DYNAMIC MODEL IN UNDERSTANDING DYNAMICS OF COMPETITIVENESS: SYSTEM DYNAMICS APPROACH IN MOBILE HANDSET VENDOR BUSINESS

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Understanding firm’s competitiveness is the central goal in strategic management. The resource based view has emerged as the main theory explaining performance differences between firms. However, a significant amount of criticism the theory has been raised against the theory and the validity of the theoretical framework has been questioned. These questions have become stronger as there is a lack of credible empirical validation due to the problematic concepts and measures used in the theory. Dynamic RBV theory has emerged to overcome challenges in the traditional RBV theory but the new theory has proven to be challenging to implement as it sets new challenges for the used research methodology. In this study, system dynamic simulation was used to overcome these challenges in an empirical case study on the competitiveness in the mobile handset vendor business. The results from simulation give support for both the created dynamic RBV framework, but also to the suitability of system dynamic simulation as a tool in strategic management research.

Keywords: Strategic management, Resource based view, System dynamics, Mobile handset vendor business

1 Introduction

The common goal of strategic management has been to understand why some firms perform better than their competitors. A variety of different major theoretical frameworks have been created to explain the competitiveness differences between firms (Porter, 1985; Barney, 1991; Williamson, 1999). The resource- based view of the firm (RBV) (Wernerfelt, 1984; Barney, 1991; Peteraf, 1993), or sometimes referred to even as the resource- based theory (Grant, 1991; Kogut & Zander, 1992), has prevailed as one of the most significant theoretical frameworks (Kor & Mahoney, 2000). The basic argument of the RBV is that firms are internally heterogeneous, and this resource heterogeneity explains the performance differences between the firms.

The RBV has been widely accepted in the academic and the business world. However, the discussion on the validity of the theory still remains an issue. Despite heavy empirical research on the topic, there is not yet undisputed evidence of the validity of the RBV theories (Barney & Arikan, 2001; Armstong & Shimizu, 2007; Newbert, 2007). The lack of empirical evidence combined with the significant theoretical criticism (Priem & Butler, 2001a; Bromiley & Papenhausen, 2003; Foss, 2005; Sirmon et al., 2008) has led to questions about the suitability of the RBV as a scientific theory (Sanchez, 2008), and implicitly also about its managerial usability (Williamson, 1999; Priem & Butler, 2001a; Lado et al., 2006). One major problem area in previous RBV research has been identified to be related to the used empirical research methodologies (Armstong & Shimizu, 2007; Newbert, 2007; Lockett et al., 2009). As the RBV has become such an important part of today's strategic management, the criticism points need to be analyzed to determine if the RBV truly is a viable theoretic framework to explain the performance differences between firms, or if new theoretical foundations are needed to understand the phenomenon.

On the conceptual level, the dynamic RBV (Dierickx & Cool, 1989; Teece et al., 1997; Helfat & Peteraf, 2003; Teece, 2007) proposes a significant development step to the original RBV theory. The dynamic RBV proposes significant shift in the RBV logic, as it suggest that the focus of research should be changed from assessing the firm's resource base to the flows increasing and decreasing this base. As such, the dynamic RBV does not challenge the logical framework created in the competence- based view, but it offers an interesting and novel perspective to address this framework. The introduction of the dynamic RBV creates an opportunity for researchers to understand the dynamics involved in strategic management, identified by Ghemewat and Cassiman (2007) as a major challenge for future strategic management research. So far, empirical research based on the dynamic RBV has been scarce, as the framework has proven to be hard to operationalize by traditional research methodologies (Armstong & Shimizu, 2007; Newbert, 2007).

The challenge of research methodologies in strategic management research has been recognized by system dynamics researchers. The suitability of system dynamics as a research tool for strategic management research has been argued by several researchers (Morecroft, 2002; Warren, 2005), but actual modeling on the topic has remained scarce. The fit between system dynamics and strategy research has been further argued by Gary el al. (2008), who identify that the raise of the dynamic RBV and the challenges it poses on empirical research are strongly aligned with the properties of system dynamics. This opens an interesting gap inside strategic management research, where system dynamics could be used to build understanding on the sources of sustained competitive advantage from the dynamic RBV perspective.

The goal for this research paper is to introduce an empirical system dynamic model that aims to simulate the dynamics of competitiveness of the big five players in the mobile handset vendor business over the years of 1997-2007. The selected five companies are Ericsson (Sony-Ericsson), LG, Motorola, Nokia, and Samsung. Firm's competitiveness is operationalized as the firm's market share of the global mobile handset vendor business.

Firm’s competitiveness is measured by using data of each firm’s yearly patenting and product launch activities.

The rest of the paper is organized so that first there will be a short literature review to RBV and RBV criticism. This discussion is followed by an introduction to the dynamic RBV framework and to the challenges it poses from research methodology perspective. The third chapter describes the conducted empirical research and results. The final chapter concludes the findings of this research.

2 RBV

The basic argument of RBV framework is that “…firms obtain sustained competitive advantages by implementing strategies that exploit their internal strengths, through responding to environmental opportunities, while neutralizing external threats and avoiding internal weaknesses” (Barney, 1991, p.99). RBV was described as a theory of rents which are based on resource market imperfections (Amit & Schoemaker, 1993). Several high profile studies (Amit & Schoemaker, 1993; Peteraf, 1993) followed Barney’s work, contributing to a fast growing body of literature on the RBV. Empirically the RBV theory built on a growing number of empirical studies showing that firm heterogeneity could explain the performance differences better than the market conditions under which the firm’s operate (Cool & Schendel, 1988; Rumelt, 1991).

