reached R&D projects.

3.4. Size and orientation of market

In the technological catch-up literature, demand has been put forward as a significant driver for catching-up, though differentiated between export-oriented and domestic market-oriented demand. The majority of studies have provided evidence in which export markets have been crucial in latecomer firms' catch-up (Hobday, 1994; Kim, 1998; Radosevic, 1999). These studies, which are mostly focused on the new Asian industrialised countries, have shown that latecomer firms enhance their technological capabilities by exporting. Through this, they learn a great deal from export markets. This model is recognised as export-led growth and assumes that the size of domestic market in many emerging economies is too small to stimulate catch-up. It thereby often underestimates the role of the domestic market in the technological catch-up processes.

The second demand orientation in the catch-up literature addresses the domestic market and contends that this market is potentially able to grow the industry. In these circumstances, domestic firms, often with the support of the government, supply the domestic market and enhance their technological capabilities to the point at which they can compete internationally. This is particularly the case for countries that have large domestic markets such as China, India and Brazil. In these countries, a large domestic market has been a major driver for learning and for the accumulation of capabilities (Malerba and Nelson, 2011). Fagerberg and Godinho (2005) also believe that technological development in the USA, Germany and Japan was firstly geared towards the home market, while for the new Asian caught-up countries exports played a similar role. However, among the recent technological catch-up cases, there has been only minor evidence showing catch-up resulting from the domestic-oriented market. Mu and Lee (2005)

[1] For example, machining of cooling holes was upgraded by electrical machining techniques. Similarly, for machining stationary blades, MAPNA uses a 'single piece grinding' method, which is a new and flexible technique, instead of 'ring turning'.

showed that in China's telecommunication industry the coordinated acquisition of foreign technology by taking advantage of the bargaining power associated with market size has been a decisive success factor. The most recent research has taken place in the Korean context, in the mobile handset industry (Whang and Hobday, 2011). They demonstrate that in the case of the mobile handset industry in South Korea, the domestic market has played a crucial role in the technological catch-up, a dimension which has been neglected in the traditional literature.

The Iranian case shares many features with the second model. MAPNA Group, with the support of government policies, supplied the domestic market and gradually enhanced its technological capabilities. The government had an economic rationale for supporting the industry: the national electricity demand has been increasing considerably, requiring industrial policy makers to increase national installed capacity by roughly 10% annually. Furthermore, industrial policy makers have perceived such a market as an opportunity for technological catch-up by domestic firms. MAPNA and its subsidiaries have accordingly tried to enhance their technological capabilities through supplying the domestic market. In these circumstances, MAPNA and its subsidiaries have been able to demonstrate an attractive market for the collaboration of foreign companies. The market includes both power plant construction and power plant equipment manufacturing.

Supplying the domestic market has gradually increased MAPNA Group's technological capabilities to the extent that the company has recently entered foreign markets. MAPNA's development model accounts for a domestic-oriented market model. However, it differs from the recent Korean model (regarding the mobile handset industry). The difference is that in the Korean case, the size of the domestic market was not large, but it acted as a test bed for the transition of the industry to a leadership position (Whang and Hobday, 2011). However, in the Iranian case the size of the domestic market has been important.

In the Iranian case, the large and growing domestic market contributed to improved interaction between indigenous and overseas knowledge sources. The existence of such a market enhanced the company's bargaining power in collaboration with foreign companies and facilitated knowledge flows from abroad. Furthermore, responding to the domestic market not only enhanced MAPNA's technological capabilities but also stimulated the export of both power generation equipment and power plant construction.

3.5. University-industry linkages

Universities and public research institutes have always been recognised as a significant factor in the technological catch-up of developing countries (Hobday, 1994; Fagerberg and Godinho, 2005; Lee, 2005; Malerba and Nelson, 2011; Mazzoleni and Nelson, 2007; Joo and Lee, 2009; Lee and Kang, 2010). Today's literature highlights indigenous technology development efforts, including the active role of universities and public research institutes (Mazzoleni and Nelson, 2007; Joo and Lee, 2009; Lee and Kang, 2010). The analysis of the Iranian case corroborates this trend and argues that university–industry relationships have influenced the interaction between indigenous and overseas capabilities. This case shows the relationships between MAPNA Group and domestic universities (and also other public research institutes) have contributed to the hastening of technological acquisition.

