RESEARCH NOTE

Impact of Technological Innovation on Growth Trajectory of Enterprise's Technological Capability: A Theoretical Analysis

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Abstract

Based on the literature of technological innovation (TI) and enterprise's technological capabilities (ETCs), this paper explains the growth trajectory of ETCs characterised "spiral-platform" by knowledge flow, product upgrading, and their harmonious relationship. Following this, the paper analyses the taxonomy of TI and investigates the radical, incremental and disruptive effects of different TI on the growth trajectory of ETCs based on the resource-based view, evolutionary and heterogeneity viewpoints. It suggests theoretically that different TI will have different influence on the growth trajectories of ETCs for incumbents and entrants. Finally, it discusses some organisational determinants such as technology roadmaps, enterprise learning, enterprise culture as well as organisational structure, which have influence on both TI and ETCs.

Key Words: Technological innovation; enterprise's technological capabilities; growth trajectory.

As competition intensifies, the pursuit of innovation becomes vital to enterprises achieving competitive advantage in dynamic, technology-based industries (Eisenhardt and Martin, 2000). Schumpeter proposed five types of innovation: product, process, method, market, and organisation. Apparently, technological innovation (TI) is only one part of innovation, including the application of new technologies urging the changes of products, services, and methods to generate product and service (Damanpour, 1987). So, TI is defined as a process in which new technologies are integrated into the development of new product or new process (Stock et al, 2002).

Industries' and enterprises' competitive advantages engendered by TI may depend upon some organisational capabilities (for example, marketing skill and effective operation) (Nelson, 1991). Enterprise's technological capabilities (ETCs),

as one kind of organisational capabilities, are related to technological assets, skills and knowhow, which enables enterprises to carry out their activities (Acha, 2000). Thus, ETCs are the base for carrying out TI to a certain extent.

Over the past decade, ETCs have been gradually regarded as an important strategic resource, which enables enterprises to achieve competitive advantage within their industry (Pietrobelli, 2000). However, not all enterprises with above average TCs have outstanding performance above the industry average (Teece et al, 1997). This indicates that there may be some macro- and micro- conditions necessary for ETCs to play a role. Some literature argued that there exists certain relationship between TI and ETCs. For example, Reed and Walsh (2002) are of the view that ETCs are composed of clusters of TI associated with different waves of industrial development, and embody TI as well as some understanding of the requirement of impending technologies. Kim (1997) says that ETCs enable people to create new technologies, which underpin the development of new products and new processes. Furthermore, the study on TI in enterprises resulted in the demand of studies on ETCs (An, 2002). Apparently, the relationship between TI and ETCs is important for the development of ETCs.

According to the resource-based view (RBV), any set of resources available for enterprises to support competition are finite and can be outdated or used up finally without recruitment (Ahuja and Katila, 2004). So it is necessary for enterprises to respond to idiosyncratic problems and opportunities created by resource scarcity through taking some paths. The path for enterprises to supplement TCs is to depend on ETCs' continuous acquisition and sustenance of growth (Wei, 2002). The process of ETCs' acquisition characterises substantive uncertainties related to what can affect enterprises to acquire TCs, how long ETCs will grow and whether their efforts will be successful (Battisti and Pietrobelli, 2000).

Since ETCs discussed here are mainly confined within enterprises, it is inevitable to deal with some organisational issues related to our work. For example, organisational structure and development stages probably affect acquisition of ETCs (George, 2004) and facilitate or impede enterprises' efforts to realise TI (Christensen and Rosenbloom,1995). Their abilities to acquire ETCs or to develop TI rest on organisational principles, communication channels and information-processing procedures (for example, Kogut and Zander, 1992).

This study aims: 1) to extend our understanding of the change of the growth trajectory of ETCs with the influence of TI in enterprises and 2) To further discuss how organisational determinants affects TI and ETCs, because organisational discrepancy can affect uncertainty of TI and acquisition of ETCs (Teece, 1996).

