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Strategic options-based framework for management of dynamic capabilities in manufacturing firms

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Abstract

Purpose – The purpose of this paper is to launch a dynamic strategic framework for a manufacturing firm for the digital age. The paper's dynamic capabilities- and strategic options-based framework is comprised of the following key issues: how to sense the weak signals at the customer interface and how to formulate them as strategic options; how to exercise these options in the (often) intangible assets markets that are imperfect or even non-existent; how to appropriate and/or share strategically relevant productive knowledge in order to obtain competitive advantage (CA) over the rivals, (iv) how to recognize the opportunities and threats of the underlying industrial structure, especially the economies of scale and scope and network externalities; and how to proactively reconfigure and reshape the existing knowledge base and capabilities in order to sustain the CA obtained.

Design/methodology/approach – The paradigm of creating CA is opened up in the context of knowledge-based engineering and digital manufacturing. The Porterian five forces model, the resource-based view and especially its dynamized extension, the dynamic capability view, are used as theoretical starting points. The modern strategic technology management literature will be complemented by means of the concepts of strategic options and related flexibility issues. Some illustrative examples will be offered as well.

Findings – In the author's view, the primary sources of sustainable CA in the digital manufacturing can be captured from active asset selection (strategic investments in both tangible and intangible assets), and efficient orchestrating of the global value net in "thin" intangible assets markets. The main determinants of CA are: the competitive nature of external environments, supply and demand conditions of the industry (economies of scale and scope and network externalities), renewal capacity of the organization, the dependence on complementary co-specialized resources and capabilities, and the strategic role of the appropriability regime.

Originality/value – This paper tries to capture the critical elements of creating sustainable CA in the context of digital manufacturing and it is considered to be useful for strategic decision-makers. The modern technology strategy management literature is synthesized in our framework and it tries to make the issues more applicable to the strategic management of the companies.

Keywords Manufacturing industries, Strategic manufacturing, Transaction costs, Competitive advantage

Paper type Research paper

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1. Introduction

Manufacturing companies have gone through three distinctive phases as for their earnings logic and business models during the last century. The first one started in the 1920s and was based on the effective utilization of electricity. This period has later

been labelled as the Fordist mode of mass production. The basic features of this manufacturing model were (Chandler, 1990; Teece, 1993; Zysman, 2003):

- the rise of large hierarchical conglomerates in order to exploit the economies of scale and scope by means of professional managers;
- the separation of production design, research and development activities and operative functions into separate divisions controlled by the general management;
- large investments in tangible production assets that made it very costly to transform existing production lines because of high sunk costs (hence the model was suitable for mass but not for customized production);
- the "push" of manufacturing products through the production systems into the market by effective marketing of standardized goods and services; and
- the earnings logic was based on the exploitation of the monopoly profits created by means of oligopolistic market structures dominated by large vertically integrated corporations.

From the business model perspective the most important feature was that large sunk investments in tangible assets implied profound rigidity both in R&D activities and manufacturing. These problems were overcome, however, through oligopolistic earnings logic. It made it possible to control the sources of market and technology-related uncertainties by internalizing all the main manufacturing related activities or transactions within the companies. Also the research and development (or more generally innovation-related) activities were organized within the large corporations and there were no need for high-powered incentives to generate disruptive technologies or to utilize the knowledge pools of other firms through networking or outsourcing. Here, we had an archetype of what Williamson (1975) called the rise of multi divisional (M-form) corporation due to high transaction costs (on the role of the so-called visible hand strategies as a response to high transaction costs, see also Teece, 1993).

The American mass production model was not challenged until the 1980s when the more flexible Japanese lean production model with demand-based just-in-time logic challenged the rigid received view of a manufacturing firm. The core companies of this production mode were vertically less integrated than their American counterparts. Instead they utilized the vertically organized Keiretsu that tightly linked the individual supplier companies (with their own high-powered incentives and R&D activities) to the core companies (the hub and spoke model) and to their clients as well (Zysman, 2003). Because of the disintegrated but tight structure the Japanese lean manufacturing system provided flexibility of output within existing production lines as well as rapid, demand-induced launching of new products and services. Because of mutual trust of the Keiretsu partners the lean production system decreased both market and technology-based uncertainties and the danger of opportunism as well, thus resulting in lower transaction costs and, consequently, a less hierarchical mode of manufacturing. This in turn made it possible to utilize both the high-powered innovation incentives of suppliers and core manufacturers and to react much more rapidly to the changes of demand. Not so surprisingly, in the late 1980s and early 1990s most leading manufacturing firms all over the world took steps toward the more networked and demand-led manufacturing system, thus following the lead of Japanese manufacturers, such as Toyota and Sony. The earnings logic was primarily based on

the efficient exploitation of specialization and innovative efforts of each partner of the network.

However, this was just a start toward a much more disintegrated and demand-induced or "customized" manufacturing system. At the moment we are witnessing the third "revolution" both in the business models and in the earnings logic of the manufacturing industry. The two main drivers are globalization, which primarily means keen global competition and focusing on core capabilities, and the digitalized mode of production, i.e. a transition from an electro-mechanical era into the much more flexible digital age. During the 1990s, it suddenly seemed that the American and Europeans producers (Microsoft, IBM, Cisco, Nokia, Motorola, French automobile manufacturers, etc.) were back in the game again. New kinds of software-based digitalized manufacturing products and services emerged first in the ICT sector (from the PC's to mobile cell phones) and then gradually in other industries.