According to Barney (1991), the sources of sustained competitive advantage are the so called VRIN resources. These resources were defined to be valuable, rare, immobile, and non-substitutable, which enable the firm to enjoy long-term superior performance. This framework was based on two main assumptions: firms are internally heterogeneous in terms of the strategic resources they control, and resources are imperfectly mobile, thus allowing long-term firm heterogeneity (Barney, 1991). The immobility of the resources as a partial source for sustained competitive advantage was also argued by Peteraf (1993), who identified that sustained competitive advantage is built on firm heterogeneity, immobility of resources, ex post limits to competition, and ex ante limits to competition. When comparing the frameworks by Barney (1991) and Peteraf (1993), a notable similarity between these frameworks is the role of immobility. Immobility of resources is required in order to gain access to the sustainability construct, which is enabled by the firm’s ability to protect its unique resource base. Although Peteraf’s (1993) framework has also received notable recognition in the academic community, Barney’s VRIN framework can be regarded as the standard framework in research.

2.1 Criticism of RBV

The RBV became the dominant approach in strategic management after its introduction in the early 1990s, but the criticism on the approach was quiet for a notably long period (Sanchez, 2008). Despite some early critics (Conner & Prahalad, 1996), the first true wave of RBV criticism came in the late 1990s and early 2000s by a wide range of researchers (Williamson, 1999; Priem & Butler, 2001a; Foss & Knudsen, 2003). The first wave has been followed by a significant number of critical appraisals on the RBV that focus on a theoretical debate (Lado et al., 2006; Sanchez, 2008; Lockett et al., 2009; Kraaijenbrink et al., 2010) and reviews of the empirical validity of RBV theories (Armstong & Shimizu, 2007; Newbert, 2007). The problems in the RBV derive from its quickly laid foundations that have led to problems in defining what does or does not belong to the RBV, and some central pieces of what seem to be missing in the literature (Foss & Knudsen, 2003). The result of this criticism is that questions have been raised of the suitability of the RBV as a scientific theory (Priem & Butler, 2001a) and its practical usability to support managerial decisions (Williamson, 1999; Priem & Butler, 2001a). In this chapter, the RBV criticism is classified into five main categories: 1) theoretical background assumptions, 2) conceptualization of VRIN resources in the RBV, 3) lack of a causality chain between resource and performance, 4) fundamental problems in empirical RBV research, and 5) research design in empirical RBV research. The discussions on these criticism points are followed by a short summary of criticism.

2.1.1 Criticism on the conceptualization of VRIN resources in the RBV

The VRIN framework has received a significant amount of criticism in strategic management discussion. The criticism has focused on the overall tautologies in defining VRIN resources (Priem & Butler, 2001a; Priem & Butler, 2001b), but also to the assumptions and problematic definitions in its components (Williamson, 1999; Sanchez, 2008). The challenging VRIN conceptualization has caused problems in measurement of resources, which has caused that most of the empirical RBV research has been based on ex post rationalization, where the winner has been already known (e.g. Sanchez, 2008). In addition to the direct criticism towards the VRIN framework, some debate has focused also on the restrictions of the framework. First, the framework has been seen to analyze only single resources, neglecting the interconnections between resources (Grant, 1996; Kor & Leblebici, 2005; Teece, 2007). The common denominator behind this criticism is that it is not the value of an individual resource, but the synergistic combination of resources that create value for the firm. Secondly, the deployment of resources is not covered in the VRIN logic (Kraaijenbrink et al., 2010). This argument states that mere possession of resources is not sufficient to build sustained competitive advantage, but the resources need to be deployed to achieve performance (Peteraf, 1993; Barney & Arikan, 2001; Priem & Butler, 2001a; Sirmon et al., 2008). Thirdly, Barney's view on sources of sustained competitive advantage is approached too directly, as Foss and Knudsen (2003) argue that the *necessary* and *additional conditions* in building sustained competitive advantage must be separated. Their (Foss & Knudsen, 2003) argument is that the two necessary conditions are *uncertainty* and *immobility*, where immobility is the central determinant of competitive advantage. This approach by Foss and Knudsen (2003) argues that heterogeneity, unique strategy, and informational inefficiency, which are the central pieces in RBV, do not need to exist in order to achieve sustained competitive advantage. The high amount of criticism against this framework is worrying, as most of the current empirical studies on the RBV are based on the VRIN conceptualization as defined by Barney (1991). In this chapter, the criticism to each proponent of VRIN is presented separately, after which the effects of these criticism points to the empirical validity of the RBV are assessed.

2.1.2 Criticism on the chain of causality

The basic argument in the RBV is that the possession of strategically valuable resources leads to a firm's performance. However, the understanding on how the resources actually contribute to a firm's competitiveness is minimal in the RBV (Priem & Butler, 2001a; Bromiley & Papenhausen, 2003), black box of the RBV (Priem & Butler, 2001b; Sirmon et al., 2007) or a lack of chain of causality (Sanchez, 2008). The discussion on this causality chain has not been only static, but the research has focused also on the dynamics of how a resource turns to competitiveness in dynamic capabilities discussions (Sirmon et al., 2007; Sanchez, 2008). The lack of a causal chain is a significant challenge for RBV framework as it prevents systematic management of resource implementation (Sanchez, 2008), which is the main practical value of the RBV as a managerial tool.