The remainder of this paper is organised as follows. The next section provides an overview of the previous studies of TI and ETCs, followed by the dis-

cussion of the connotation of the growth trajectory of ETCs. It argues the influences of TI on the growth trajectory of ETCs based on the taxonomy of TI. Some organisational determinants, which have influence on TI and ETCs, are presented in the penultimate section

Review of the Literature

Technological Innovation (TI)

The major research streams on TI have focused on new recognition and diffusion of TI (Pietrobelli, 2000). One research stream argues that TI is a specialised process, which involves basic and applied research, product development, manufacture, marketing, selling, and serving as well as the inclination of the adoption of TI (Damanpour, 1991). The process of TI is carried out by individuals or groups at the micro-level (Kogut and Zander, 1992) in order to build accumulative knowledge through the process of engendering, integrating, and modulating (Johnson, 1992). Therefore, it is likely to consider TI as a process associated with constitution and culture characterising dynamic interaction (Balthasa et al, 2000), or a result reiterative negotiation among different relevant groups (Nieto, 2003).

Another research stream focuses on factors influencing TI, and they deal with extensive provinces such as organisational change, manpower, communication, and technological complexity. Some significant studies include:

(1) The mixed organisational framework, potentially advances enterprises to achieve technologies and possibly meet the cost and programmed deadline than other forms (Marquis, 1969).
(2) Individual communication has positive influence on successful TI (Balthasar et al, 2000).
(3) Technological framework mainly focuses on improving the regulating tools to promote the efficiency of the system of TI (Tassey, 1996).
(4) Different types of knowledge spillovers probably inspire new research projects or new applications and cause new knowledge to be used (Kumaresan and Miyazaki, 2002; Bertola et al, 2003).

The third research stream mainly involves two aspects. One is understanding of TI engendered by environment change. For example, Jones (2003) asserted that enterprises had different performance after TI was introduced into enterprises, and Afuah (2004) claimed that incumbents and entrants differ in the timing of the introduction of new technologies. Some theories emerging in recent decades are employed in the investigation of TI. They include:

(1) Strategic management was introduced to exploit the determinants of the research endeavours of enterprises (Beneito, 2003).

(2) RBV is used to explain the positive association between enterprises and others, such as competitors, are important resources of TI (Ahuja, 1996; Afuah, 2000). They provide theoretical foundation that TI is often achieved through the combination and recombination of existing elements with novel artifacts (Hargadon and Douglas, 2001).
(3) The evolutionary viewpoint describes TI as an evolutionary process (Lewens, 2002).
(4) The heterogeneity theory explains that the ability of an enterprise to continuously implement TI derives from heterogeneous resources, which is generated to respond to idiosyncratic situations faced by enterprises (Ahuja and Katila, 2004).

Enterprise Technological Capabilities (ETC)

With attention on the internal mechanism of the rapid development of industries in new industrialised countries, many studies on ETCs focus on the concept, mechanism, research method, and development process at the macro- and micro-levels (Cassiman, 2000). As a whole, the literature focused on two research directions: one direction relates to the influence of TCs, and the other concentrates on the development of TCs.

The direction related to the influence of TCs on enterprises' performance has been widely articulated. Lieberman and Montgomery (1988) viewed that ETCs could raise the likelihood of reaping pioneering advantages. Karlsson and Ahlstrom (1999) suggested that the realisation of advantages engendered by ETCs should be attributed to ETCs accelerating the pace of new product developments and process innovation. Considering some variables such as technological creation, technological infrastructure, and skills development, Coco and Archibugi (2004) suggested the positive relationship between ETCs and the enterprises' performance. Furthermore, Kuen-Hung (2004) proposed that the impact of ETCs on productivity growth performance is greater than that of other conventional factors. When the growth TCs is based on resources heterogeneity, it can lead an enterprise to heterogeneous competitive positions (Knott, 2003).