As for the earnings logic we conclude that the very nature of manufacturing was dramatically changing because of the rapidly decreasing transaction costs (due to the effective use of computers, internet, and telecommunications and better tools for hedging financial risks related to innovation activities) and even more rapidly increasing transaction benefits. Our concept transaction benefit mainly refers to the benefits of using the open global knowledge-based asset markets instead of firm internal hierarchies. Transaction benefits are based on the opportunities:

- to utilize complementary resources and capabilities available in open markets by means of global networks of suppliers and sub-suppliers;
- to utilize the global knowledge pools by means of knowledge-based networks; and
- to sense weak signals by means of large customer interface generated by the partners of large global networks (Blomqvist *et al.*, 2002).

The role of transaction benefits as catalysts of the rise of loose global networks is the higher, the more important is the role of (scientific) knowledge gathered and utilized through inter-organizational global networks. Good examples are the PC's or mobile cell phones. Their value added is embedded into their intellectual property, i.e. knowledge intensive chip-based software components, and in standards which they have to be built to. Here, is the key of the modern earnings logic, it is based on intangible knowledge-based assets and the ability to profit from them by means of tight appropriability regimes (i.e. by means of legal means such as patents, copy rights, trade marks, and trade secrets or by means of effective isolating mechanisms, such as the use tacit knowledge or standards, see Teece, 1986; Hurmelinna *et al.*, 2007).

New digitalized and globally networked manufacturing logic results in the very disintegrated mode of production. There are primarily three reasons for that:

(1) No single firm is any more able to generate all the necessary pieces of knowledge all alone, they have to network in order to form useful knowledge pools, i.e. to exploit transaction benefits.

(2) Networks are effective when sharing either the risks of orchestrating the value chains in the multi-cultural global markets or sharing the high fixed sunk first copy cost so typical for a modern manufacturing product.

(3) The effective use of transaction cost logic implies that outsourcing or loose networking are good governance options when transactions do not belong to the domain of the firm internal core capabilities.

As a result of these tendencies one can conclude that the main strategic issue faced by modern manufacturing firms is how to effectively orchestrate global supply chains that consists of complex value nets of different suppliers and buyers.

In this mode the business logic is based on thinking in terms of globally produced components, subsystems, and modules out of which the final services and goods will be flexibly built in a customized way. Almost necessarily this logic results in much more disintegrated value chains, since almost each of the subsystems can be organized either within the firms themselves or by means of networking partners operating in open markets all over the world. Dell in the PC and Nokia in the mobile phone industries are perhaps the two best known examples of how to strategically exploit the opportunities opened up by global value chain orchestration. The main challenge is, of course, how at the same time to profit from the knowledge assets generated within the firm. This issue will be replied in our next chapters. Our claim is that in the near future the global supply chain management or orchestrating the global value net will become the most important single strategic management issue even in the most traditional, vertically organized manufacturing firms. Table I summarizes the main message of Introduction.

2. Obtaining and sustaining competitive advantage in knowledge intensive global industry

2.1 Dynamic capabilities and strategic options as tools of thinking

Recent advances in the theory of the firm emphasize that all the firms can in fact be interpreted as portfolios of tangible and intangible assets (resources) and (production-related and organizational) capabilities. Earlier even in global (not to mention in local) markets the competitive advantage (CA) used to mainly flow from the ability to build up a idiosyncratic resource base that consisted of valuable, rare, inimitable and non-substitutable (i.e. VRIN attribute-based) resources which generated Ricardian, scarcity-based rents. To profit from them the firm had to be able to build up what Rumelt (1984) called isolating mechanisms (Teece, 1986; Winter, 1995). Their basic function was to make the relationships between the resources and the firm's extraordinary performance causally ambiguous either by means of legal means or tacitness.

Quite recently, the increasing pressure of global competition and the need for even higher customization of services and goods has shifted the strategic focus from the effective management of the "given" resource base toward the ability to proactively modify it in order to meet the rapidly changing needs of customers. This brings us to the core of the so-called dynamic capability view of the firm (Teece *et al.*, 1997; Teece, 2000; Helfat *et al.*, 2007). According to it the earning logic is based on the distinctive ability to purposefully create, shape, extend, and modify the existing resource base and especially its knowledge-related intangible assets so as to quickly respond to changing preferences revealed in the markets or new technologies. In sum, the firm's capacity to exercise these opportunities (strategic options) is based on what Teece *et al.* (1997) have called dynamic capabilities.