The problems from the lack of chain of causality can also be seen in the empirical RBV literature, where testing has been performed by identifying the firm's resources, but also through measuring either the firm's capabilities or its core competences (Newbert, 2007). The use of a firm's capabilities or core competences as measures can be seen to be closer to performance than resources in the causal link between a resource and performance, and thus the gap between the measured and predicted object is shorter. This shortened gap is evident also in empirical studies, as the studies based on measurement of resources show significantly worse support for the RBV than studies based on measuring capability (Newbert, 2007). This finding can be interpreted with two significantly different views. Either resources cannot explain performance as well as capabilities, or this shows the problem that arises from inadequate understanding of the causal chain between resources and performance.

2.1.3 Criticism on research design in empirical RBV research

The execution of empirical RBV research has also been under significant discussion, if not directly criticized. The source of this discussion is apparent in the strongly divided views on the validity of the RBV in literature reviews about empirical research in the area. Where Barney and Arikan (2001) argue that only 2% of the results are at least partially inconsistent with the RBV logic, thus giving clear support to RBV theories, more recent literature reviews (Armstong & Shimizu, 2007; Newbert, 2007) highlight the mixed support from empirical tests for the RBV logic. These mixed findings show significant methodological problems in empirical RBV research, which were further corroborated by Newbert (2007) who found in an extensive literature review on empirical RBV studies that there are significant differences in the support for RBV based on applied research methodology. Armstrong and Shimizu (2007) approach this same problem by assessing the overall methodologies used in empirical RBV research. On the basis of these literature reviews, four main problems in the empirical research methods in RBV research can be identified: operationalization of the dependent variable, operationalization of independent variables, selection of sample, and collecting data.

The problematic conceptualization in RBV inevitably leads to problems in the operationalization of independent variables. A wide spectrum of different ways to operationalize resources or capabilities have been used, leading to a scattered field of empirical research (Newbert, 2007), which makes the comparability of the studies more complex. Newbert (2007) notes that the empirical RBV research is heavily dependent on the traditional theory of Barney (1991), which is reflected in the high number of empirical research based on resource heterogeneity. The introduction of the dynamic perspective to the RBV has opened interesting opportunities for strategic research (Armstong & Shimizu, 2007; Newbert, 2007), but the research based on this approach has remained scarce, partly because of the methodological challenges related to this research approach (Newbert, 2007).

The traditional way to execute an empirical RBV study is to use cross-sectional analysis on a large sample observations with secondary data (Rouse & Daellenbach, 1999). Rouse and Daellenbach (1999) highlight the importance of case selection. Case selection is usually done by screening for suitable case companies from multiple industries, a selection logic criticized by Rouse and Daellenbach (1999). They continue that research based on such case selection is likely unable to separate the effects from industry, environment, or firm strategy, and thus fails to identify the source of sustained competitive advantage (Rouse & Daellenbach, 1999). For these reasons, carefully selected field-based comparisons are more likely to produce a detailed enough level and richness of data for analysis. However, several researchers (Makadok & Walker, 2000; Levitas & Chi, 2002) have identified that large sample studies have their benefits and should not be neglected by researchers. Rouse and Daellenbach (2002) later responded to the criticism by Levitas and Chi (2002) and specified that large sample methods should not be neglected, but used in conjunction with methods that allow the use of richer data. Sample selection becomes even more complex if the earlier suggested longitudinal approach is implemented. As no apparent solution for this problem exists, Armstrong and Shimizu (2007, p.962) set the challenge for future RBV research, when they call for "creatively operationalized constructs" to further the understanding on sustained competitive advantage. The practical implication of this statement is that researchers need to find new ways to collect the relevant data for RBV research.

2.1.4 Criticism on fundamental problems in empirical RBV research

In addition to direct criticism, the RBV has also been criticized on a more fundamental level. These fundamental problems cause significant challenges to the scientific research of the RBV (Sanchez, 2008), which can in part explain why especially the empirical research on the RBV is challenging, if not impossible. These issues are divided into three main categories: implicit problems in measuring resources, the predictive ability of the RBV, and the generalizability of the findings.

The first built-in feature in RBV research is that resources are implicitly hard to measure. The core reason for this is the causal ambiguity argued by Barney (1991), which defines that the most important resources for building competitive advantage are also those that are the most hard to identify. The direct implication of this is that from the theoretical point of view, the most interesting variables are those which are least identifiable and measurable (Spender & Grant, 1996). The unwanted consequence of this phenomenon has been that the measured resources have been selected for analysis based primarily on their measurability and not on their importance in building the firm's competitiveness (Lockett et al., 2009). One commonly used method to dodge similar problems in measurability is to use *proxies* in the measurement. This method has also been implemented in RBV research, which has resulted in a varied set of proxies used for key resource measurement, making systematic comparisons across the empirical literature difficult (Lockett et al., 2009).

The second problematic area rises when the problem is inspected from the Popperian (Popper, 2004) philosophy of science perspective, which argues that a scientific theory should be able to both credibly explain and ultimately predict the phenomena of interest. However, the RBV lacks the required systematic tools to identify strategically valuable resources currently, but also those resources that would be valuable in the future (Sanchez, 2008). The lack of these tools and thus its questionable ability to explain and definite inability to predict a firm's competitiveness suggest that the current logical base of the RBV is not fit for a scientific theory (Sanchez, 2008).