The other research direction that emerged in recent decades focused on the growth of ETCs. Some studies investigated growth models of ETCs such as two-stage model from technology transfer to technology development (Jai, 1988), three-stage model including acquirement, assimilation, and improvement (Kim, 1997) and four-level model of assemblage, modulation and indigenousness of components, product redesign, and self-sustaining product design (Leonard-Barton, 1995). Other studies focused on factors which influence TCs growth. For example, Prencipe (2000) proposed that ETCs grow along two dimensions

of breadth and depth and the need for trade-off between the two dimensions is likely to be amplified in enterprises where resource is limited. These resource constraints may force enterprises to choose between further deepening their existing ETCs and broadening their capabilities without necessarily knowing which route would enhance enterprises' value or performance (George, 2004). Ahuja and Katila (2004) proposed that through science or geography search, enterprises can obtain resources heterogeneity, which will counteract the influence of resources scarcity and help them to acquire particular TCs.

In addition, there are substantive factors, which have beneficial effect on the growth of TCs, such as (1) alliances, including enterprise' co-opetitors (Afuah, 2004); (2) capabilities of assimilation, transformation and cooperation (Tyler, 2001), which enhance enterprises technological learning capabilities inducing the growth of TCs. But for techno-pursuing enterprises, to build and accumulate ETCs are opposed to the direction of the evolvement of industrial technologies, taking on mature technologies and then introducing growing and budding technologies (Chen and Feng, 2004).

Connotation of Growth Trajectory of ETCs

Previous studies on how to develop ETCs, mainly include those undertaken by Rosenberg (1976), Meyer and Utterback (1993) as well as Wei (2002). Rosenberg (1976) regarded technology development as new knowledge created by discontinuous knowledge accumulation, which is engendered by technological disintegration with technological convergence. Technological disintegration is in favour of internal accumulation of one kind of technological knowledge, while technological convergence leads to occasional knowledge colligation between different kinds of technological knowledge. Meyer and Utterback (1993) asserted that the development of TCs was exhibited by product platform upgrading, and a product platform is underpinned by a set of core technologies, which embodies technical skills, market knowledge, and manufacture competencies. Wei (2002) argued that ETCs indwell in resources of enterprises, which have to combine with continuously obtained resources increment in order to realise their dynamic growth which can be illustrated as the "platform-step" mode.

Based on some previous viewpoints and combining them with the notion of technological trajectory, which is defined as the series of path dependent experiences that track the evolution of a technology (Dierickx and Cool, 1989), we propose that the growth of ETCs comprises a series of path dependent experiences that track with the evolution of components of ETCs, and can be described by two dimentional fields in terms of "spiral-platform".The fields consisted of knowledge flow and product upgrading.

Knowledge Flow

Knowledge flow, in the forms of internal and external flow, referred to the reciprocity between enterprises and environmental elements, and mainly focuses on knowledge sharing, creation, transfer, learning, and operation (Tao, 2002). Knowledge flow begins with new technologies being introduced into an enterprise. After that, the technologies are transformed into practical knowledge through technological disintegration, and then the practical knowledge is stored in the forms of ideas, files, drawings, data and so on. Thus, it interacts with original organisational knowledge or individual knowledge in order to be mastered and applied. Finally, the new technologies are deposited in organisational technological resource.

Knowledge flow is an upward spiral process, and can be explained in three aspects. One aspect is that it must be conceived in a dynamic sense (Rosenberg, 1976), because there is a important learning and applying process which includes the acquisition and diffusion of new skills and techniques. The second aspect is the technological resources in an enterprise are enlarged in quantities and improved in qualities in the process. The third is that new technologies may be accepted or resisted because of technological disequilibrium. Any important improvement in components of a product is likely to create an obstacle or an impetus imposed by another component as well as human power and organisational institutions (Rosenberg, 1976), so knowledge flow may be impeded or accelerated and have different changes at different moments.

