Radical innovations from a dynamic capabilities point of view

A Hybrid-Modeling Approach to Generate Pseudo-Empirical Data

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Abstract:

Sustained competitive advantage is a major issue in the field of management research. A growing number of scholars utilize the Dynamic Capabilities View as a reason for over average performance and adaptability of a firm, especially to radical innovations that threaten a firm's survival. Due to the abstract character of the concept, the nature and impact of dynamic capabilities is still vague and empirical evidence is rare. This paper presents a formal simulation model that builds on previous work on the accumulation of dynamic capabilities to explore the micro foundations of the concept. To generate pseudo empirical data, a mixed agent based and system dynamics modeling approach is developed. The preliminary results suggest that further development of the method promises to be fruitful to understand the micro foundations of dynamic capabilities and their role for companies which face radical innovations.

Introduction

Neo classical microeconomic theory proposes above zero rents can not be achieved in a competitive market, especially not in the long term (Jacobson 1992). Still companies like General Electrics or Hewlett Packard managed to sustain not only positive but above average profits over long periods of time. Building upon the work of other strategy schools as the market or the resource based view, a lot of recent management research addresses to the dynamic capabilities framework in order to explain sustainable competitive advantage. While the market based view seeks for an explanation in the company's competitive environment, concerning industry structure and a firm's stra-

tegic market position as well as the build up of market entry barriers (Porter 1980), the resource based view stresses the importance of the company's internal capabilities and resources that allow a company to perform better than its competitors (Barney 1991; Henderson and Cockburn 1994; Wernerfelt 1984)

Both perspectives fail to explain sufficiently how those barriers can be held up over long periods of time and in dynamic contexts. Critics address the limits of both perspectives concerning this static nature that does not account for change, especially in dynamic environments as growing markets characterized by rapidly increasing returns (Eisenhardt and Martin 2000). In this context the implications of such a static approach can be very misleading (Merten 1991; Sterman et al. 2007). The dynamic capabilities view, though still based on the resource perspective, accounts for the mentioned limitations. Still valid in dynamic environments as high-technology industries, the perspective states that the competitive performance of a company is based on its ability to adapt to a quickly changing surrounding by reallocation and recombination of its resources – rather than just on the resources themselves (Teece, Pisano, and Shuen 1997).

Closely related to the questions raised by some companies' sustained success is the one asked by Christensen and his concept of disruptive innovations: why do great companies struggle or even fail when facing rapid technological change? (Christensen 1997). A company like Kodak was very successful over some time and managed to survive strong competition – mainly based on a strategy of innovation. Yet a technological innovation, in the case of Kodak digital photography, led to a severe crisis the company still seeks to recover from. This raises the question what distinguishes firms like Kodak, that were able to yield above normal returns on the mid range from the one sustaining their competitive advantage on the long run as General Electrics. According to the dynamic capabilities perspective the latter companies possess higher level capabilities enabling them to modify their operational capabilities and build new ones faster in the face of a changing competitive landscape (Eisenhardt and Martin 2000; Teece, Pisano, and Shuen 1997).

Literature review and hypothesis development

Companies that have survived an industry shake-out process have adapted to the market setting through a trial and error process, analogue to the organizational learning described by March (1994). The history of trial and error is closely linked to the exploitation of an existing technology. The very question in this context is, why do these firms that have survived harsh competition, accomplished to adapt to a dynamic environment, created dynamic capabilities (Stamboulis, Adamides, and Malakis 2002) and emerged as dominant competitors loose their position or even fail at a high rate when facing another phase of discontinuous technological change (Barnett and Pontikes

2006; Spencer, Kirchhoff, and White 2008). There are numerous examples of market leaders like Kodak that, though dominant with classic lithographic photography, failed to play a similar role within the following market.

Henderson and Clark (1990) identify a difference in the organizational capabilities required by a company facing incremental or radical innovations as a cause for failure of former leaders. A radical innovation destroys the usefulness of an established company's specific knowledge and organizational structure. The characteristic of initial inferiority or unrealized potential of a discontinuous innovation makes it especially hard for successful companies to recognize its destructive power and to react in time. Like a competency trap in organizational learning, processes and routines remain unchanged because of their success, thereby hindering an exploration of new alternatives (March 1991, 1994). In the context of initially inferior but eventually superior technologies this has severe consequences for the corporation.