MAPNA and its subsidiaries hired domestic university experts on technology transfer projects at different phases of the process. As Fig. 2 indicates, domestic universities were engaged in technology transfer contract from the beginning of the project between MAPNA and foreign company. Domestic universities' experts, particularly in manufacturing fields, advised MAPNA to install advanced manufacturing lines. Furthermore, universities supported MAPNA and its subsidiaries by supplying educated people. The relationship between MAPNA and its subsidiaries with domestic universities increased the companies' absorptive capacity to better assimilate foreign technologies. It has also helped strengthen indigenous technology development efforts by escalating bilateral projects between MAPNA Group and universities.

3.6. Geographical agglomeration

The studies of technological catch-up, to date, have not specifically examined the role of physical proximity of latecomer firms in the technological catch-up process. This could be due to two main reasons. Firstly, in-depth analysis of technological catch-up cases has only recently increased in the literature. Secondly, the cases studied so far have been in sectors which have not tended towards clustering. In the context of this paper, cluster means the geographical agglomeration of firms operating in the same industry (Swann and Prevezer, 1996; Giuliani, 2005). There are often three main factors that attract firms to a particular location: specialised labour, specialised intermediate inputs, and spillovers of knowledge (Marshall, 1920; Swann and Prevezer, 1996). Spillovers of knowledge are the most important factor that attracts firms in high-technology industries to be clustered (Krugman, 1991; Swann and Prevezer, 1996). Swann and Prevezer (1996) added two other benefits of clustering to those mentioned: the infrastructure benefits (e.g. access to major communications networks) and informational externalities.

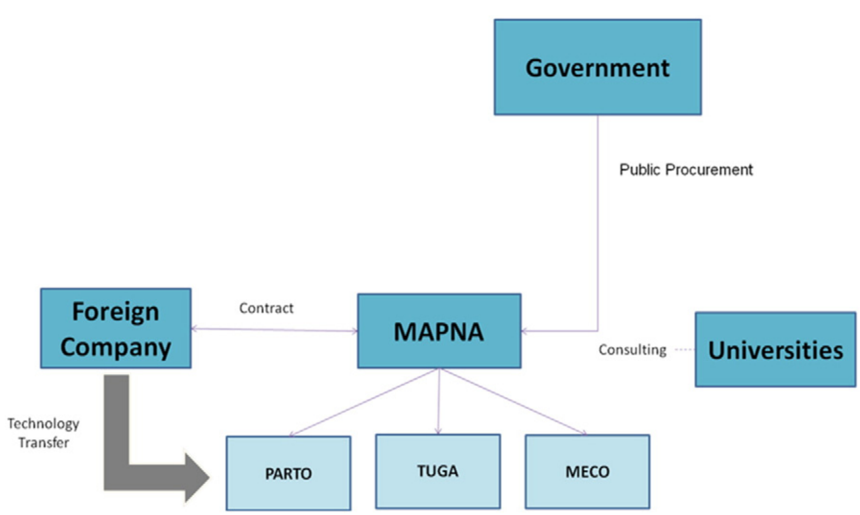

Fig. 2. Technology transfer contract between MAPNA & foreign company.

The Iranian case shows that the physical proximity of the subsidiaries was an important issue in MAPNA's success. MAPNA's subsidiaries, those manufacturing primary equipment such as turbines, generators and boilers, are agglomerated geographically. The case study shows that physical proximity among the main gas turbine equipment manufacturers – TUGA, PARTO and MECO – has facilitated their interactions. Physical proximity has contributed to the technological development of the industry in different ways. Firstly, the companies frequently interact with each other by holding regular seminars, meetings and training courses. Due to their physical proximity, the arrangement of these events is not difficult. These events are opportunities allowing people from various companies to share their knowledge and experience through face-to-face interaction. Thus knowledge flows among all parties are facilitated by their physical proximity.