Product Upgrading

As Meyer and Utterback (1993) pointed out, when a new product platform substituted an existent product platform, that is, product upgrading, it indicates that new technologies have been translated into new skills and techniques, and then became core technologies to underpin the product platform. Moreover, these new skills and techniques, embodying ETCs to some extent, have mingled with accumulated organisational technological experience. According to Wei (2002), it is apparent that ETCs are developed because accumulated technological experiences are expanded by product upgrading.

Product upgrading can explain well the relative stability of the growth of ETCs. When new technologies became peripheral technologies without core technologies being changed, it means that existent functions of products are changed in the same product platform, so that elements of existent ETCs are complemented without any effect on the development trends of ETCs. It shows that the growth of ETCs has the characteristic of relative stability, which is beneficial for new skills and techniques to be fused with organisational technological experience.

Harmonious Relationship

The two dimensions, knowledge flow and product upgrading, reflect two equilibriums: the dynamic and the static, and the internal and the external. The direction of knowledge flow represents the direction of accumulation of technological resources in enterprises, which indicates the direction of product upgrading. Product upgrading as the external characteristic can be recognised according to all sorts of information feedback and appraised from enterprises outside, while knowledge flow as the internal characteristic is represented by product upgrading. If knowledge engendered by a technology cannot be employed during the process of product upgrading, it is unlikely that the enterprise will invest in relevant resources to develop the technology. Thus, the technology cannot become a component of ETCs.

Taxonomy and the Effect of TI

The literature reveal that different stresses of studies brought forward different classification of TI and different types of TI have different effects on enterprises' operation. Thus, it is necessary for our work to firstly clarify the problem of TI types before we discuss how TI affects the growth trajectory of ETCs.

There are many studies on TI taxonomy, and five viewpoints have been identified:

(1) Based on different carriers for carrying out TI, there are four types of TI including product or service, process, organisational structure, and personnel (for example, Knight, 1967);

(2) According to effect range aroused by TI, it comprises incremental, technology development, market development, and radical (for example, Fu, 1998; Chandy and Tellis, 2000);

(3) In the light of innovativeness of new product development, related investigations can be obtained such as Abernathy and Clark (1985), Henderson and Clark (1990), Kleinschmidt and Cooper (1991) along with Freeman (1994);

(4) In terms of fashions of TI taking place, for example, Anderson and Tushman's (1990) discontinuous and continuous, Meyer and Tucker's (1989) radical and routine, Christensen's (1997) sustaining and disruptive;

(5) Considering the effect magnitude of TI, it is the most familiar taxonomy of TI including radical and increment (for example, Balachandra and Friar, 1997; Rice et al, 1998).

Can new technologies engendered by TI have influence on existing resources and assets which embody ETCs? How do they affect ETCs? Usually, it is mainly

related to two factors. One is organisational inertia created by the internal dominant technology of enterprises (Miller and Friesen, 1980), which may constrain the gradual development of other emerging technologies (Christensen and Bower, 1996). In other words, whichever TI is possibly resisted by existent technological capability TCs, because any change aroused by TI, are accompanied with risk.

The other is the relationship between technological trajectories to which new technologies and existent technological resources belong. Different technological trajectories may be complementary or competitive (Rosenkopf and Nerkar, 1999). Complementary trajectories lead to their convergence—where progress in one domain directly fuses with progress in another and result in acceleration of the constituent technologies (Levinthal, 1998), while competing trajectories reduce their charateristics reciprocally so that one trajectory is likely to become dominant, thereby sapping another (Abernathy and Clark, 1985). In addition, because entrants have no accumulation of TCs, the paper will focus mainly on the effects of TI on the TCs of incumbents. This paper proposes three types of TI: radical, incremental, and disruptive, and investigates their influences on the growth of ETCs.