Barnett and Pontikes (2006) find empirical evidence for their hypothesis that a history of survived fierce competition in one context makes moving into a new context even more hazardous in data from the U.S. computer history. In concurrence with these results a simulation model based on the work of Tushman and Romanelli (1985) shows that the structure enabling a companies competence and success in one context, causes its inertia and reduced capability to adapt to a radically changed environment (Sastry 1997). Rahmanadad (2007) finds that one reason for this is the prevailing myopic allocation of investment and resources to operational capabilities instead of building up dynamic capabilities. This effect is amplified by strong competition and the delayed impact on performance of investment in higher order capabilities. Looking at these insights from a dynamic capabilities point of view, a first hypothesis is proposed:

> *Hypothesis 1: Adapting to a specific context efficiently leads to gradual erosion of an organization's dynamic capability over time, impeding adaptation to a radically new context.*

Following the above findings, a firm's history has a dominant influence on its future. Organizational ecologists therefore argue that strong path dependency limits the strategic options for the actual management, if there are any, to the very early stages of a firm's history (Carroll and Hannan 2000). Considering this, dynamic capabilities can not be build up but only born during the foundation of a company (Winter 2003). Augier and Teece (2008) do not reject this completely, but argue for a definition of strategy as evolution with design. A company's path therefore is not completely bound to prior decisions and investments and can be influenced by its management. This is supported by examples of companies such as IBM, which were able to respond to a crisis caused by a fundamental change of their environment – in this case the transition of the computer market from mainframes to personal computers (Sterman 2000) – through a new orientation, hardly rooting in the creation of the organization. Rigid mental models of experienced and formerly successful

managers are responsible for a lack of adaptation rather than a general impossibility of actively managed change (Weil 2004).

Facing the challenge of a radical innovation, researchers recently have identified the need for an ambidexterity of a firm's organization, enabling for excellence in explorative as well as in exploitative tasks (Assink 2006 ; O'Reilly and Tushman 2007). Inertia is useful to complete the day-to-day tasks of an organization efficiently but a firm needs the ability to overcome this inertia when adaptation is needed. Feldman and Pentland (2003) challenge the traditional understanding of organizational routines as creating inertia in organizations, arguing that organizational routines can be a source of change as well as stability. This is in line with Winter's (Winter 2003) definition of dynamic capabilities as 'high level routines' that govern the change of ordinary capabilities. One example of a company overcoming its inertia for a limited period of time, without seriously damaging the basis of daily tasks, is the 'Innovation Jam' IBM has established to make use of their employees ideas and creativity. For a few days all employees are encouraged to discuss on strategic topics, highly relevant for the company's future (Bjelland and Wood 2008). While the 'Innovation Jam' origins from a dynamic capability it is not necessarily one in itself. It reflects an increase of IBMs organizational capability, a change of the organizational structure enabling employees to be more creative outside of their day-to-day business, yet without reducing the efficiency of their routines. Based upon this argumentation a second hypothesis is proposed:

> *Hypothesis 2: Dynamic capabilities enable an organization to overcome its inertia, when necessary.*

Research Design

Due to the conceptional nature of the perspective it has so far proven a tough task to empirically determine the nature of dynamic capabilities or examine their impact on firm performance. Nevertheless the framework enables researchers as well as managers to look at the ability of an organization to adapt and to stay alert in the face of a changing environment. In addition the generic character allows applying the concept globally, not limited to specific examples. This seems reasonable, since strategically significant capabilities of an organization are by definition hard to describe or measure (Barney 1991; Nelson 1991), otherwise they could not be an enduring source of competitive advantage (Henderson and Cockburn 1994).

The hypotheses postulated in this paper share the abstract character of the approach since it is one aim of the further research to clarify some theoretical aspects in the understanding of dynamic capabilities. Therefore a system dynamics model – that accounts for conceptional factors and allows examining their dynamic interaction – helps to understand and discuss the theoretical character of dynamic capabilities as well as their impact on firm performance. As every formal model

is a set of hypotheses, the structure of a system dynamics model is a collection of structural hypothesis from which dynamic behavior emerges. Even though single hypotheses might seem reasonable and fairly simple, their interplay and connection is complex enough to make prediction of behavior a tough task. The simulation of a formal model helps in the understanding of its structure and above that makes the hypotheses implied in it testable and available for validation. Above that, simulation experiment enable for an examination of the impact of dynamic capabilities hardly available in real world setting – due to the abstract character of the framework. To test the hypotheses, we built a generic simulation model, whose structure is based on previous work on the nature and the accumulation of dynamic capabilities, innovation literature and several system dynamics studies. The simulation contains several heterogeneous firms competing in a high technology market, allowing for entry of new competitors and exit of incumbents.