The third fundamental problem in the RBV is the generalizability of the findings. The underlying assumption of the RBV that firms are heterogeneous on which the performance differences between firms are built on, directly increases the case sensitiveness of the findings (Gibbert, 2006). From the scientific perspective this implication causes severe challenges for the research. Firstly, as the research is highly case- sensitive, the reproducibility of requirements becomes an issue (Sanchez, 2008). Secondly, a higher- level consequence is the challenge of making generalizable statements from the research, as the findings can be argued to be highly case- sensitive (Sanchez, 2008; Lockett et al., 2009). One method which researchers have used to control this problem has been to limit the focus of their study on a single industry (Lockett et al., 2009).

2.2 The Dynamic RBV

2.2.1 The framework

The dynamic RBV (Helfat & Peteraf, 2003) brings significant changes to the traditional RBV theories, which have later been labeled as the static RBV. The theory builds on many, mostly independent theoretical development steps (Dierickx & Cool, 1989; Prahalad & Hamel, 1990; Teece et al., 1997; Eisenhardt & Martin, 2000) for which Helfat and Peteraf (2003) later added the label dynamic RBV. The dynamic approach proposes that the analysis should be focused on the processes of change within the company that are linked to the firm's resources, rather than the stock of resources in the firm's possession. The practical implication of this is that the level of analysis should be changed, leading to a relatively clear classification between the dynamic and static approaches. However, the classification of the different development steps behind the dynamic RBV is not easily done, as for example the competence- based view (Sanchez, 2008) or dynamic capabilities (Teece et al., 1997; Eisenhardt & Martin, 2000) can be treated as their own 'schools of strategy'.

The structure of the dynamic RBV is presented in Figure 1. The structure consists of stocks of resources ($R_{1\text{-}n}$), competences ($C_{1\text{-}n}$), products ($P_{1\text{-}n}$), markets ($M_{1\text{-}n}$), and the processes that control these stocks. Resources, competences, and products are seen as a firm's internal attributes, whereas markets are an external entity. Markets are included in the structure to illustrate the changes in business environment; more detailed inspection is restricted, however. The different internal concepts in the figure can be identified as alternative levels of analysis.