Effect of Radical TI

Radical TI is defined as the first adoption of new technologies and their first introduction to market (Fu, 1998), which opens up an entirely new market structure with potential application (Colarelli, 1998) and often initiates a process of creative destruction. Foster (1986) presented technology S-curve to describe the origin and development of technologies engendered by one radical TI without the effects of other technologies. He showed that technological product performance grows along an S-curve, as illustrated in Figure 1, until technical limitations cause research effort, time, and/or resource inefficiencies to result in diminishing returns. Examining the relationship between resources and TCs, the S-curve can statically describe the growth of TCs.

Because of technological organisational inertia, incumbents probably tend to abandon adopting or impede developing new technologies, while new entrants occur as a result of the radical TI only when TI can earn profit. The phenomenon can be explained as follows. According to the definition of radical TI, it is apparent new technologies are completely different from existent domain technology, and the relationship between them is likely to be competitive, complementary, or unrelated.

Figure 1: S-curve of TCs Growing with Time
Adapted from Foster (1986)

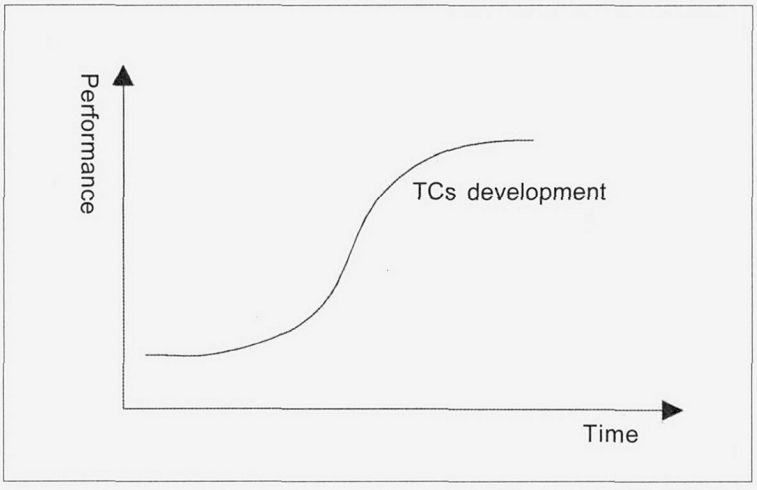
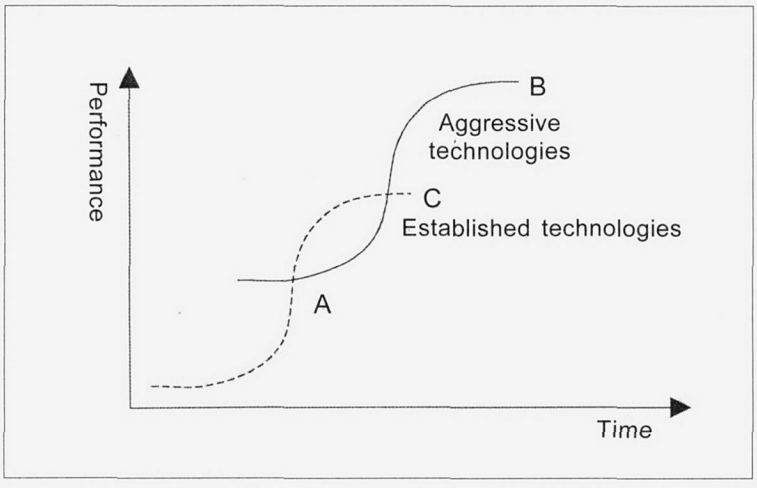


Figure 2: S-curve of TCs Growing with Time
with Effects of Aggressive Technologies
Adapted from Foster (1986)



If new technologies are complementary, they will accelerate incumbents to develop existent technological resources, moreover, the new can get reciprocal improvement. For example, tape technology is complementary for recorder technology, and they are reciprocally enhanced. In order to improve recorder technologies, incumbents will invest in tape technology. To some extent, it expands the width of incumbents' ETCs because of the increase of related technologies. At the same time, the depth of ETCs is accelerated with the development of recorder technology such as the occurrence of all sorts of Walkman. Because new entrants have to accumulate their TCs from the start, incumbents may have advantages over entrants.