Furthermore, such proximity has resulted in important local externalities by which each company is able to use these spillovers. Engineering knowledge sharing from one company to another is much easier than when companies are physically far away. The interview data show that the clustered companies often share their experiences of working with domestic and overseas sources. The relationship of one company with domestic universities or foreign companies can be useful and insightful for the other companies. Therefore, they can better deal with foreign companies and the interaction of indigenous and overseas sources is facilitated.

Thus, the facilitation of knowledge flows, spillovers of knowledge and infrastructural benefits such as networking are the main benefits of geographical agglomeration in the Iranian case.

The above line of reasoning leads to a precise and neat conclusion that although geographical agglomeration of latecomer firms may not have a direct influence on the decision to import technology and knowledge or to develop indigenously, it promotes an interactive atmosphere among latecomer firms by which they can better deal with the challenges and difficulties of technological catch-up process.

This paper argues that the literature of the technological catch-up process, to date, has paid inadequate attention to the influence of geographical agglomeration on technological catch-up processes and in particular on the interaction processes between indigenous and overseas technology/knowledge sources.

3.7. Type of technology

The evolution of gas turbine technologies has originated from multi-billion dollar military and civil programmes and other public R&D budgets (Mowery and Rosenberg, 1982; Winskel, 2002; Watson, 2004). Even outstanding innovations, such as material and coating technologies in gas turbines, first occurred in the aircraft jet engine industry. Despite the recent privatisation in few developed countries, the market still tends towards being an oligopoly, where OEM companies are reluctant to transfer technologies to the newcomers (Majidpour, 2012). In these circumstances, it is bound to be difficult to deal with foreign suppliers regarding technology transfer.

The analysis of the Iranian case corroborates this. Foreign companies have been, in most cases, interested in making turnkey agreements with Iranian companies, but have been unwilling to transfer know-how to the Iranian side. This is clearer when MAPNA Group's contracts in different technology areas are compared. For instance, the case study analysis shows that transferring technologies for steam turbines is not as challenging as for gas turbines. Steam turbines, in contrast to gas turbines, typically operate at low temperatures, and manufacturing technologies are not as advanced as for gas turbines. Likewise, interview data suggests that the transferring of other power plant equipment, such as boilers, was not as difficult as for gas turbines for MAPNA Group. Therefore, the analysis of the Iranian case shows that, other influences aside, the type of technology has influenced the interaction processes between indigenous and overseas capabilities to the extent to which transferring various technologies has not been at the same level of difficulty. In fact, among types of power plant equipment, gas turbines have been the most difficult parts with regard to foreign technology transfers. However, as explained in Section 3.2.1, MAPNA (with support of government) dealt with this issue by offering a large and aggregated project to foreign company.

It can be argued that in the case of Iran's gas turbine industry, the type of technology and the global market structure have acted as negative factors and have made a problematic situation for MAPNA's managers. This argument shares some characteristics with the argument of Radosevic (1999), who argues that firms in industrialised countries are inclined to transfer older technologies to the industrialising world. However, the Iranian case shows that the difficulty of transferral in the gas turbine industry is not about the vintage of technology but about the type of technology. The evolution of gas turbines shows that the technologies are at a mature stage.

3.8. Sanction regimes

Due to US-led sanctions, MAPNA was not able to collaborate with American companies (such as GE), as one of the main foreign technology sources. One of the interviewees commented that:

“Compared to other foreign companies, GE's products had higher quality and lower prices but we couldn't work with them due to US-led sanctions.”

Obviously, the direct effect of sanctions on domestic industries has been to limit their access to foreign knowledge and expertise. This factor has hindered the speed of the technological catch-up process, as the interaction between indigenous and foreign expertise were not as easy as under normal conditions.

The second drawback of the sanctions on Iranian firms has been the additional cost of technological acquisition. According to the interview data, MAPNA managers believe that GE's prices are lower than other suppliers and that GE's quality is better in some technological areas. Furthermore, as the lead companies in the gas turbine industry are limited in number, and since US-led sanctions prevented GE from collaborating with MAPNA Group, the bargaining power of MAPNA Group was weakened.