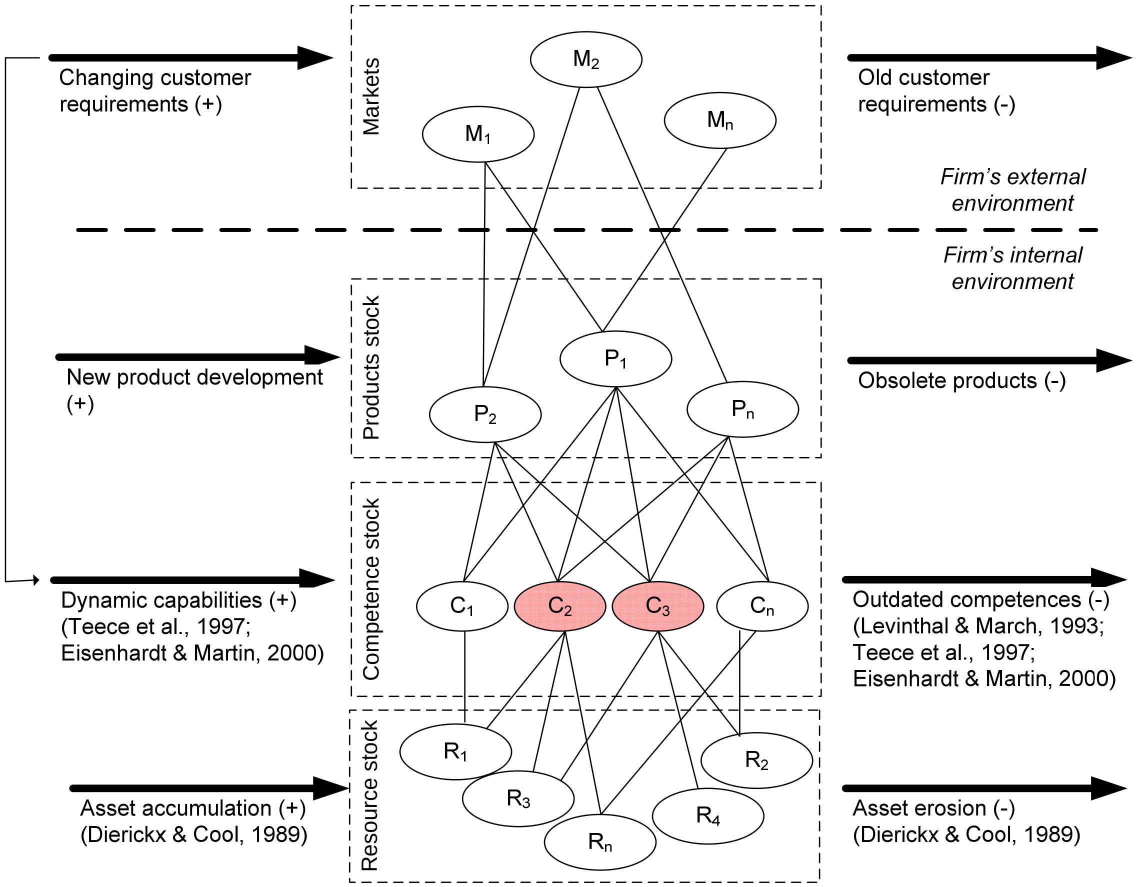

Figure 1. Conceptual structure of the dynamic RBV

The lowest level of analysis in the dynamic view is a resource ($R_{1\text{-}n}$), or the firm's stock of resources, to be more precise. A resource is defined as "… as asset(s) that a firm can actually access and use in developing and realizing products to create value in its product markets" (Sanchez, 2008, p.46). The level of the firm's resource stock is controlled by the flows that increase and decrease the amount of resources. Dierickx and Cool (1989) call these processes asset accumulation and asset erosion. Dierickx and Cool (1989) do not specify what these processes actually are, but they use R&D as an example of a process where the stock of resources is know-how, and investments in R&D define the inflow of know-how, which needs to overcome the know-how erosion over time. Based on this logic, Dierickx and Cool (1989) argue that a firm's resource stock is determined by the long term accumulation of resources, and thus firms need to replenish their resource stock constantly in order to stay competitive.

The second identified level is competence. Competence is seen as a firm's ability to produce value that is created through combining resources. Like resources, a firm also has a stock of competences. The idea of competence builds on the discussion on organizational routines (Nelson & Winter, 1982), which argues that although resources are important, they are insufficient by themselves and need to be implemented as a part of an organizational routine in order to produce value for the firm. This concept can also be approached from the resource side, as those resources that are used as a part of a firm's competences can be identified as active resources, defining the rest of the resources as passive (Sirmon et al., 2008). Through this classification, it is possible to acknowledge that mere possession of a resource is enough to produce value (Peteraf, 1993; Priem & Butler, 2001a), but the resource needs to be tied to the firm's value creating routines.

The level of competence stock is controlled by the firm's internal processes. Teece et al. (1997, p.516) label this process in their highly influential study as 'dynamic capabilities', defined as the "… firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environment". An alternative definition has been presented by Eisenhardt and Martin (2000, p.1107) who arguethat dynamic capabilities "… are the organizational and strategic routines by which firms achieve new resource configurations as markets emerge, collide, split, evolve, and die". Both these definitions have two significant aligned messages. Firstly, a dynamic capability is a process that changes the firm's resource configurations, and secondly, resource configurations are adjusted according to the changes in the firm's business environment.

The last internal level of analysis in the framework is the firm's stock of products. The firm's stock of products is controlled by the new product development (NPD) process, which has been intensely studied in the innovation management discipline (Cooper, 1988; Cooper & Kleinschmidt, 2007). The objective of the NPD process is to create products for the current and/or future markets identified in Figure . Products are created by combining the firm's competences (Prahalad & Hamel, 1990), and thus the quality of products is dependent on the competences. As competences themselves are dependent on the resources, products and resources can be seen as two sides of the same coin (Wernerfelt, 1984). It is axiomatic that the overall quality of a firm's products is ultimately defined in the marketplace when compared against competitor's products, thus ultimately defining the firm's competitiveness. This stream of logic offers an interesting view to resources as argued by Dutta et al. (2005), and later agreed on by e.g. Sirmon et al. (2008), that a firm's resource base should not be thought of in absolute measures but as relative amounts compared to its competitors. The notion of relative capabilities can be seen to build on the logic by Kay (1993) , who argues that competitive advantage is always dependent on the market or industry, thus the competitive advantage that a particular competence can give can only be judged when compared to competitors' abilities.

According to the framework presented in Figure 1, a firm's performance is dependent on three distinctive internal processes. However, as these processes draw from different theoretical backgrounds, the framework as a whole has not been previously studied in the literature. An alternative framework describing a similar logic as the one in the dynamic RBV has been presented by March (1991). This framework has been later discussed as an organization's exploration and exploitation processes (March, 1991; McGrath, 2001), or as organizational ambidexterity (Raisch & Birkinshaw, 2008). The fundamental finding in this research track is that firms need to engage in both exploration to provide capabilities for the future and exploitation efforts aiming to leverage the firm's capabilities to gain short-term competitiveness (March, 1991). The central theoretical argument is that firm needs to balance between these activities to achieve highest performance over time (March, 1991; McGrath, 2001), which has also received empirical validation (Uotila et al., 2009). The need for a balance between exploration and exploitation processes is created when they have both a positive and a negative correlation. A positive relation is created when the exploitation activities are dependent on the output of the exploration process, as the firm needs to possess the resources required to remain competitive in the future (March, 1991). A negative relation is created when these processes require similar organizational resources, causing the situation that concentrating efforts on one process leads to fewer resources available for another process (March, 1991).

Although a direct linkage between the exploration and exploitation processes and the dynamic RBV framework cannot be presented, some clear similarities do exist. The exploitation process is strongly linked to the NPD process, whereas exploration can be tied to the accumulation of resources. From the linkage perspective, the problematic process is the dynamic capability, which could be argued to have elements from both exploration and exploitation. The connection between the dynamic capability and exploration can be argued to be based on the logic that the firm should adjust its competences according to future market needs to build its capabilities for the future. On the other hand, the dynamic capability builds also on the firm's current skill base by adjusting current configuration to suite the changes in the market place, linking the concept also to exploitation. The framework presented in Figure 2 connects the exploration and exploitation processes to the resource classification between passive and active resources. The exploration process is seen to add to the firm's total resources, whereas the exploitation process can be used to turn resources from a passive to an active state.