Table I.
Different modes of manufacturing production and their main drivers

	Fordist mode of production	Japanese lean just-in-time mode of production	Knowledge-based mode of production
Main source of CA	Large investments in tangible assets and effective control over physical capital and markets through oligopolistic markets. CA is based on the goods or factors markets imperfections	Ability to establish and control networks managed by core corporations (Keiretsu) CA is based on VRIN resources as well as on intangible "relational" assets	CA is based on the ability to flexibly extend, modify and reconfigure internal and external resource base to address rapidly changing environments, i.e. CA is primarily based on dynamic capabilities
Target of corporate strategy (Winter, 1995)	Utilize Porterian monopoly profits based on the economies of scale and scope. Position the firm rightly in the market and build up entry barriers!	Utilize Ricardian rents based on VRIN resources by means of networks!	Utilize Schumpeterian entrepreneurial profits based on new combinations, sense of weak signals, and seize the opportunities, i.e. exercise strategic options at the right time!
Means of manufacturing strategy	The use of monopoly power by controlling both the market- and technology-based uncertainties by means of multi divisional conglomerates. Mainly incremental innovations are generated in terms of firm specific R&D activities and consumers are "tamed" by means of standardization and mass marketing	Focus on your core capabilities and resources with VRIN attributes and let your partners do all the other activities or transactions. Disintegrate manufacturing but keep the core capabilities (e.g. R&D) at your own control	Focus on VRIN-based intangible knowledge assets and exploit the imperfections of their markets. Be alert and flexible as for the changes at the consumer interface! Customize your products!
Economics-based explanation of earnings logic	Economize on transaction costs by means of hierarchical governance structures	Minimize transaction costs by increasing mutual trust and dependence between the partners = > less hierarchical network solutions	Minimize transaction costs and maximize transaction benefits at the same time = > use loose networks and markets and orchestrate them efficiently
Representative type of organization	Large vertically integrated conglomerates	Tightly organized hub and spoke networks	Loosely networked firm clusters that also use open innovations (Chesbrough, 2003)

Before we go into the managerial implications of the dynamic capability-based view of the modern manufacturing firms we will briefly launch the concept of strategic options. The basic ideas behind them are derived from the real options approach that in turn can be seen as an extension of financial options theory to real assets (Trigeorgis, 1996). In our view, strategic options include all the tangible and intangible real assets that are of strategic importance for a firm. Modifying a bit the real options definition given by Amram and Kulatilaka (1999, p. 5) we define the strategic options as follows (our additions in italics):

> A (*strategic*) option is the right, but not the obligation, to take a (*strategically important*) action in the future. (*Strategic*) options are valuable when there is uncertainty. Many strategic investments create subsequent opportunities that may be taken, and so the investment opportunity can be viewed as a stream of cash flow plus a set of (*strategic*) options.

Often (but not always) strategic options represent the management's ability to delay an irreversible decision until after at least some technology or market-based uncertainties have been resolved (a strategic deferral option). Strategic options deal with both the downside risks as well as not yet realized upside opportunities that can be found from either already existing capabilities or activities within the company or outside the company, or they must be somehow purposefully extended, generated or modified from the existing capabilities or they can be created as radical new innovations.

It is clear that the options theory always copes with uncertainty: the value of the (strategic) option is the greater, the greater is the uncertainty. The main problem, however, is that in the real life the uncertainties faced by the manufacturing firms are often related either to the game theoretic type of endogenous uncertainty or to uncertainties that come close to ignorance because of very imperfectly functioning assets markets. These types of uncertainties (i.e. when uncertainties depend on maneuvres taken by the players or the efficient assets markets are inefficient or non-existent) cannot be tackled by means of traditional random walk-based options valuation models from theory of finance.

Nevertheless, even if the valuation of strategic options is often impossible, there exist many ways, however, to utilize this approach as a strategic tool in the global setting when trying to control downside risks related to uncertainty and to seize the upside opportunities opened up.

Downside risks associated with strategic options can often be informally assessed and the not-accepted alternatives can be identified and (hopefully) also avoided. In order to avoid the downside risks the strategic investment can be, e.g. delayed (a strategic deferral option), or the size of the investment can be decreased (a strategic scaling option). In cases where the initial large investment is split, the small investments support learning before large investments (a strategic learning option). Of course, all the above option alternatives always include the option to abandon the whole strategic investment project.

On the other hand, the upside opportunities that are rejected in traditional discounted cash-flow approaches can flexibly be taken into account by identifying strategic growth options through learning or by developing and innovating during the R&D project. In sum, strategic options provide flexibility through limiting the downside risk while maintaining access to upside potential (the window of opportunities) at the same time.

The real value of strategic options-based thinking can be understood when we look at traditional ways of coping with uncertainty in the manufacturing investments.

Uncertainty is usually considered as an undesirable element in the strategic R&D decision-making. In this (too) simple discounted cash flow-based thinking the high systematic risk by definition means higher discount rate of interest thus reducing the attractiveness of a strategic investment. This approach clearly cannot recognize the flexibility-related "hidden" growth options embedded in the most important strategic investment opportunities They neglect such important issues like:

- how to open up the real windows of opportunities by means of strategic actions in strategic space;
- how to make the managers aware of the downsize risks involved; and, most importantly
- how to offer useful strategic tools to overcome the crucial strategic problems by proactive actions realized by the management.

Instead, the strategic options approach opens up for the management an opportunity to adjust their decisions to the new situation that no-one can foresight, i.e. the management can now genuinely proact (when sensing weak signals, for instance). When facing the challenges of the third manufacturing revolution the firms have to be strategically responsive and able to commit resources and capabilities, and to build up its dynamic capabilities within flexible structures, thus avoiding over-commitment in fixed assets. Figure 1 shows the strategic options perspective as follows.

Next we briefly sketch some examples of how Figure 1 can be used as an illustration of strategic options- based thinking in the manufacturing management context:

> The window of opportunities or (original) upside opportunity frontier (the upper dark line) should never be taken for granted. It crucially depends on the strategic moves taken by the firms in the industry, institutional actors (e.g. regulators), and the acts of buyers/customers. One of the basic ideas of strategic management is to generate strategies in order to shift this frontier upwards, thus improving the CA of the firm over rivals (the upper dotted line in Figure 1).