These two factors were observed in the Iranian case as the negative consequences on the industry of the US-led sanctions. They can be clearly interpreted as unconstructive influences on technological catch-up as they are in contrast with the general assumption of the technological catch-up concept in which successful cases have greatly benefited from overseas knowledge.

The analysis of the Iranian case definitely does not refute this general idea; however, it reveals a different type of access to foreign knowledge with a different perspective and in a dissimilar influential context. Furthermore, this case has shown that the sanction situation has had other consequences which might be interpreted as positive outcomes. The sanctions strengthened the determination of the industry authorities. They enacted further supportive policies and inspired such determination in the firms' managers. Accordingly, MAPNA promoted indigenous technology developments and made serious efforts to reinforce indigenous capability buildings. Likewise, MAPNA and its subsidiaries intensified intra-firm knowledge acquisition processes. Similarly, the sanctions led to the formation of R&D in MAPNA and its subsidiaries. It is worth noting that the acquisition of indigenous technological and scientific capabilities - due to changing conditions — have become, and will continue to become, of ever greater importance for catching-up countries (Mazzoleni and Nelson, 2007). Therefore, intensifying indigenous technology capability building efforts has a positive effect on technological catch-up process.

The case analysis has revealed that it is not easy or straightforward to judge whether the sanctions hamper or hasten the technological catch-up process. Instead, it is more accurate to conclude that while sanctions have undoubtedly jeopardised access to foreign knowledge (mainly US sources in the Iranian case) and may have imposed additional costs, they may simultaneously stimulate motivations to intensify indigenous efforts to acquire technology (Majidpour, 2013).

4. Summary and concluding remarks

As explained in Section 2.2, the matrix (Table 1) was operationalized in the case of this paper. The framework of influencing factors in the context of this study was shown in Table 3.

As Table 3 shows, a number of influencing factors corroborate the findings of the literature, while others contribute new insights to the literature. Sanction regimes, type of contract, the type of technology and geographical agglomeration are new insights that have been introduced by this study to technological catch-up and in particular to the substitution/complementary literature. Furthermore, the distinctive features of MAPNA's contractual terms with foreign companies as well as the size and orientation of the domestic market are influences that have rarely been touched upon in the literature. The remaining factors have been discussed in the literature, and the findings of this study corroborate them. However, the status of intellectual property rights regimes is the only factor discussed in the literature which was not observed as a factor in MAPNA technological development.

Furthermore, the influences can be split into two parts in the context of interaction processes between indigenous and overseas technology sources. The first influences observed have had a direct effect on these processes. US-led sanctions, the type of technology, the type of cross-border contracts and continuous engagement in the interactions with foreign technology sources are the influences which may directly strengthen or weaken indigenous and overseas interactions.

The second group of influences has had an indirect effect, though they are not less important than the direct influences. Government policies, university-industry linkages, the size of the domestic market, the latecomer firm's absorptive capacity and geographical agglomeration have had indirect effects in the interactions. These influences have played supportive roles in the Iranian case. For instance, MAPNA, with the support of government policies, has been able to better deal with foreign technology sources in order to catch up. Similarly, its relationship with domestic universities and other public research institutes has enhanced MAPNA's absorptive capacity and hastened the technological acquisition process

The Iranian case shows that there is a dynamic relationship between these influencing factors. For instance, government policies on one hand have provided a domestic market, and supplying such a large market has enhanced MAPNA's technological capabilities. On the other hand, these policies have been indirectly related to MAPNA's interactions with domestic universities. This argument confirms the existence of a dynamic relationship among the factors in technological catch-up, as Malerba and Nelson (2011) comment: "often one factor alone cannot trigger catch-up unless other factors are present, and they feedback on each other" (2007, p 19).

