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Contextual Variables Affecting Technology Planning at Industry Level

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Abstract

Technology is used and improved by companies and needs to be managed -like any other resources- at corporate level. But, its management at supra-firm level is also necessary since technology plays a crucial role in national competitiveness and wealth creation. Regarding different characteristics and context of industries, such as dissimilarities in convergences and/or the degree of fragmentation or integration, the process and content of technology planning vary from one industry to another. In this paper, a set of contextual variables are identified which affect the process of Technology Planning at Industry Level (TPIL). TPIL process deals with selecting and prioritizing key technology areas of a particular industry.

A qualitative approach based on the grounded theory methodology has been applied. In this methodology, the researchers start with minimalist prior constructs deep into a substantive issue (contextual variables affecting TPIL in this case) and interactively tests and forms theoretical constructs. For this purpose, a series of semi-structured interviews were organized and accomplished with top and middle managers in Oil & Gas, automotive and aerospace industries of Iran. Some of university faculty members having experience in TPIL were also interviewed.

Based on forty interviews, 469 initial codes, 221 final codes, 70 categories and 14 themes were explored. Among them, velocity and intensity of industry context, competitive dynamic, industry structure, technology regime, actual and potential importance (priority) of industry in development plan of country are identified as the contextual variables which influence TPIL process. This study helps policy makers, managers and experts of technology planning, at sector or industry level, to take in account the industry characteristics in selecting the appropriate process and method of TPIL.

Keywords: *Technology Planning, Industry Level, Contextual Variables, Grounded Theory, Thematic Analysis.*

1. Introduction

Technology is defined as the practical implementation of knowledge and experience in the form of products, services and operation process to respond human endeavors. Technology is used and improved by companies and needs to be managed -like any other resources- at firm level. Management of technology (MOT) is concerned with planning, directing, control and coordination of technological capabilities to shape and achieve targeted objectives (NRC, 1987). Owing to the fact that technology has a crucial role in national prosperity and security as well, its management at supra-firm level is valid and compulsory. At supra-firm level, strategies are crafted for a group of firms and/or organizations, including for- profit, public, governmental, and non-governmental organizations (Hooshangi *et al.*, 2008). These strategies can be classified at three levels; National level (Chandler and Alfred,_1969), Sectoral level (Best, 1986) and Network level (Wet & Meyer, 2010).

Sectoral-level consists of a particular industry (such as oil & gas, automotive and aerospace) or a technology area (such as ICT or Bio Tech). Industry, as a network of firms producing related goods and/or services, plays a key role in countries' economy. Having a specific and appropriate policy (strategy) for each industry is crucial for growth and competitiveness. The key role of technology in enhancement of industry competitiveness emphasizes the necessity of technology strategy at industry-level. Technology planning at industry level (TPIL) -like other planning processes- is influenced by its internal and external context which should be addressed. Lack of knowledge about variables and forces, which influence the industry, leads policy makers and industry managers to invest on less strategic technology areas, which decrease competitiveness and total productivity of industry value chain. Regarding different characteristics and context of industries, such as dissimilarities in convergences and/or the degree of fragmentation or integration, the process and content of technology planning vary from one industry to another. Review of academic studies and practitioners works indicate that during past decades, many scholars have tried to develop methods and tools for technology planning and technology foresight (Phaal and Muller, 2011; Albright and Kappel, 2003; McMillan, 2003; Keenan, 2003) apt to prioritize the core technology areas of industries (e.g. kostoff and Schaller, 2001; Phaal, 2002).These studies which primarily have employed technology road map (TRM) technique, simply focus on environmental drivers and trends, and do not cite clearly other affecting variables especially those relate with internal context of the industry. The importance of environmental elements in technology strategizing (Spital and Bickford, 1992), and the crucial role of context foresight as the starting point of technology strategy formulation (Chiesa, 2001) stress having knowledge regarding contextual variables affecting technology planning. At supra-firm level, identification of these variables becomes much more critical because of structural complexity and ever-changing evolution of exploited technologies in different segments of a concerned industry. The research question of this paper, which states a part of our study- describing major elements of TPIL, is: what are the affecting variables influencing TPIL?. For answering this question grounded theory method based on paradigm model approach (Strauss and Corbin, 1998) was conducted. Results of this paper classified in intervening and contextual variables assist industry policy makers, managers and experts to take in account them, as well as industry characteristics, in selecting an appropriate process and method for TPIL. Moreover, it helps them to formulate effective technological priorities at industry level by better evaluation of contextual forces. Following this introduction, Section 2 reviews the literature. The next
section defines the research methodology. Section 4 is devoted to data analysis. Results are discussed in section 5, and the work end with a conclusions and possible future lines of research.