Presentation of Model Structure

A model addressed to a similar question able to generate this behavior and explain the generic dynamics of such a market is presented by Weil and Utterback (Weil and Utterback 2005). Their approach is an aggregated view on the market, which focuses on the macrostructure of dynamic industries. The presented model mixes an agent-based and a system dynamics approach to explore the micro-foundations of dynamic capabilities. In cases where empirical data is hard to obtain or the research objective is as abstract as dynamic capabilities, agent-based modeling has proven useful in order to create pseudo-empirical data (Axelrod 2006; Weitert 2007).

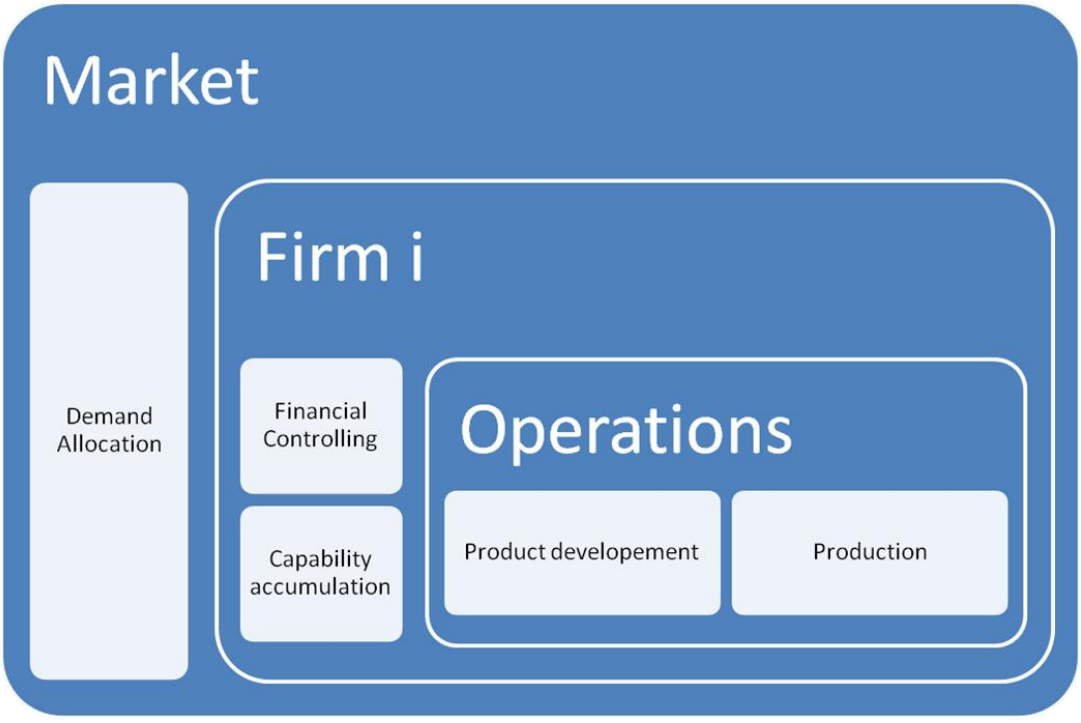

Figure 1: Structural Overview of the Model

The internal decisions and processes of each firm are modeled in continuous manner as a stock-flow diagram, while each firms acts as an individual agent on the market. Figure 1 illustrates the modularized structure of the Model.

The model is divided into 5 main modules:

- the market place, where demand is allocated due to relative performance of the firm, and where all agents compete for the market potential
- a financial controlling monitor where each firm's operative result, its survival and investment is determined
- the capability sector which controls each company's accumulation of dynamic and operational capabilities
- the product development module, representing the R&D activities of each agent
- a production sector, describing the value creation processes of each firm