Competitive technologies are substitutive, so existent technologies are often replaced by new technoloies, as illustrated in Figure 2. Section AC of the dotted line describing established TCs is substituted by section AB of S-curve of aggressive technologies. For example, candle technology and bulb technology are competitive. The latter brings competitive threats to existent candle manufacturers because it destroys the application of existent competencies comprising applications of architeture knowledge and component knowledge (Tushman and Anderson, 1986). Facing the challenge aroused by radical TI, incumbents may be forced to abandon original accumulation of TCs or keep up existent technologies. Because of the existence of switch cost and lock-in effect, it means that to pursue bulb technology, incumbents may pay out much more expense than the entrants so that they lose the advantage. While keeping up candle technology, incumbents may use constrained resources to extend candle product lines so that the width of their ETCs is increased. But finally, incumbents often go into bankruptcy or retreat from the candle market because of the technology's diminishing returns when the market environment changed. Thus, if incumbents have necessary financial and managerial resources to master such an adaptation, they had better adapt to radical TI (Christensen and Bower, 1996), particularly in advanced technologies, to avoid being eliminated through selection or contest. Certainly, it is built on incumbents' new areas of TCs with high profitability (Katila and Ahuja, 2002).

When new technologies are unrelated to established technologies, radical TI may have little effect on the technological resources of enterprises such as skills or techniques, unless an enterprise has great enthusiasm for introducing TI so that technological convergence can accelerate the development of technology. For example, fibre-optics occurs by the momentum given to optics and electronics as a result of their convergence.

Effect of Incremental TI

Incremental TI often emerging after radical TI (Nelson and Winter, 1982), introduces relatively minor changes to the existing product through exploiting the potential of the established design (Dewar and Dutton, 1986). Apparently, based on existent ETCs, incremental TI reinforces the dominance of incumbents (Tushman and Anderson, 1986) because it follows a 'compulsive sequence', that is path dependency, in which incumbents are largely likely to improve product component technologies that are closely related to their existing skills and technologies (Arthur, 1994).

Incremental TI only improve components technologies, and do not break through established dominant technology trajectory. New technologies are results of the accumulation of substantive skills, knowhow and creativity of technologies, and they as incremental TI have remarkable economic outcome over time. For example, when an antilock braking system is added to automobile design, new component technologies are introduced into an essentially unchanged product architecture, the whole functions of automobile are optimised in the established market and the degree of recognition of established demand is enhanced.

Another example is that architecture innovation in product development, which alters the ways that components work together without changing the core design and fundamental knowledge underpinning components (Henderson and Clark, 1990). It is evident that architecture innovation redistributes components of established architecture in essence and readjusts structurally the existent technologies.

The two examples indicate that incremental TI only slightly changes existent products by improving, enhancing, and complementing their functions without dominant technologies being changed or replaced. That is, incremental TI can enhance the depth of ETCs through expanding component technologies, while for entrants incremental TI is usually not easy bringing them advantages. The reason is that entrants need to bear the cost to accumulate TCs similar to incumbents. In addition, it is necessary to invest in heterogeneous resources relative to incumbents so that new entrants have opportunities to exceed incumbents.

Effect of Disruptive TI

Disruptive TI is a successfully exploited product, service or business model through making use of either a new combination of existing technologies or new technologies. It can provide exceptional value to some customers who are less satisfied with the current technology product paradigm through initiating a new product platform (Kostoff et al, 2004). Moreover, it significantly changes mainstream market demands and disrupts existent domain technologies (Thomond

and Lettice, 2002). To some extent, it is similar to the competitive case of radical TI. The former, without important technology breakthrough which is based on fundamental science and research, mainly focuses on entirely new application of established technologies to attract new users (Foster, 1986); while the latter, along with important technology breakthrough of fundamental science and research, focuses mainly on the first application of new technologies.