2. Literature review

2.1. Technology Planning at Industry Level (TPIL)

MOT which is defined as an interdisciplinary field integrating science, engineering and management knowledge and practice, has two major perspectives: micro/firm-level and macro/supra-firm level (Khalil, 2000). From a macro-level perspective, MOT can be defined as a field of knowledge concerned with the setting and implementation of policies to deal with technological development and utilization. The impact of technology on society, organizations, individual and environment is evaluated and taken in account for policy making (Khalil, 1993). Technology planning is thus about proactively shaping of technological capabilities and leading activities regarding technology development and diffusion. Policy makers have therefore to select key areas of focus for development and strategic actions to pursue their diffusion and commercialization (Geels, 2005). The nature of decisions and the process of policy making are influenced by the context of industry.

2.2. Variables affecting TPIL

Hooshangi et al. (2013) explored contextual factors affecting R&D strategy of Iran's power industry. Among them, strong dominance of governmental ownership, existence of several research organizations and governmental funding challenges are identified. UK Foresight Vehicle was conducted as collaboration between industry, government and university to identify and demonstrate technologies supporting UK industry in the globally competitive market for transport products and to provide sustainable mobility for UK citizens (Phaal, 2002). This work addresses six major themes which influence TPIL, such as social, economic, environmental, technological and infrastructural trends and derivers.
AAI[1] (1997) set forth long-term vision of how United States Aluminum Industry maintain and build its competitive position. Therefore, a TRM was developed to provide the critical link between defined strategic goals and the research portfolio, which should be persuaded through cooperative R&D partnerships. In this study, energy costs, oversupply in world market, government regulation as well as public policy and economic structure were considered as affecting issues. DOE & ETL (2000) defined strategic technology areas of United States Gas industry. In this work four major contextual variables were mentioned like, market and customer growth, national regulations and policies, technology development and environmental issues. CTT (2008) report shows that the Canadian Textile Industry prepared a twenty-year strategy known as the Technology Roadmap to determine its future positioning. In this study, human resource, production, commercialization, finance, research & development and government support are perceived as contextual variables. ASC[2] (2000) prepared a vision of how United States Chemical industry meets its competitive challenges through the year 2020 with the support of a group comprised of key individuals from industry, government and academic institutions. In this study, contextual variables were considered in two classifications, such as technology opportunities and market opportunities. The UK automotive industry through its vision to became competitive, growing, and dynamic; in order to make a large and increasing contribution to employment and prosperity in the UK (NAIGT, 2009), developed its technology plan. This sector-level TRM mentioned five key success factors that affect the process of technology planning such as, support of government, industry coordination, critical mass or scale for operation, availability of skills and integrated supply chain.

[1] - Aluminum Association Inc.
[2] - American Chemical Society

3. Methodology

Concerning the research question a qualitative approach has been applied, and grounded theory (GT) methodology (Strauss & Corbin, 1998), which is one of the most suited inductive research strategies in empirical research (Melnyk & Handfield, 1998) was employed. GT methodology encompasses joint collection as well as coding and analysis of data in the underlying operation (Glaser and Strauss, 1967). It essentially attempts to explore, develop and generalize formulations about features of a particular phenomenon while simultaneously it grounds the account in empirical observations or data (Martin & Turner, 1986). Therefore, it needs a cyclical pattern of data collection, coding, theory generation, reflection and comparison with other data sources and concepts for testing purpose (Douglas, 2003). Application of GT in the research fields which lack substantive theory is one of its main advantages (Seidel & Recker, 2009). This methodology is primarily conducted based on two major principles. First, the process of theory building is highly iterative as a comparative analysis. Second, GT is built upon a theoretical sampling, which is a process of data collection and analysis. This methodology is driven by concepts emerged from the study. Moreover, it appears to be of relevance to the nascent theory (Strauss & Corbin, 1998). There are two main streams of exploiting GT: 1) Glaser & Strauss (1967) introduced it as a general qualitative research methodology concluding two level of coding, first into as many categories as possible and then integration of categories; 2) study of Strauss & Corbin (1998) revised it by proposing paradigm model and using three level of coding. In this study, data analysis process was conducted based on Strauss & Corbin (1998) proposed method including open, axial and selective coding.