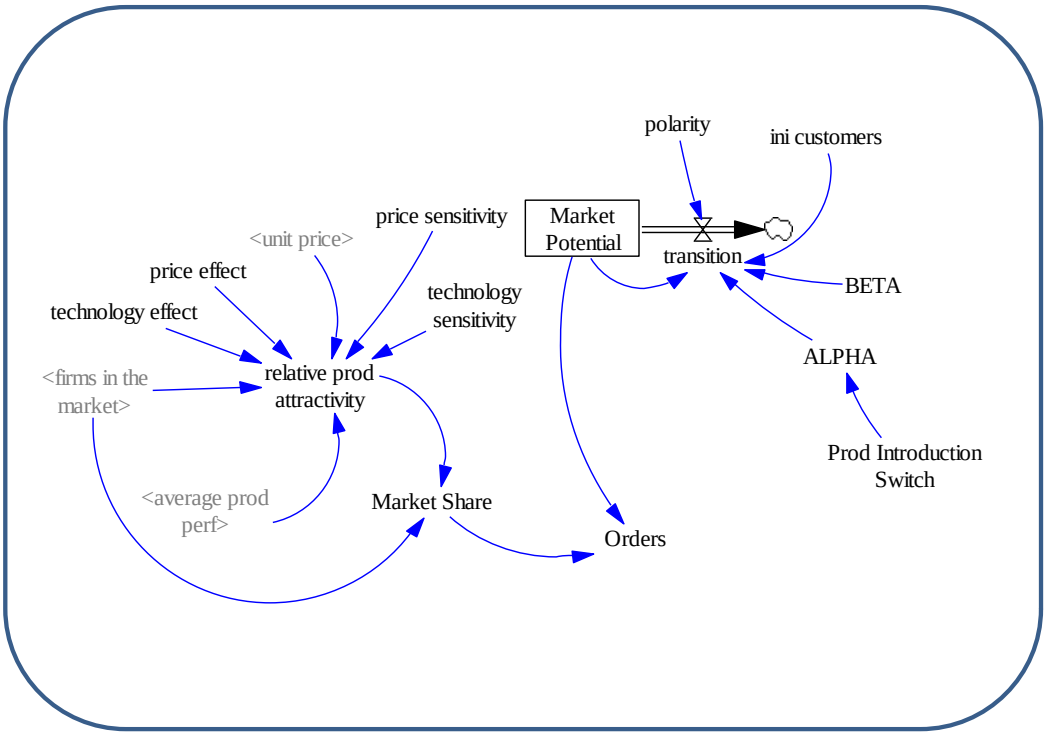

Figure 2: The market module

Market Sector

Since the demand allocation process is not under research – the main task of this sector is to make the performance impact of different capability levels among agents comparable – its incorporation

in the model is rather simple. The individual market share is a function of each firm's *relative product attractiveness*, which result from its price compared to the average market price and its relative technological performance. The transition of the market potential in between product generations is portrayed as a simple bass diffusion process (Thun, Größler, and Milling 2000). Figure 2 shows the stock and flow structure of the simplified market process.

Financial Controlling

This part of the model calculates the operating figures of each company and governs market entry and exit due to bankruptcy. The entry rate is exogenous at this stage of the modeling process, though entry based on market growth and intensity of competition – as proposed by Weil and Utterback (2005) – will be considered for future versions of the model. Upon market entry each firm receives an initial start-up capital to start its operations. From this point on the company's capital is determined by the operating result, which is a function of its turnover from sales reduced through cost of operations and investment in R&D and capability accumulation. The unit price is defined through a mark-up on the individual's variable unit costs. Additional to the mere calculation of these management ratios the market exit of a firm is dependent on its financial resources. If the stock of *Capital* decreases to zero, the agent is considered as insolvent. Figure 3 illustrates the structure of this part of the model.