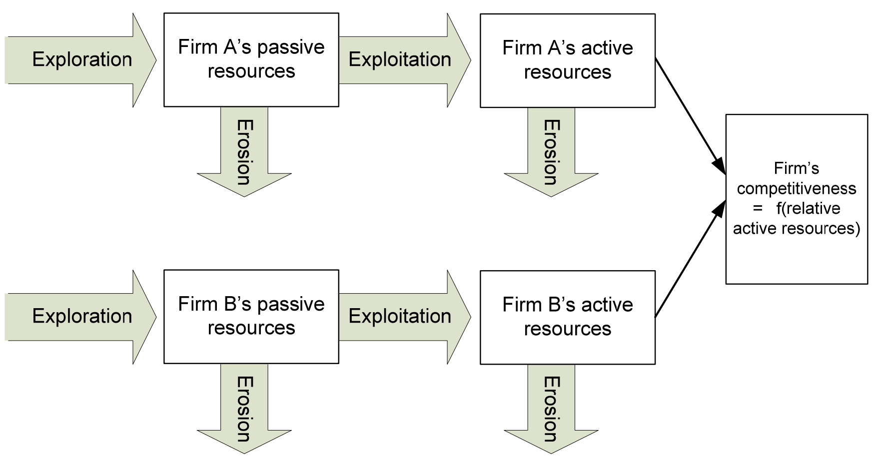

Figure 2. Firm's competitiveness based on exploration and exploitation processes

When comparing the frameworks in Figure 1 and Figure 2, the biggest difference is on the level of detail included in the frameworks. The added detail level in Figure 1 increases the realism of the framework, but it also increases complexity if it is used as a base for empirical research. As such, the situation becomes a question of balancing between achieving the desired accuracy versus the complexity of the implementation of empirical research.

2.2.2 Challenges set by the dynamic RBV for empirical research

The empirical research based on the dynamic RBV approach has proven to be challenging, which is evident in the low number of empirical studies published (Newbert, 2007). From the perspective of empirical testing, the dynamic RBV framework has several inherent properties that cause significant challenges to research. These challenges can be divided to three major components: 1) measurement of process performance, 2) longitudinal research, and 3) operationalization of relative resources.

The first problem area is how to measure the flows, both inflows and outflows. Direct measurement of these flows is challenging, or even impossible. A common way to divert such a measurement problem is to use objective proxies to give an estimate of the process performance, which can be divided to two classes: input and output proxies. Of these, the use of input proxies, such as investment in R&D or R&D personnel, has been used more widely than the output proxies. However, in their recent look at empirical research Armstrong and Shimizu (2007) note that the use of input proxies in RBV research is dubious, and researchers should strive to use output proxies to measure the firm's performance. The added value of using output proxies is that they approximate the actual products that the firm's processes have created, as opposed to input proxies which describe the investments made to the processes. As such, output proxies offer a more accurate measure of the actual performance of the company.

The second problematic area is that dynamic RBV research is inherently longitudinal, which causes three major challenges for the research: time series data is required, implementing the accumulation of stocks, and statistical testing of the results. The longitudinal research approach requires time series data that needs to be commensurable over time. The commensurability of data sets challenges for the use of traditional research data sources, for example the use of surveys as a way to produce commensurable longitudinal data is challenging. The second challenge from the longitudinal approach is that the methodology used needs to be able to adopt the accumulation of stocks over time to estimate the firm's resource stock at a given period of time. The final challenge is tied to empirical testing of the research results. The end result of a longitudinal research is a time series, which with this theoretical background is expected to autocorrelate due to path dependency phenomena. This combination sets mathematical challenges for the validation of the results.

The third problem area in empirical research on the dynamic RBV is the use of relational measures to determine a firm's resources against its competitors' resources. Inclusion of relative measures increases the accuracy of the used numbers, but the practical implication from this is that all sample firms need to be measured together. This also highlights the importance of data collection procedures that produce commeasurable data so that each firm is apprised correctly.

3 The Empirical research

3.1 System dynamic model

The system dynamic model is presented in Figure 3. The model is based on the logic of the framework (**Error! Reference source not found.**2), but it also includes the independent variables used to operationalize each flow in the model, and the dependent variable of market share, which is used to explain firm's competitiveness. These indicators are presented with more detail descriptions in Appendix A. Patent information has been previously used in studies related to a firm's performance (Jaffe, 1986). The early studies on patents show that the mere number of patents can not be used to understand firm's performance or market share systematically because of the lack of methods to apprise the heterogeneity of the patents. As an end result, there have emerged some general qualitative measures for patents, such as the '*citation index*' (Trajtenberg, 1990) and '*technology cycle time'* (TCT) (Kayal & Waters, 1999). Patent and product information can be defined to be output proxies that are used to describe the productivity of a process(es). In our model, these processes are tied to organizational learning, and the information is used to provide an indirect way to measure the accumulation of a firm's resource base. An alternative approach to indirect measurement of process performance, is the use of input proxies, such as 'R&D investment' or 'years of experience', but Armstrong and Shimizu (2007) argue that the logic of input proxies is against the core logic of RBV, and thus '…researchers should strive to use output measures for proxies'.