In addition, Figure 1 shows that one can often avoid the downside risks simply by waiting (strategic deferral options). One can also reduce the risks by staging the investments and waiting, learning and seeing until radical uncertainty decreases. These actions reduce the risk of fixed sunk costs and shift the lower dark line upwards (the lower dotted line). In the next chapter we connect this thinking into the dynamic capability framework.

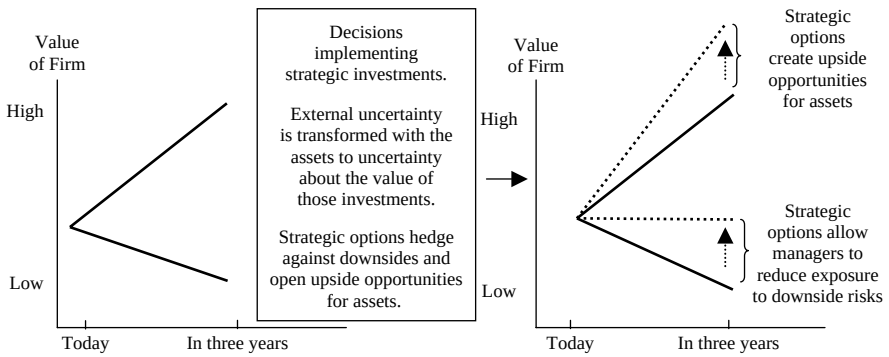

Figure 1.
Strategic options approach in terms of upside opportunities and downside risks

2.2 Towards a dynamic capability-based view of the challenges faced by modern manufacturing firm

After introducing the main concepts to be used as analytical tools, i.e. the strategic options approach and dynamic capabilities we are now ready to have a closer look at issues based on the dynamic capability view of he firm. Figure 2 shows our view about the most important elements that a modern manufacturing firm has to confront when trying to sustain its CA in turbulent and competitive global markets characterized by high market and technology uncertainties.

The basic idea of Figure 2 is to put together the many strands arising from modern strategic management research in a way that makes it possible to respond to the challenges faced by manufacturing firms in the digital era. Next we shall look at the strategic options (i.e. upside opportunities and downside risks) connected with each box separately. In conclusions (Chapter 4) the managerial implications based on them are summarized.

2.2.1 Porterian positioning and the role of external environment. The main idea of this box is to bring into the discussion the downside risks and opportunities opened up by the changes in external environments. From the Porterian perspective the most important message is that the firm has to position itself effectively in the competitive "space". The main players at this level are rivals, substitute producers, buyers, suppliers, consumers, and institutional actors. From the digital era perspective it is a question of, how to orchestrate the global value chain in the conditions where most of the production-related and R&D processes are becoming more and more commoditized and customized. This again means that the choice of the boundaries of the firm (markets, networks or hierarchies) will be one of the most important strategic decision criterion. As a starting point one can utilize the transaction cost logic, whose basic lesson is that transactions should be organized in a way that economizes on transaction costs at the same time when the value of transaction benefits will be maximized (Blomqvist *et al.*, 2002; Teece, 2007).

When organizing the global supply chain it is also important to recognize "hidden" change potential in the global competitive environment. A firm has to sense weak

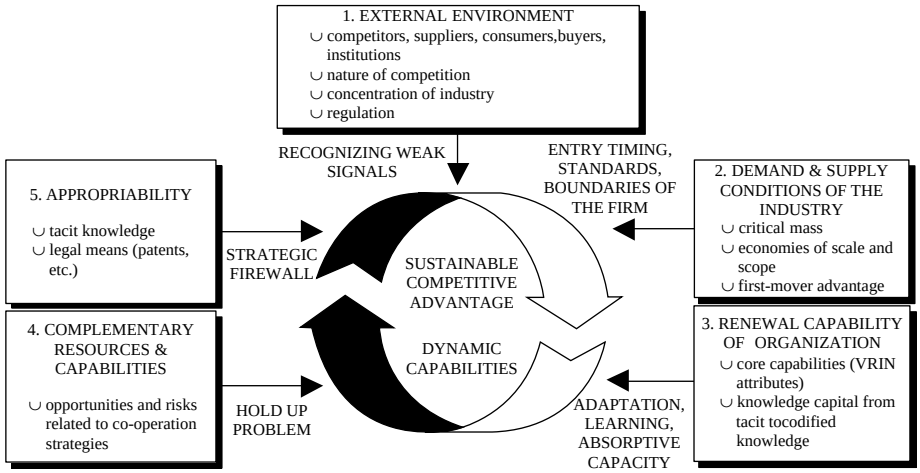

Figure 2.
Dynamic capability view of manufacturing firm

signals that are "only in the air" in order to be able to profit from forthcoming changes. Also the manufacturing firm has to be more and more proactive as for the strategic steps taken by rivals or (de)regulators. Of utmost importance is the ability to sense weak signals concerning the changes at the consumer interface. In order to realize these potential advantages the firms have to be ready for organizational changes which cannot be done without dynamic capabilities.

Successful strategic maneuvers of rivals shift the opportunity frontier downwards (if the moves are profitable for rivals) and upwards (if the moves are unlucky from the rivals' point of view).

When the preferences of customers or the regulations put forward by the authorities change, the frontier shifts upwards or downwards depending on whether they are suitable for the firm or not.

To sum up, the window of opportunities is partly externally determined and depends on the acts of rivals, suppliers, complementary capabilities holders, authorities and customers. The higher is the uncertainty as to the potential effects of these external actions, the more advisable it is to understand the value of the options to wait or the options to abandon.