The paper has emphasised that in order to have a deeper understanding of the interaction processes between the two main knowledge sources, a new perspective should be developed. This paper suggests the dynamic approach. 'Dynamic approach' in this paper refers to a synthesis of indigenous expertise and imported knowledge in a dynamic manner; that is to say, the two parts of this tango should constantly interact with each other to produce richer expertise to deal with the ongoing development of technological methods and procedures as well as the materials and ways of shaping them. In this way, the practitioners who invoke this approach constantly try to improve their own technical knowledge in the light of what they learn from the imported know-how, as well as through the experiences and enlightenment they gain from their own indigenous tradition. Therefore, the best way forward is in constant interaction with the latest developments while 'synthesising' them with indigenous ideas. This process is certainly an ongoing

Table 3
The Framework of Explored Factors in the Case Study

	Factors in the case	How influenced?	Direct or indirect influence
Internal factors (firm level)	Technological capability and absorptive capacity	The domestic firm had practised assembling and constructed a basic level of technological capabilities before entering the cross-border technology transfer. Its absorptive capacity was not static but has continuously enhanced during the technology transfer project. Indigenous capability building efforts have positively enabled domestic firm to better assimilate foreign technologies.	Indirect
	Continuous interactions with foreign players	The model of collaboration between MAPNA and foreign source was based on Co-manufacturing. The evidence suggests that MAPNA could manage to interact continuously and constructively with foreign partner.	Direct
	Type of contract	The domestic firm with the help of government designed an effective type of technology transfer contract in order to deal with the acquisition of advanced technologies. This finding highlights the role of type of contract in latecomer firms' technological development (rarely touched upon in the literature).	Direct
External factors (industry, national and global level)	Government policies	Government mainly conducted public procurement policy. Government also granted large projects to the domestic firm to facilitate domestic firm's interactions with foreign partners.	Indirect
	Sanctions	Sanctions jeopardised access to the US technology sources and have imposed additional costs; however, they stimulate motivations to intensify indigenous efforts to acquire technology. This finding provides new insights to latecomer firms' growth literature.	Direct
	Size and orientation of markets	Due to a large and growing domestic market, the government had economic rationale to support the domestic firm. Responding to the domestic market not only enhanced MAPNA's technological capabilities but also stimulated the export. This is in tandem with Brazil and Chinese cases.	Indirect
	Geographical agglomeration	Geographical agglomeration of MAPNA's subsidiaries had promoted an interactive atmosphere by which they can better deal with the challenges and difficulties of technological development. This finding adds new insights to the literature of international technology transfer particularly in acquisition of CoPS technologies.	Indirect
	Type of technology	Acquisition of advanced technologies, particularly in concentrated markets, can make problematic circumstances for latecomer firm to interact with foreign technology owners. This paper suggests that government plays a key role to deal with these difficulties.	Direct
	Universities and public research institutes	Domestic universities engaged in technology transfer projects from the beginning of the project and their involvement increased during the domestic firm's growth.	Indirect

Note: Some of factors are at various levels. For instance, although type of contract relates to technology owner and technology recipient negotiations and is perceived as firm level factor, in the Iranian case the domestic firm with support of government designed an effective type of contract. Similarly, university-industry linkage is also an influence at all levels, though it is shown at the industry and national levels influences.

and never-ending process, which should be passed from one generation of indigenous experts to another. However, this process is a very complex one and thus the dynamic approach suggests focusing on challenges, difficulties and influencing factors rather than examining the type of relationship.

Dealing with multiple levels of factors often requires different angles of vision in different periods of history. These factors form the context, in that latecomer firms act in a highly sophisticated, changeable, and unpredictable context. A latecomer firm may face various situations within which many external influences exist which might be beyond the will or power of managers. However, these factors should still be recognised, understood and dealt with.

The corollary of this position is that the interaction processes between indigenous and overseas technology sources cannot be reduced to the study of the type of relationship. Today, it is not enough to argue that there is a complementary relationship between these two technology or knowledge sources; instead, understanding the dynamics and the complexity is much more important. Far more attention needs to be devoted to what factors are important in the different contexts and how these factors affect the technological development of different firms across different industries and in different countries. Nevertheless, this study argues that the dynamic approach should be considered from research design stage in which the methods are specified for the research. Most previous studies have used quantitative approaches, mostly through survey analysis. However, in order to reach a deep understanding of the phenomena, the methods should be different from the traditional literature, which has focused on studying the type of relationship between indigenous and overseas technology sources. Perspectives and methodologies also need to be able to reveal the influencing factors across international, national, sectoral and firm levels. This paper suggests operationalizing case studies in different countries across different industrial sectors with the dynamic approach.

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