4.Data Analysis

Glaser and Strauss (1967) encourage researchers conducting GT methodology to use multiple data collection techniques since it allows considering multiple viewpoints from which an emerging concept can be analyzed, substantiated, and developed. Consequently, data collection process in this work involved semi-structured interviews and document analysis. In order to prevent from digressing in interview process, an interview protocol was designed and employed. Forty semi-structured interviews with selected top and middle level managers of Iranian Oil &Gas, Auto making industries and Aerospace sector were setup; Furthermore, some interviews were conducted with university faculty members having relevant experience in TPIL.

4.1.Open Coding

Open coding is a micro analysis (Strauss & Corbin, 1998) employed to identify initial codes describing the phenomenon- contextual variables affecting TPIL in our research. In this stage, a line by line analysis of transcribed interviews is conducted to explore initial codes, which are unit of analysis of theory building. In this study, 469 initial codes were explored based on precisely review of forty transcribed interviews. After that, among explored codes, 221 final codes which were repeated or emphasized by interviewees or were noteworthy based on researches viewpoints were selected. Table 1 shows some of the explored initial codes detected in open coding process.

Table 1
Some of explored initial codes detected in open coding process

Transcribed interview	***Initial codes***
The circumstance of a country and its national policies affect industry technology planning. Furthermore, structural attributes of under- planned industry is also considerable. For instance, whether the sector position would be at upstream or downstream of industry value system, it affects TPIL. Existence of required national/governmental- plans and/or policies accelerates and simplifies TPIL. In addition, tendency of experts to participate in TPIL is rather necessary; Moreover, existence of a process owner and commitment of industry top managers to determine critical decisions in technology strategizing are crucial.	▪ Industry structural attributes ▪ National- level plans ▪ Country policies ▪ Experts commitment ▪ Existence of process owner ▪ Disparity of industry sectors
Unclear understanding of planning at supra-firm level, absence of integrated industrial policies and/or strategies and international forces like sanctions influence TPIL. Trust level between actors of industry value chain and the collaboration history among them also are rather important. Industry structural characteristics and its maturity level affect the process of technology planning at industry level.	▪ Industrial policies ▪ International context forces ▪ Trust in industry network ▪ Collaboration history ▪ Industry value chain ▪ Industry maturity level
Complexity of exploited technologies in the value chain of industry is very important; Furthermore, macro policies of industry should be perceived in TPIL. The state of sectoral innovation system (SIS) also affects the process of industry technology planning. In addition, government's policies in assistance of selected industries influence TPIL.	▪ Technology complexity ▪ Industry macro policies ▪ SIS attributes ▪ Government policies ▪ Backing level by government
The country state at the time of planning is very important. Moreover, the fact that industry origins are internal or external is also considerable. Country foreign policies in international context have major influence on TPIL.	▪ Country state & policies ▪ Time of planning ▪ Industry origin
Identifying drivers of technology development, access of needed information for planning and conditions which influence acquisition of technology resources affect TPIL. In addition, having access to experts and familiarity of them with planning concepts and tools are rather important in TPIL. Readiness of industry network for entering to planning process and availability of financial resources are crucial.	▪ Discern of technology drivers ▪ Availability of needed information ▪ Readiness of industry network ▪ Availability of needed resources

4.2.Axial coding

Axial coding is the second stage of data analyzing process in GT. This intermediate coding is conducted to develop main categories by interconnecting and clustering related final codes. In other words, axial coding links structure to the process of data generation. In this work, 70 categories were developed. Table 2 demonstrates some of these major categories.