2.2.2 Demand and supply conditions of the industry have to be recognized. This box reminds us of the necessity to recognize the existing and, more importantly, forthcoming special characteristics of the industry. It is a question of how to organize your earnings logic in a way that you can profit from your knowledge-related assets.

Traditionally in the mature industries the most decisive source for the CA has been physical (tangible) capital, the main driver of the economies of scale and scope. If there still are some advantages to be exploited the deepening of vertical integration and acquisitions and mergers are the best ways to go further. However, because of global competition these advantages are becoming scarce.

New sources for CA can best be found either from a more efficient orchestration of the global value chain (e.g. Dell and Nokia) or from exploiting the modern economies of scale arising from the demand side, i.e. the network externalities. It is typical for digitalized information-based products and services that their market equilibrium does not get determined in terms of a declining demand curve (thus implying diminishing marginal utilities and willingness to buy) and increasing supply curve (implying increasing marginal cost) but in vice versa. Increasing demand (depending on the increasing value of a network when the amount of its members increases) and decreasing supply curve due to economies of scale in production result in an unstable equilibrium, i.e. the necessity to reach the critical mass (Sappinen and Kyläheiko, 2007). The firm which can first reach this point will most likely also enjoy the first mover's advantage so typical for the ICT industry (e.g. Microsoft, Cisco, Intel, partly Nokia). The more digitalized the manufacturing sector becomes, the more there will be new opportunities for exploiting the first mover's advantages originated from production and/or demand-related local monopolies. To put it briefly, for a modern manufacturing firm right timing as for a market entry is becoming a crucial issue. Also the ability to generate standards and profit from them through license fees is also very important.

Since, most initially radically uncertain new technologies become less uncertain by time it is often advisable to use learning options, i.e. to take time to learn more and let the uncertainty to fade away. In these cases, the downside risk curve shifts upwards when a firm takes the option to wait.

In some cases, as mentioned-above, there are strong first mover's advantages because of the network externalities and other demand and supply-related economies of scale and scope. In such a situation it is most advisable to exercise the strategic option as soon as possible in order to be able to set standards for further competition.

2.2.3 Knowledge assets, dynamic capabilities and the role of organization. In dynamic capability-based view a company consists of its knowledge assets (from tacit to codified), capabilities, and physical resources. In the future, the profits have primarily to be based on market imperfections in the markets of knowledge assets, since keen competition will level out most traditional sources for profits. It is not any more enough to have valuable basic resources. What are needed are valuable, rare, inimitable, non-substitutable, and not so easily transferable capabilities. In dynamic conditions even the so-called VRIN attributes above can generate only short run Ricardian rents. To be profitable in the long run a firm has to have what we have earlier called dynamic capabilities (Teece *et al.*, 1997; Winter, 1995).

To be able to generate core capabilities with VRIN attributes and dynamic capabilities to reconfigure them when needed, modern manufacturing firms have to be innovative to exploit their existing capabilities through incremental innovations and to explore new opportunities through radical innovations (if necessary due to drastic environmental changes) and, most importantly, to be flexible enough. In addition, they have to have enough absorptive capacity to utilize new codified information available from the idea markets or new tacit knowledge obtained from new partners.

However, the most important single ability in the future will be the ability to learn both from own and partners' experiences, from weak signals, and from generic science-based codified information. Always when tacit social learning takes place within the firm's organization it also enables to embed firm-specific internal knowledge so deep into the organization that the rivals cannot ever trace the causal relationships between the firm's knowledge assets and its economic performance. This in turn guarantees that the rivals cannot imitate the sources of profitability.

When looking at Figure 2 one can conclude that from the knowledge and resource base perspective the firm can exploit its firm-specific, tacit, and cumulative capabilities through continuous learning. This shifts the curve upwards, thus demonstrating the strength of learning-related growth options. New capability-enhancing partnerships that extend the knowledge pool or resource base shift the frontier upwards as well. The partnerships also reduce the sunk fixed costs so typical for the R&D projects.

The explorative acts that generate or create new capabilities within the firm or result in radical innovations may also shift the frontier upwards. However, since these innovations are often capability-destroying by their nature they can also create organizational rigidities or even rejections with negative outcomes. If the explorative acts fail, the curve can shift drastically downwards. Hence, the strategic options that are related to capability-destroying innovations have to be analyzed carefully and started incrementally, using learning options.

One of the main problems when trying to extend, modify and create dynamic capabilities as strategic options relates to the very imperfect nature of the intangible assets on which dynamic capabilities are based. Since, there are no efficient markets for intangible knowledge-based and other idiosyncratic assets there are market failures that call for competent managers to fill the gap. Teece (2007, pp. 20-2) has emphasize that because of the market failures the managers have to cope with issues like:

- orchestrating complementary assets;
- selecting governance modes and their incentive systems;
- designing business models;
- nurturing innovation processes/routines;
- making strategic investment choices; and
- providing leadership, vision and motivation to employees.

In good old times most of these issues were to be done mainly on the basis of routine-based experience gained from the industry. Now the routine-based management does not help much in turbulent circumstances. It is just like driving a car by looking at the white line in the rear-view mirror in on the road with sharp curves. Figure 3 shows this problem.