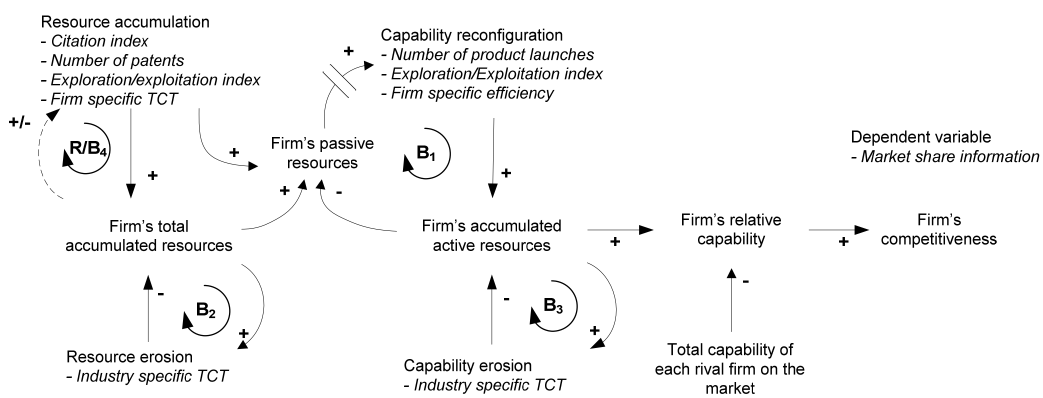

Figure 3 The system dynamic model and the balancing feedback loops

The model illustrated in Figure 3 represents the system dynamic model on the level of a single firm. In practice, the whole model includes five identical sub-models that allow simultaneous estimation of all firms. Information between different firms is transferred through the variable 'Total capability of each rivalry firm on the market', but also through each indicator that is measured with a relative scale. The model includes four balancing feedbacks (B_{1-4}) (e.g. Sterman, 2000), based on theoretical background and logic. These feedback loops control the model and they prevent unlimited growth in the model. The existence of these loops also increases the dynamic complexity of the system, which is very difficult to define, model and to solve (Sterman, 2000).

Sterman (2000) has identified fundamental sources of dynamic behavior (or "dynamics") that re-occur across various types of human and natural systems. The various combinations of these generate common types of dynamic behavior, such as exponential growth, exponential decay and oscillation. We have identified several important sources of dynamics that are related to linking organizational learning processes to competitiveness, describing these in the model (Figure 3) and the latter part of this section. Such sources of dynamics and dynamic complexity are the logical and/or theoretical feedback loops (B_1, B_2, B_3, B_4), the delay between firm' passive resources and capability reconfiguration, the stock-and-flow structures and the slow movement in them caused by resource accumulation, and the market share development that are strongly tied to actions taken by rival firms. In addition to the dynamics within the model, the interrelationships between the competing companies cause interesting dynamic behavior also to the exploration-exploitation balance calculated from the dataset. The combination of these multiple sources of dynamics creates extremely complex dynamics in organizational learning processes, as well as their links to firm's competitiveness. Such dynamics makes it difficult to a) intuitively understand the stocks and flows related to organizational learning especially during longer periods of time, as well as to b) model them by traditional types of analysis methods.

Feedback loop B_1 is created around the accumulation of the firm's active resources. The process involved in the loop is the capability reconfiguration process, whose function is to activate the firm's passive capabilities. This feedback loop estimates the firm's stock of passive resources that can be activated, and at same time it controls that only passive or newly developed resources may be activated, which effectively prevents the firm's unjustified growth. Feedback loop B_1 also includes a delay (Sterman, 2000) caused by long lead times in the product development process. This combination causes oscillation (Sterman, 2000) around the firm's accumulated active resource balance point, and thus to each firm's market shares.

Feedback loops $B_{2\text{-}3}$ are caused by the erosion of the firm's capability over time (Dierickx & Cool, 1989; Eisenhardt & Martin, 2000). The erosion is seen to be caused by technological progress at the industry level, which erodes each firm's resources when a portion of current knowledge becomes outdated. Although B_2 and B_3 are connected to different levels of resources in the model, the fundamental logic behind these processes is based on the balance between resource stock erosion and replenishment speed, as suggested by Dierickx and Cool (1989). The size of these flows $B_{2\text{-}3}$ is defined to be relational to the firm's current level. The fundamental logic is that a firm with a high absolute level of stock will lose more in absolute measures than a firm with a low level of absolute stock. The yearly erosion rate is estimated through the industry average TCT. The suitability of this measurement was tested statistically and support was found for the hypothesis that industry average reflects the behavior of each firm's TCT rates.

The last feedback loop in the model is $B_{4,}$ which is created between the firm's resource accumulation and total accumulated resources. This feedback loop ties the quality of firm's patents to its current technical level. The logic in feedback loop that is that a technological leader is expected to gain better quality patents opposed to those firm's pursuing in technological capability. Thus the firm's current technological position is assumed to set expectations on the quality of firm's patents. This expected quality needs to be taken into account when assessing the firm's resources accumulation process from qualitative perspective.