New technologies engendered by disruptive TI can arouse many other new, typically revolutionary, technologies to be deployed in order to meet multiple consumer-based performance objectives, such as micro-technologies, materials technologies, component technologies, human factors research, and so on. So, if incumbents accept disruptive TI, there will be multiform technologies converted into knowledge fusing with the existent knowledge sources and thus accelerate the growth of ETCs.

Most enterprises with a discipline of listening to their best customers often keep their loyalty to existent technologies and fail to invest in the new market engendered by disruptive TI (Christensen et al, 2001). Because of disruptive TI providing customers more convenient and cheaper products than that in the mainstream market, new markets created by disruptive TI are gradually competitive with mainstream market. With the foundation of new technology normal, the development of technological resources and knowhow in new market is enhanced are accumulated. Thus, the new technology trajectory and the new product paradigm may return to overtake and surpass established domain design in the original market. Under the conditions, incumbents may be forced to disrupt its continuous accumulation of established TCs and adopt the disruptive technologies, but entrants as the result of applying disruptive TI rapidly accumulate their TCs. However, which one can have advantages over the other? It is different with timing for incumbents to employ the result of disruptive TI. If incumbents are sensitive to disruptive TI, they can have advantages over entrants because the core of disruptive technologies is the same to the existent, or they will lose.

Christensen and Rosenbloom's (1995) conclusion illuminates that disruptive TI in fact focuses on architecture recombination such as the development of disc drive in computer industry, and hardly engages in components innovation. If incumbents pay attention closely to the future changes in market, they will have more advantages than entrants for their accumulation of component technology ahead.

Organisational Determinants

The discussion above shows the growth of ETCs is a dynamic evolvement process, and TI is a sustaining drive for enterprises to obtain TCs. How to keep

the favourable effect of TI on ETCs?

Technology Roadmaps

Since technology roadmaps characterise technology forecasting and selection (Kappel, 2001), they can meet enterprises' needs to manage potential threats and opportunities through existing and potential technological resources (Christensen, 1997). Furthermore, they can also provide enterprises the ability to rapidly recognise changes brought on by TI such as disruptive TI, and the means to make certain evolutionary direction of existing and potential resources.

When the trends of technology development interact with different factor market segmentations and different levels of investments in ETCs, the trends can lead to the emergence of multi-technology, technological gaps, and technological discontinuity in an industry (Battisti and Pietrobelli, 2000). Therefore, enterprises have to focus on the depth of ETCs in one subdivision market and at the same time to extend the width of ETCs touching upon integral market by gradually utilising technology knowledge and external sources (Prencipe, 2001).

Enterprise Learning

The formation, improvement and accumulation of ETCs are often realised or sped up by the enterprises' learning (Gao, 1996), which is a process to integrate internal technological strengths with those of other firms (Vanhaverbeke et al, 2002). According to the three-stage episteme mode (Kim and Shu, 2002), the process of enterprise learning goes along with (1) "Research learning" to obtain advanced technology, (2) "Practical learning" to adapt and regulate the technology to local environment and convert it into indigenous specialties, and (3) new technologies creating to support the growth of ETCs.

Grant and Baden-Fuller (1995) supposed that "learning alliances" can improve the efficiency of the enterprises' learning through exploiting knowledge (Stuart, 2000) developed by other members of the "learning alliances".

Technological failures sometimes occur due to tacit technological knowledge and lack of technical or managerial experiences or market-related systems along with the inadequate comprehension and imitation (Prencipe, 2000). It can impede or restrain the indigenous process of technologies obtained from outside, and the gradual improvement of research, development, design, and engineering, which further engender failures of indigenous ETCs (Madanmohan, 2000). Thus, to understand these failures and to obtain knowledge from the failures will be helpful for subsequent technology or product development (Maidique and Zirger, 1985) when they are translated into the enterprise's memorised experiences.