2.2.4 Critical role of complementary strategic assets. Since, modern manufacturing firms are more and more dependent on subsystems and components acquired through partners or through market forces they are also facing the danger of getting held up by strategically more powerful holders of complementary assets. Therefore, it is important for a traditional manufacturing firm that it takes into account this hazard every time when it is establishing its global value chain. Transaction cost economics reminds us, that the more imperfect complementary assets markets are, the higher are also the transactions costs. This means that in such conditions the cooperation has to be based on quite firm relationships (joint ventures, strategic alliances,

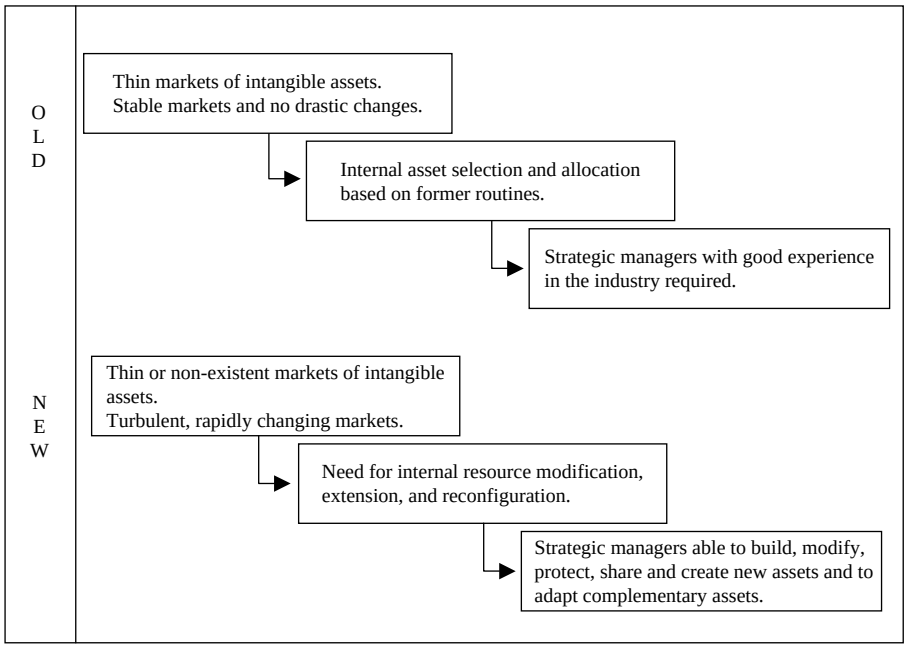

Figure 3.
Thin markets of strategic assets and managerial choices

Source: Teece (2007, p. 24)

fusions, mergers). The situation is well-known for many small and medium-sized enterprises that are suppliers for a great buyer. Fortunately, there are many strategic options to try to overcome this problem. The best option is to have strategically non-substitutable and inimitable resources that keep their value over time. This means that even in the worst scenario you will have the portion you have deserved. Another option is to commit a joint venture which means that the risks and mutual benefits will be shared. The third option is to unite together with other suppliers against the powerful buyer.

Generally speaking, the more flexible and non hierarchical the knowledge-based manufacturing organization is, the easier it can cope with the complementary asset hazards.

2.2.5 The critical role of appropriability regime. This box relates to the very nature of knowledge assets. As already mentioned, in the global markets the ability to profit from knowledge fundamentally depends on the efficiency of knowledge assets markets. The more imperfect they are, the better are the chances to profit due to market imperfections. Hence, one of the best strategies to generate extra profits is to build up what we have called the strategic fire wall. It can be established roughly in two ways. First, one can use legal means, such as patents, copyrights, trade secrets, etc. for appropriating knowledge assets from the use of rivals. Second, one can embed valuable idiosyncratic knowledge deep into the organization by keeping it tacit.

Unfortunately, there are some drawbacks associated for both solutions. First, it is normally very hard to build up an iron-clad patent not to mention copy right. Second, nowadays it is very important to share information among partners (Chesbrough, 2003). The more tacit the piece of knowledge is, the harder is the transfer of knowledge as well. These problems become even harder when there are reasonable first mover's advantages to be gained through license revenues arising from the effective use of standards. Therefore, many firms have nowadays chosen an intermediate solution. They try to appropriate the profits from the knowledge assets which are open for everyone but owned by a firm that created them.

The most important lesson for a manufacturing firm is that the more digitalized and knowledge-based its activities are, the more important it is to understand the very complicated trade-off issues related to the immaterial property rights management. Nevertheless, the ability to create market imperfections for the markets for knowledge assets will be one the most important prerequisites for sustainable CA s in the future as well.

3. Responding to manufacturing uncertainty of digital era with flexibility in terms of strategic options

3.1 From operational to strategic options-based flexibility

In general, manufacturing flexibility can be defined as the ability of an organization to manage its production resources and uncertainties to meet various customer requests (Zhang *et al.*, 2003). The scope with which the flexibility can be examined is wide: it can be seen as a property of an individual machine, or as a strategic element of business along with cost, quality, and dependability (Hayes and Wheelwright, 1984).

The value of flexibility quite obviously depends on the perspective with which the outcomes are considered. For that purpose, it is useful to make a distinction between operational flexibility and strategic options-based flexibility. With operational flexibility is meant the capabilities that can successfully and profitably respond to

the short-term variations in demand. The strategic options-based flexibility is the ability to convert the changes in the long-term product mix and competitive shifts into the benefits and CA of the company.