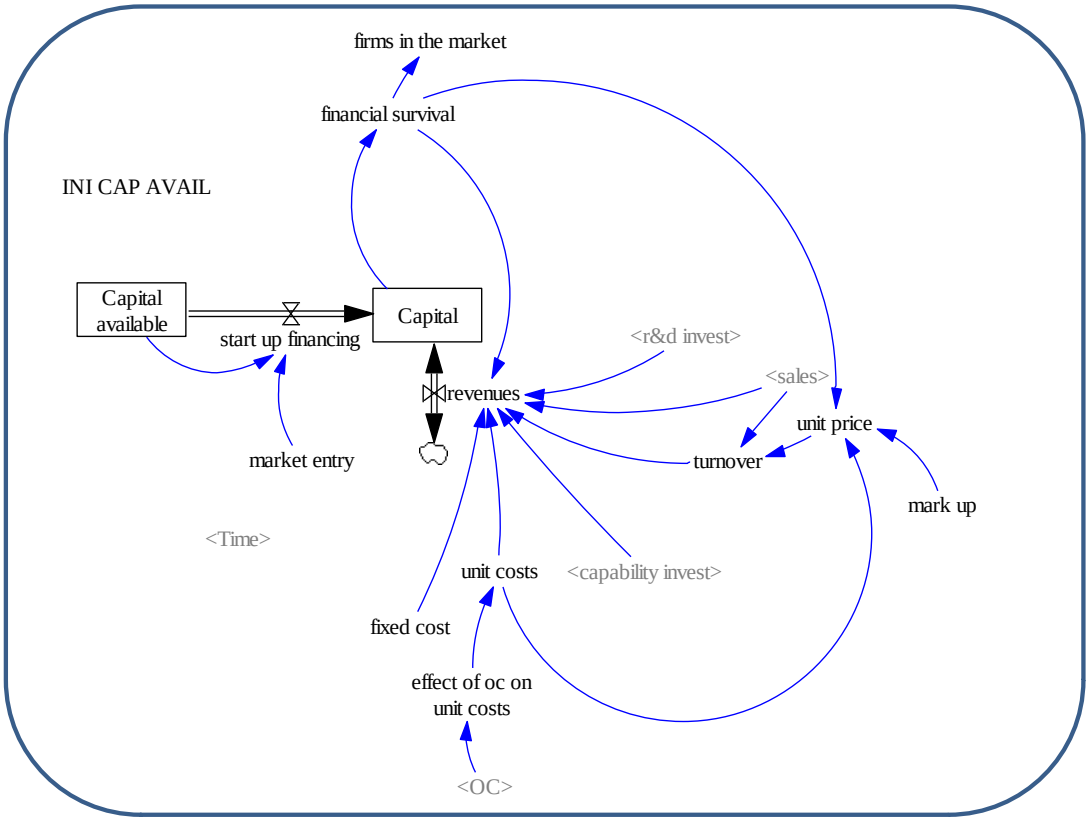

Figure 3: Stock and flow structure of the financial model sector

Capability accumulation

As mentioned above, dynamic capabilities are often described as higher level capabilities enabling a firm to modify its operational capabilities and build new ones faster in the face of a changing competitive landscape (Eisenhardt and Martin 2000; Teece, Pisano, and Shuen 1997). Winter (2003) adds that "[...] dynamic capabilities govern the rate of change of ordinary capabilities." Therefore the efficiency of the accumulation process of organizational capabilities in the model is influenced by the level of each firm's dynamic capabilities. Since generation of organizational capabilities are said to result from the repeated execution of specific routines and learning as well as financial investment it seems reasonable to model them as stocks (Chirico and Salvato 2008; Rahmandad and Repenning 2008). Processed R&D development tasks – product development is considered as an example for a dynamic capability (Winter 2003) – are one input factor for the routine generation and accumulation of *DC.* In contrast operational capabilities evolve from the firm's day-to-day business and are therefore increased by the company's experience with the production process.