Table 2
Some of developed categories in axial coding

Final codes	categories	Final codes	categories
Industry centralization level	Structural attributes of industry	Readiness of industry for TPIL	Involvement of industry experts
Industry complexity level		Tendency & commitment of experts	
Industry integration level		Richness of needed information	
balance of different sectors of industry		Strength and integration of industry's SIS	Communication between industry's SIS actors
		Tendency of SIS's elements for collaboration in TPIL	
Diversification of industry sectors		Quality of information flow through SIS actors	
Centralization level of R&D in industry value system	Structural attributes of	Overlaps between SIS's actors	

Diversification of decision making in the field of R&D	industry's R&D activities	Priority of industry development in national policies	National priorities in industrial sector
		Relationship of industry with national competitiveness	
Information flow in the field of R&D		Industry's development model	
Complexity of industry's critical technologies	Complexity of technology	Strategies of Knowledge & technology suppliers	Strategy variation of technology suppliers
Resources of innovation		Tendency of technology and knowledge owners for cooperation	
Position of industries' critical technologies in their life cycle		Country's political situation in international context	Country's International context & its foreign policies
		Stability and complexity of external environment of industry	
The impact of technology on industry's value system	Impact of technology on industry	Possibility of technology collaboration	
		Bases of industry development	Roots of industry forming
Diversification of technological requirements in dissimilar sectors		Basic requirements of industry forming	
		Attributes of industry's customers	
The impact of technology on industry performance		Position of industry in its own life cycle	Industry's maturity level
		Industry's history	
industry's culture in the operation field	Cultural dimensions	Industry's absorptive capacity	
Culture of utilization & development of technology		Intensity of competition	Key elements and pattern of competition
		KSFs of industry	
Decision making process in the field of R&D	Process-oriented complexity	Accompany of industry's operational body with its R&D activities	Supporting of industry network
Rate of reevaluation of plans during execution and resource allocation phases		Infrastructures quality of industry's technology management & development	
Timing of technology development		Quality of cooperation in industry network	

4.3.Selective coding

The final analytical phase is selective coding which identifies the main categories or themes. In this phase, explored themes are connected to other categories systematically, and the connections are validated. In addition, categories which need refinement are developed. Analytical activities of this stage are not distinctively separate from each other. however, they are taken through an interactive process along with axial and open coding. In selective coding themes which are at higher level of abstraction are developed to integrate other categories. In this study, 14 themes were explored (Table 3).

Table 3
Contextual variables influencing TPIL

Context variables	Intervening variables
industry structure	velocity and intensity of national context
technology regime	
industry development level	velocity and intensity of international context
Complexity of planning at industry level	
effectiveness of governmental policies	priority of technology development at national level
Attributes and performance of industry SIS[1]	
Industry advantages	industry capability in TPIL
commitment of industry experts	
Supporting systems	dynamism of competition

[1] - Sectoral Innovation System (SIS)

To assess trustworthiness of results, nine criteria suggested by literature of interpretive research and grounded theory were applied. From interpretive approach, criteria such as credibility, transferability, dependability, conformability and integrity were focused (Hirschman, 1986; Lincoln and Guba, 1985; Wallendorf *et al*., 1989). In addition, fit, understanding, generality and control were employed based on GT literature (Strauss and Corbin, 1990). As demonstrated in table 4, we believe that rigor and relevance criteria (Gordon, 2008) of our study were met.

Table 4
Validity of the Study and Findings: Interpretive and Grounded Theory Criteria

Validity Criteria	**Criteria focus** (Flint *et al*., 2002)	**Addressing approach in this study**
Credibility	Extent to which the results appear to be acceptable representations of the data.	Interviews were conducted five months 19-page summary of initial interpretations was provided to the participants for feedback.
Transferability	Extent to which findings from one study in one context will apply to other contexts.	Theoretical sampling.
Dependability	Extent to which the findings are unique to time and place; the stability or consistency of explanations.	Participants had on many experiences covering recent events as well as past events.
Conformability	Extent to which interpretations are the result of the participants and the phenomenon as opposed to researcher biases.	More than 140 pages of interpretations and documents analyzed independently
Integrity	Extent to which interpretations are influenced by misinformation or evasions by participants.	Interviews were conducted professionally, with nonthreatening nature, and anonymous.
Fit	Extent to which findings fit with the substantive area under investigation.	Addressed through the methods used to address credibility, dependability, and conformability
Understanding	Extent to which participants buy into results as possible representations of their worlds.	Executive summary of findings to participants; asked if they reflected their stories. Presented a summary to practitioners.
Generality	Extent to which findings discover multiple aspects of the phenomenon.	Interviews had sufficient time and openness to elicit complex dimensions of phenomenon
Control	Extent to which organizations can influence aspects of the theory.	Some variables within the theory have aspects, which participants would have some degree of control.