Enterprise Culture

Organisational culture is essentially the informal organisational institution that powerfully shapes the behaviour of individuals and groups (Schwarts and Davis, 1981). Open culture environment of an enterprise can provide circumstances for sharing information, which is in favour of enhancing absorptive capabilities, integrative capabilities, coordinative capabilities, and generative capabilities (Prencipe, 2001). It also acts as relatively steady knowledge repository and conveyance belt, which focus on fostering the evolution of skills and knowledge of both the group and the individual (Johnson, 1992). Apparently, enterprise culture underpins organisational and dynamic growth of ETCs (Hodgson, 1998). With a strong open culture enterprises can spell out behaviours of people and take steps for the growth of ETCs.

Organisational Structure

Different types of TI need entirely different organisational structure (Nelson and Winter, 1982). For example, steady organisational structures, such as hierarchical organisations having properties inimical to radical TI, can effectively manage incremental TI and exploit potential ETCs with rules, norms, and system. Flexible organisational framework, such as special business units, well-integrated function teams, or flatter and specialised structures, can build a new value chain to radical TI (Prencipe, 2000). The reason is that different organisational properties can provide different resources to support organisational learning going along different paths (Cimoli and Dosi, 1995).

In general, resources heterogeneity of enterprises may arise from resource scarcity (Peteraf, 1993), but in fact it is more likely for first-mover advantages (Lieberman and Montgomery, 1998), engendered by organisational institutions, to create resource scarcity. For example, alliances including an enterprise's competitor gradually become an critical source for acquisition of ETCs and TI (Ahuja, 1996), since alliances can fully employ existing resources of enterprises and their competitors to develop heterogeneous resources by radical or disruptive TI. Moreover, they can exploit potentials of TCs of enterprises by learning technologies from incremental TI. In fact, supply chain, to some extend, is a practical form of the alliance and there is an emerging research stream paying attention to it (Singhal and Singhal, 2002; Coates, 2003; Attaran, 2004).

Conclusion

This paper analysed the growth trajectory of ETCs and, based on the taxonomy of TI, discussed the effects of different types of TI on the growth trajectory of ETCs. Finally, we analysed relevant organisational determinants which

may have influence on TI and ETCs. The value added of the work presented here increases as it follows the above sequence.

We investigate the connotation of ETCs and their growth and explain knowledge flow and product upgrading. Then, we explain the taxonomy of TI, and developed a framework for analysing impacts of different types of TI on the growth trajectory of ETCs. If this analysis is correct it will have strong implications for management in assessing the technological strength of enterprises. At least, it is clear that not all TI can bring advantages for incumbents. If TI renders existing heterogeneous ETCs obsolete, then it may become a handicap for incumbents accepting new technologies to develop ETCs early (Leonard-Barton, 1992).

The framework presented here is designed to merge research views of TI and ETCs from two respective domains into an integrated domain. From this work, we can conclude:

(1) In spite of whichever TI introduced, the quality and quantity of connotation of ETCs are both changed evolutionally by complementary trajectories or retrogressively with competitive trajectories.
(2) Organisational structures have inconsistent effects of on TI and ETCs except for incremental TI.
(3) It is necessary to consider TI together with TECs, otherwise, it is likely to minimise the virtues of TI or ETCs because sometimes TI destroys existent ETCs with valuable complementary assets changing (Tripsas, 1997), or ETCs that make an enterprise embrace one TI early can abandon another TI (Argyres and Liebeskind, 1999).

While the exposition of this research shed new perspectives on growth trajectories of ETC and types of TI, it has some limitations. First, the retroaction of ETCs on TI as an aspect of the relationship between TI and ETCs is not analysed, and may probably impede comprehension over the relationship. Second, the paper has left out empirical investigation which will be a focus of future work. Finally, it is not enough to consider other factors relating to TI and ETCs such as economic environments and entrepreneur behaviour. Thus, our future work needs to discuss them.

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