The definitions of the most common manufacturing flexibility types mentioned in the literature are as follows (Browne *et al.*, 1984; Parker and Wirth, 1999): machine flexibility (measured, e.g. by the cost of switching from one operation to another), process flexibility (the ability to change between the production of different products with minimal delay), product flexibility (the ability to change the mix of products in current production), routing flexibility (the capability to use alternative processing routes to make a product), volume flexibility (the ability to operate profitably at different production volumes), mix flexibility (the ability to produce different combinations of products economically and effectively given certain capacity), expansion flexibility (the ability to expand the capacity of the system as needed), operation flexibility (the capability to interchange the sequence of manufacturing operations for a given part). Manufacturing flexibility can be used to describe the universe of part types that the manufacturing system is able to make. This flexibility type is a consequence of the previous flexibility types. In the era of digital manufacturing supported by the knowledge-based factory, engineering and services the above flexibilities can be collected under the concept adaptive manufacturing.

However, from our perspective, the much more important concept is strategic flexibility, i.e. the ability to sustain CA in the changing competitive situation. The determinants of strategic responsiveness arise from the ability to maintain the balance or strategic fit between firm specific internal capabilities and resources and external environment consisting of rivals, suppliers, buyers, customers, and institutional actors. Internal capabilities can be adjusted by means of (in)tangible investments or by generating new capabilities either by enhancing the already existing manufacturing system or by exploring new capabilities. The capabilities can be found either from the company or from business partners or they can be acquired outside the company. Learning is essential in this process. The considerations of strategic responsiveness include also both upstream and downstream manufacturing related services.

3.2 Facing the challenges of knowledge-based manufacturing

The dynamic capabilities needed in the digital era can be implemented by organizational routines, internal entrepreneurship or strategic investments – both tangible and intangible. These issues are studied actively in the manufacturing literature also (Gindy *et al.*, 2006; Jambekar and Pelc, 2006; Ungan, 2007). Traditionally manufacturing firms have had their focus on tangible investments that increase efficiency and operational flexibility (about manufacturing flexibility, see Sethi and Sethi, 1990; Ranga and Maliyakal, 1991; Browne *et al.*, 1984; Parker and Wirth, 1999; Boyle, 2006). Typical for the investments of digital manufacturing is that they are intangible, create new strategic options, and that the traditional investment evaluation tools (e.g. net present value and its derivatives) are invalid (Kaplan, 1986; Shank and Govindarajan, 1992).

The non-usefulness of traditional investment valuation methods puts great challenges on the analysis of manufacturing investments creating strategic flexibility as these investments are typically intangible and their form, functions, end products, not to mention expected cash flows, are difficult to estimate. And it is not always clear, when the improved flexibility pays back (if ever). Typical intangible investments in the

manufacturing firms include investments in multifunctional machinery, multiscale simulation, factory data management, digital design and prototyping, planning and coordinating systems, data bases, as well as investments in developing the routines of the organization, and capabilities of the personnel. As already discussed in the previous chapter, one alternative to solve the valuation problem is to develop strategic options-based framework either in its strong form of the real options theory to be used as a core valuation tool (Kyläheiko *et al.*, 2002; Cucchiella and Gastaldi, 2006), or in its more moderate forms as a ranking tool, heuristic or a metaphor. The roots of strategic options logic can be found in the following articles: Kogut (1991), Sanchez (1993), Bowman and Hurry (1993), McGrath (1997), Foss (1998), Kogut and Kulatilaka (2001), Bowman and Moskowitz (2001) and Miller and Folta (2002). Table II collects examples of investments with option features that help management in creating CA in the frame of dynamic capability view of manufacturing firm.

Traditional methods to respond to keen competition and external uncertainty have concentrated on manufacturing and vertical control of markets by final assemblies. Manufacturing firms have tackled market uncertainty with the use of different kinds of buffers or slack resources (inventories and excess capacity). Basically, these traditional approaches have worked reasonably well in simple oligopolistically controlled environment, which was typical a few decades ago. However, when the complexity of the environment increases and the dependence on partners and rivals grow, the rigid capital intensive vertical manufacturing sites and buffering against uncertainty become quite too expensive or even impossible. In this situation companies are forced to shift their strategic emphasis from the factory level to the management of the global supply chain (or preferably value net, see, e.g. Kuhn, 2006) that is extended both into the marketplace (downstream activities) and back into development (upstream activities). The downstream

Elements of dynamic capabilities	Capturing upside opportunities by means of asset selection using strategic options logic	Hedging downside risks with strategic options
1. Porterian positioning, external environment	Databases on customers, competitors, value net. Investments in research and development (R&D)	Learning options (R&D, customer basis), waiting and staging options, collaboration, coopetition
2. The nature of an industry, demand and supply conditions of the industry	Investments in economies on scale or scope (e.g. multifunctional machinery). Mergers, acquisitions	Investments on digital planning and coordinating systems, learning, waiting, switching and staging options (e.g. R&D)
3. Managing knowledge assets and organizational capabilities	Investments in VRIN attributes, i.e. professionals, best practice processes and routines	Long term human relations management, learning options (R&D), building absorptive capacity
4. Complementary resources and capabilities	Investments in acquisitions and collaborative relations. Developing supply and outsourcing strategy	Learning options, staging, waiting, contracting
5. Appropriability issues	Investments in patents, recruitments	Learning options, switching, contracting

Table II.
Dynamic capabilities and strategic options based framework for asset selection

activities are usually not linked to where the good is manufactured as contrary to the upstream activities that can have strong ties to the manufacturing operation.