5. Results and Discussion

In this study, fourteen themes were explored. Based on Strauss and Corbin (1998) paradigm approach, the results have been classified as context and intervening variables. Nine themes mostly related to industry characteristics and nature of planning at supra-firm level shape context variables; moreover, five themes emphasizing the dynamics of external and internal environment construct intervening variables.

Among context themes, industry structure concerns with structural characteristics, like fragmentation, convergence, vertical and horizontal integration level of industry value chain; moreover, structural attributes of industry R&D field, like centralization degree in technology development are considerable. In addition, Technology regime of an industry affects the TPIL process. Complexity and diversification of exploited technologies in industry value chain as well as their impact on industry performance are some variables, which are emphasized in this theme. Industry development level is another context variable which has crucial effect on TPIL. Complexity of planning triggered by high level of diversification of technological requirements, in addition to complexity of exploited processes, is a challenging issue in technology planning at supra-firm level. Governmental policies are one of the major inputs of TPIL, which must be supported by industry technology strategy. Hence, the effectiveness of these upper policies is so crucial for successfulness of TPIL. Attributes and performance of sectoral innovation system (SIS) such as the characteristics of its constructing elements and quality of interactions between them impact TPIL. Industries advantages derived from some key issues, like national potentials and industry comparative advantages as well as the broadness of industry activities, also affects TPIL. An integrated TPIL needs commitment of experts with diversified knowledge and skills which should be selected from different sectors of industry value chain as well as constructing elements of related SIS. Existence of supporting systems, which are derived from industry body, increases effectiveness of TPIL. Supporting systems in R&D activities, as well as proper allocation of resources, motivation-oriented, and authority- oriented backing are some instances in this case.

On the other hand five themes explored as intervening variables like, velocity and intensity of national context such as changes in national policies, fluctuations in economic conditions and revising industry upper strategies as well as demand forces affect TPIL. Similarly, velocity and intensity of international context influences TPIL. For instance, changes in foreign technology supplier strategies as well as their tendency to cooperate and the quality of international relationships are considerable. Priority of technology development in the upper strategies of industry is so crucial, which relates to technological, operational and altitudinal facts. Existence of needed capability for the purpose of technology strategizing at industry level is rather critical for achievement of TPIL. There are some variables that shape and affect this capability such as human resource competence, process-oriented variables as well as analytical and cognitive facts. Dynamism of competition is also a critical variable which must be considered in TPIL.

6. Conclusions

In this paper, we have attempted to clearly identify contextual variables affecting technology planning at supra-firm level. In previous works- mostly done by industry’s practitioners, some limited variables, which generally concern external context, in evaluation phase of TPIL, are simply perceived without any classification. In this study, we employed GT method to deeply concentrate on both internal and external variables and forces influencing TPIL. Based on paradigm approach, final themes are classified in two groups such as, contextual and intervening classifications. Contextual themes such as, technology regime and industry development level, mostly concern about internal context of an industry while intervening variables such as, velocity and intensity of national and international context, mostly regard to outer context and contain much more dynamism. From importance point of view, among identified variables, industry’s structural characteristics, development level and advantages as well as industry capability in TPIL seem to have considerable effect on technology planning at supra-firm level.

This research has three major implications for managers and policy makers dealing with TPIL. First, configuration of technology planning process in different industries/sectors should be developed in a way that it could effectively respond to diversified variables affecting TPIL process. Moreover, different experts should be invited in dissimilar panels to support above mentioned diversity and complexity. Second, in order to effective technology strategizing at supra-firm level, industry’s nature and attributes must be perceived precisely. In addition, the process owner of TPIL must attempt to increase the support of industry and SIS networks. Third, regarding considerable effect of upper policies and strategies, before starting TPIL , documents concerning industry and national strategies and policies must be reviewed in order to explore their technological requirements completely. Although this study has sought to address variables influencing technology planning at supra-firm level, some limitations remain. First, with regard to methodological aspects, this work has studied three Iranian industries such as: oil & gas, auto making and aerospace industries, so future studies could usefully concentrate on other industries. Second, this work focused on identification of affecting variables. Thus, one of the future lines of research would be to determine affecting weights of variables with regard to differences of understudied industry.

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