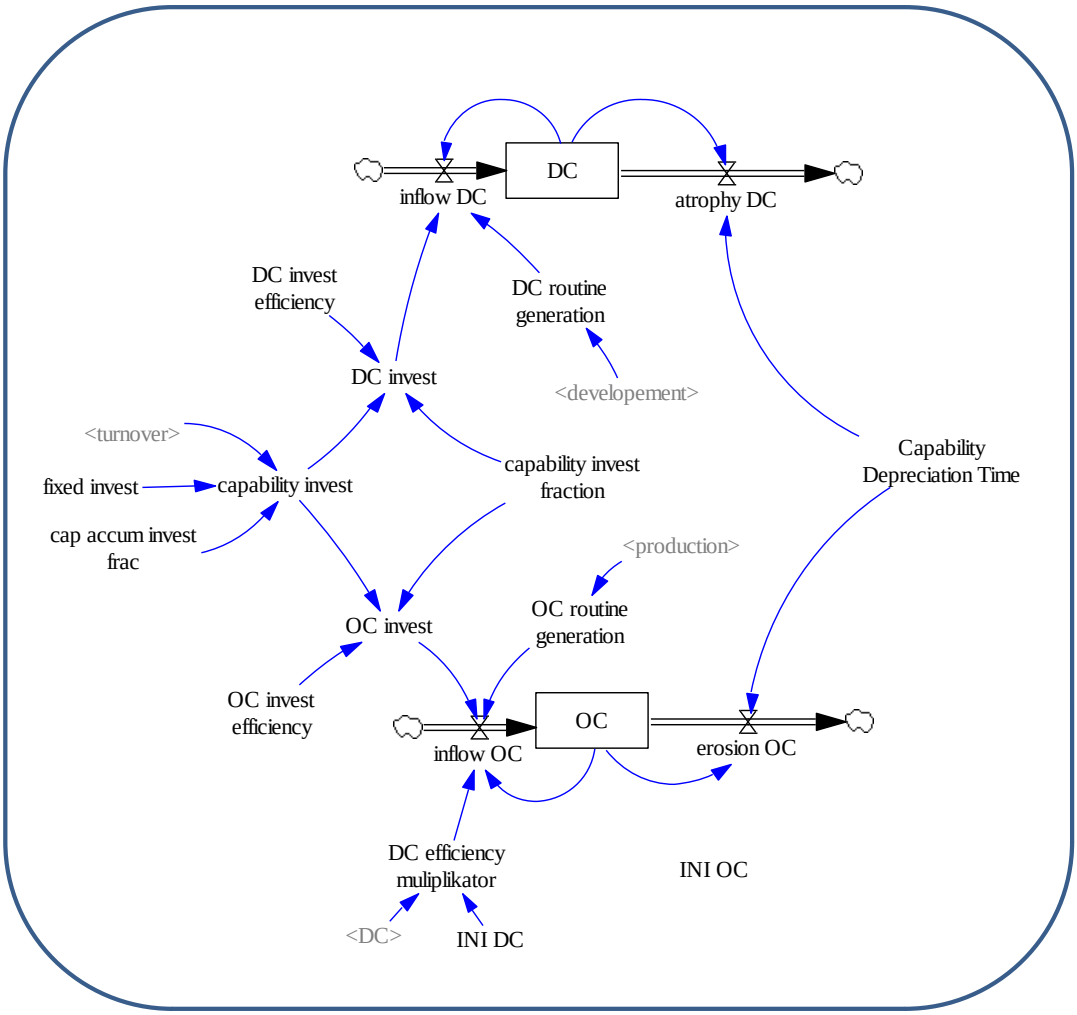

Figure 4: The capability accumulation process

As illustrated by Figure 4 the capability accumulation process is not only dependent on the organizational routine generation, but the direct investment of resources. For simplification reasons only the allocation of financial resources is considered. The dependence of capability generation on endogenous resources acquired through the firm's operations incorporates the positive feedback of the accumulation process in the model.

Production and product development

The organizational capabilities affect both product development and operational performance. The two operational modules are displayed by Figure 5 and 6. While the product

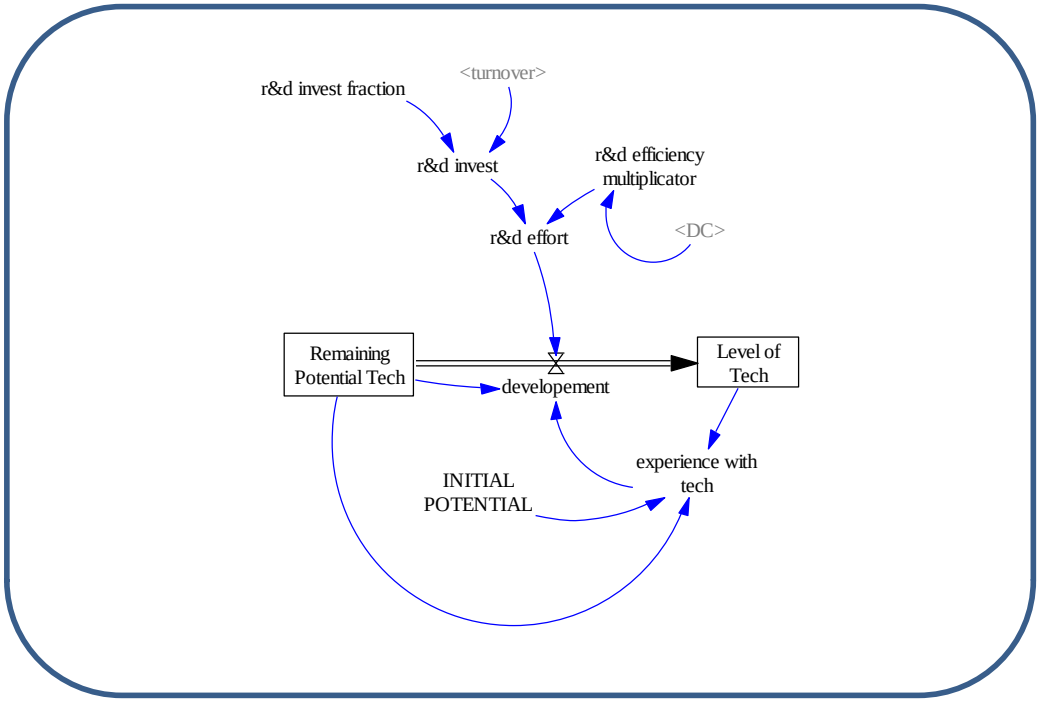

Figure 5: The stock and flow formulation of the R&D process

development is a basic structure to generate the s-shaped growth of technology exploitation processes (Foster 1986), the production process is modeled as a simple co-flow to generate the product performance attribute that determines the *relative product attractiveness*.