3.3 Implementing strategic options-based framework in the digital manufacturing era

Based on our strategic framework introduced in Chapter 2 we next illustrate the steps behind various manufacturing strategy designs. The steps are as follows:

- to sense the weak signals;
- to recognize the underlying industrial structure (economies of scale and scope and network externalities);
- to proactively reconfigurate the existing knowledge base and capabilities; and
- to appropriate relevant knowledge.

The weak signals are captured from the competitive environment comprising of competitors, customers, end-users, suppliers and institutions. Weak signals in manufacturing are used both when specifying the manufacturing scope and when defining the role and position that the company has in the global supply or value net. Companies relying on the sensing of weak signals must consciously generate and develop intangible assets, i.e. persons specializing on complex environment scanning, on routines and capabilities supporting the processing of weak signals and on development of usable knowledge bases. One possibility to acquire options for sensing better the future could be investing in collaboration either with competitors, suppliers, end-users, institutions, or with partners coming from other industries.

To recognize the underlying industrial structure (economies of scale and scope and network externalities). The industry level demand and supply either has a critical mass for focusing, or offers possibilities to realize economies of scale. In mature industries economies of scale can be achieved either with investments in manufacturing and vertical integration or by mergers and acquisitions. In emerging industries the dominant standard provided either by regulators or by users can give the needed first mover's advantage to profit from the economies of scale and scope. The logic of industry determines the composition between tangible vs intangible assets when creating CA.

To proactively reconfigurate the existing knowledge base and capabilities means that companies relying traditionally on economies of scale have to find more innovative business models and reorganize their global supply chain and distribution channels more effectively, thus corresponding to the needs of digital era. Dell and Nokia can be used as pioneers. What is the very logic of creating most value-added and where in the value chain should the company be are the basic strategic issues that determine the orchestration of the global value chain and strategic moves within it. In the environment where market uncertainty is high the firm can aim at long-term customer contracts. This usually means investments in customer specific manufacturing or process lines and personnel.

To appropriate relevant knowledge means getting hold on intangible assets that include relevant knowledge for instance patents, trade secrets, tacit organizational knowledge, partnerships or business routines. The means with which to capture relevant knowledge for strategic options are research and development, personnel management and capital spending.

4. Conclusions and managerial implications

This paper introduced a theoretical framework based on the dynamic capability view and strategic options approach. The aim of the framework is to illuminate the determinants of the strategy implementation in the digital manufacturing era and this way help managers to make decisions creating CA. Table III collects the managerial implications from our ideas.

The management implements strategy via asset selection which aims at creating value in the chosen strategic focus areas. The main problems faced by the management are that there typically exist no well developed markets for strategically most important assets and that there are uncertainties that can seriously affect the strategic choices. When comparing tangible assets (e.g. machinery, plants) to intangible assets (e.g. patents, collaboration, tacit knowledge, and valuable, rare, inimitable, and non substitutable core capabilities) it can be argued that the carefully selected and developed intangible knowledge-related assets give greater flexibility than physical assets. When utilizing tangible assets there is a danger of sunk costs and a rigid structure. If this risk will be realized the company usually responds to it by cutting costs. In the longer run, this strategy most probably results in organizational anorexia where the capabilities relevant for sustainable CA are thrown away in the name of cost savings. In the digital era even the traditional manufacturing firm has to be ready for investing in new knowledge-related capabilities in order to maintain its competitive position amongst the rivals.

Implementing strategy with the framework	Create upside opportunities	Sources of downside risks
1. Porterian positioning, external environment, to sense the weak signals.	Look up opportunities from markets Position in niches to get monopoly power Use information outside firm	Internal resources not adjusted with external opportunities Resources and capabilities are not able to change (rigid structures, sunk costs)
2. The nature of an industry, demand and supply conditions of the industry, to recognize the underlying industrial structure	Be prepared to exploit either economies of scale or scope Use waiting and learning options to avoid sunk costs	Sunk costs arise when aiming at scale effects with large investments Sunk costs arise from investing in scope effects that have big technology or market uncertainty
3. Managing knowledge assets and organizational capabilities, to reconfigurate knowledge base and capabilities	Manage human resources proactively Enhance learning	Rigid structures and over investments
4. Managing complementary resources and capabilities, to reconfigurate knowledge base and …	Make alliances, mergers, collaborative and coopetitive relations Buy services from experts	Getting held up! Sunk costs
5. Appropriating relevant knowledge	Build active and sound contracting capability Commit and reward professionals in the company	Brain drain Data losses, security Regions with poor or unreliable regulation and legislation

Table III.
Managerial implications based on strategic options thinking

Despite the difficulties of building flexibility with tangible assets, companies often choose them instead of (perhaps more valuable) intangible knowledge assets. If only the tangible assets are developed, even with options logic involved, it represents the second phase of the earnings logic of manufacturing firms. This second-phase is the Japanese lean production model that can be seen as a start towards a much more disintegrated and demand-induced system. This is what we are witnessing now, i.e. the third "revolution" in the earnings logic of the manufacturing industry. Its two main drivers are globalization and the digitalized mode of production. The nature of manufacturing probably changes dramatically and the companies should be ready for responding to it. Our theoretical framework presented in this paper made a modest attempt to open up the challenges created by increasing knowledge intensity, globalization and high market and technological uncertainty.

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