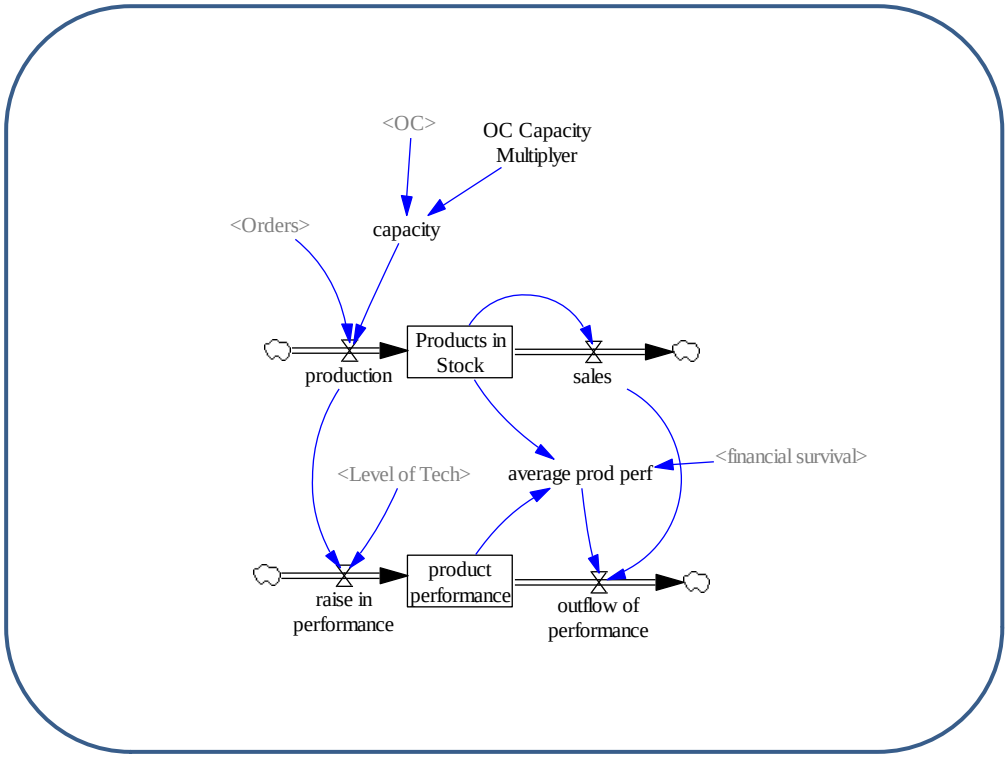

Figure 6: Stock and flow diagram of the production process

Preliminary Results and further Development

To generate pseudo empirical data, all firm specific variables are subscripted to allow the structural reproduction of the internal processes for all companies. Exogenous input parameters like the investment fraction in dynamic capabilities, market entry time, and technology transition time were altered with random numbers to generate a large artificial sample (10000 simulation runs with a maximum number of 34 firms in the market). Considering firm performance investment in dynamic capabilities has a significant positive effect. The optimal investment fraction depends on the intensity of competition with product one and the point of time when new firms enter the market with the following product generation. Over all simulated scenarios an average investment fraction of 0.24 of total invested financial resources to dynamic capabilities seems optimal.

Despite these preliminary results, the quality and validity of the data output is so far not sufficient to comprehensively test the hypotheses postulated above. Therefore further development of the model structure and statistical analysis is necessary. Nevertheless the hybrid modeling approach promises to be fruitful for the further understanding of the micro foundations of the concept of dynamic capabilities.

Bibliography

Assink, Marnix. 2006 Inhibitors of Disruptive Innovation Capability: a Conceptual Model. *European Journal of Innovation Management* 9 (2):215 - 233.

Augier, Mie, and David J. Teece. 2008. Strategy as Evolution with Design: The Foundations of Dynamic Capabilities and the Role of Managers in the Economic System. *Organization Studies* 29 (8-9):1187-1208.

Axelrod, Robert. 2006. Advancing the Art of Simulation in the Social Sciences. In *Handbook of Research on Nature Inspired Computing for Economy and Management*, edited by J.-P. Rennard. Hersey, PA: Idea Group.

Barnett, William P., and Elizabeth G. Pontikes. 2006. The Red Queen, Success Bias, and Organizational Inertia. Stanford Graduate School of Business: Stanford Business School.

Barney, Jay. 1991. Firm Resources and Sustained Competitive Advantage. *Journal of Management* 17 (1):99.

Bjelland, Osvald M., and Robert Chapman Wood. 2008. An Inside View of IBM's 'Innovation Jam'. *MIT Sloan Management Review* 49 (1):32-40.

Carroll, Glenn, and Michael Hannan. 2000. *The Demography of Corporations and Industries* 1ed. Vol. 1. Princeton, NJ: Princeton University Press.

Chirico, Francesco, and Carlo Salvato. 2008. Knowledge Integration and Dynamic Organizational Adaptation in Family Firms. *Family Business Review* 21 (2):169-181.

Christensen, Clayton M. 1997. *The Innovator's Dilemma: When New Technology Causes Great Firms to Fail*. Boston, MA.: Harvard Business School Press.

Eisenhardt, Kathleen M., and Jeffrey A. Martin. 2000. Dynamic Capabilities: What are they? . *Strategic Management Journal* 21 (10/11):1105.

Feldman, Martha S., and Brian T. Pentland. 2003. Reconceptualizing Organizational Routines as a Source of Flexibility and Change. *Administrative Science Quarterly* 48 (1):94-118.

Foster, Richard. 1986. *Innovation - The Attacker's Advantage*. New York: Summit Books.

Henderson, Rebecca, and Iain Cockburn. 1994. Measuring Competence? Exploring Firm Effects in Pharmaceutical Research. *Strategic Management Journal* 15:63-84.

Henderson, Rebecca M., and Kim B. Clark. 1990. Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. *Administrative Science Quarterly* 35 (1):9-30.

Jacobson, Robert. 1992. The "Austrian" School of Strategy. *Academy of Management Review* 17 (4):782-807.

March, James G. 1991. Exploration and exploitation in organizational learning. *Organization Science* 2 (1):71-87.

———. 1994. *A primer on decision making: How decisions happen*. New York.

Merten, Peter P. 1991. Loop-Based Strategic Decision Support Systems. *Strategic Management Journal* 12 (5):371-386.

Nelson, Richard R. 1991. Why do Firms differ and how does it matter? *Strategic Management Journal* 12:61-74.

O'Reilly, Charles A. III, and Michael L. Tushman. 2007. Ambidexterity as a Dynamic Capability: Resolving the Innovator's Dilemma. Harvard Business School.

Porter, Michael E. 1980. *Competitive strategy*. 1 ed. Vol. 1. New York: Free Press.

Rahmandad, Hazhir. 2007. Why myopic policies persist? Impact of growth opportunities and competition. 25th International Conference of the System Dynamics Society, at Boston.

Rahmandad, Hazhir, and Nelson Repenning. 2008. The Dynamics of Capability Development and Erosion. Virginia Tech.

Sastry, M. Anjali. 1997. Problems and Paradoxes in a Model of Punctuated Organizational Change. *Administrative Science Quarterly* 42 (2):237-275.

Spencer, Aron S., Bruce A. Kirchhoff, and Craig White. 2008. Entrepreneurship, Innovation, and Wealth Distribution: The Essence of Creative Destruction. *International Small Business Journal* 26 (1):9-26.

Stamboulis, Yeoryios A., Emmanuel D. Adamides, and Thomas E. Malakis. 2002. Modeling the Product-Process R&D Dynamics. Proceedings of the 20th International Conference of the System Dynamics Society, July 28 - August 1, at Palermo, Italy.

Sterman, John D. 2000. *Business Dynamics : Systems Thinking and Modeling for a Complex World*. Boston: Irwin/McGraw-Hill.

Sterman, John D., Rebecca Henderson, Eric D. Beinhocker, and Lee I. Newman. 2007. Getting Big Too Fast: Strategic Dynamics with Increasing Returns and Bounded Rationality. *Management Science* 53 (4):683-696.

Teece, David J., Gary Pisano, and Amy Shuen. 1997. Dynamic Capabilities and Strategic Management. *Strategic Management Journal* 18 (7):509-533.

Thun, Jörn-Henrik, Andreas Größler, and Peter M. Milling. 2000. The Diffusion of Goods Considering Network Externalities:

A System Dynamics-Based Approach. Proceedings of the 18th International Conference of the System Dynamics Society, at Bergen.

Tushman, Michael L., and Elaine Romanelli. 1985. Organizational evolution: A metamorphosis model of convergence and reorientation. In *Research in organizational behavior, 7*, edited by L. L. Cummings and B. M. Staw. Greenwich, CT: JAI Press.

Weil, Henry B. 2004. Disrupting Mature Markets with Innovative Technology. 22nd International Conference of the System Dynamics Society, July 25-29, at Oxford, England.

Weil, Henry Birdseye, and James M. Utterback. 2005. The Dynamics of Innovative Industries. Proceedings of the 23rd International Conference of the System Dynamics Society, at Boston.

Weitert, Christian. 2007. Analysis of Investor Behavior in an Artificial Stock Market. Proceedings of the 25th International Conference of the System Dynamics Society, at Boston.

Wernerfelt, Birger. 1984. A Resource-based View of the Firm. *Strategic Management Journal* 5 (2):171-180.

Winter, Sidney G. 2003. Understanding Dynamic Capabilities. *Strategic Management Journal* 24 (10):991-995.