3.2 Data and simulation set-up

The adoption of industry level and longitudinal analysis sets requirements for the empirical data. The dependent variable of the model is the market shares of the big five companies during the years 1997-2007. The companies included to this study cover 80% of the global markets, and they are: 1) LG, 2) Motorola, 3) Nokia, 4) Samsung, and 5) Sony-Ericsson. The independent variables used in the model are patent information (between 1980-2005) and product launch information (between 1996-2008). The patent data has been extracted from the PATSTAT database, from which only patents in the US patent system was selected, which were further restricted to so called mobile patents (He et al., 2006). The restriction to patents in US system was made for two reasons: data comparability, as most previous studies were made on US patents, and exclusion of duplicate patents caused by cross patenting to different patenting systems. The total number of included patents was 18.947. Product launch and market share data was bought from Strategy Analytics. The total number of product launches included was 3.545.

Although the actual simulation period for market share prediction is defined as 1997-2007, the simulation is initiated from 1980 to set-up the accumulated resources. This set-up period is required to initiate the accumulation of resources for the actual simulation period. The model is calibrated on the year 1997 when each firm is set to on a correct market share level with a calibration constant that remains fixed throughout the simulation period. The logical justification for this calibration constant is alternative sources of competitiveness and differences between organization cultures.

3.3 RESULTS

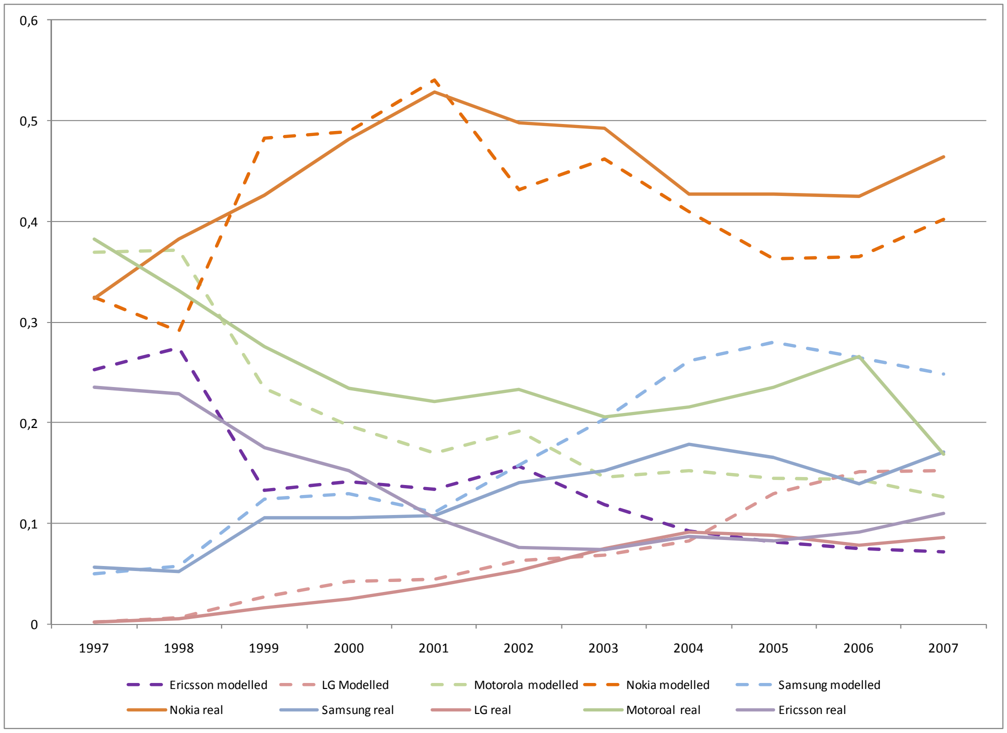

Figure 4. Simulation results

The Figure 4 shows the simulation results from the system dynamic model and the descriptive statistics are shown in Table 1. The results show Motorola and Samsung prove to be most challenging firm's to predict. The model shows a tendency to over-estimate the competitiveness of LG and Samsung that are companies which are firm's that engage in highly exploitative strategies and produce more products than their competitors. The over estimation of these two companies is countered with under estimation of other companies. The modeling results also show increasing amount of error as the simulation time progresses due to accumulation errors.

Table 1. Descriptive statistics from simulation results

Real errors

	SUM	MIN	AVG	MAX
Ericsson	0,11	-0,04	0,01	0,08
LG	0,21	-0,01	0,02	0,07
Motorola	-0,52	-0,12	-0,05	0,04
Nokia	-0,32	-0,09	-0,03	0,06
Samsung	0,51	-0,01	0,05	0,13

Absolut errors

	SUM	MIN	AVG	MAX
Ericsson	0,33	0,00	0,03	0,08
LG	0,24	0,00	0,02	0,07
Motorola	0,60	0,01	0,05	0,12
Nokia	0,47	0,00	0,04	0,09
Samsung	0,53	0,00	0,05	0,13

Yearly errors

	1997*	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
SUM	0,04	0,18	0,17	0,10	0,10	0,22	0,19	0,18	0,31	0,40	0,29
MIN	0,00	0,00	0,01	0,01	0,00	0,01	0,01	0,01	0,00	0,02	0,04
AVG	0,01	0,04	0,03	0,02	0,02	0,04	0,04	0,04	0,06	0,08	0,06
MAX	0,02	0,09	0,06	0,04	0,05	0,08	0,06	0,08	0,11	0,13	0,08

* Calibration year

The statistical testing of the model's ability to predict market share change was done with Pearson's correlations (Table 2). We find a strong correlation between the predicted and the actual market share changes (Pearson correlation .61, p=.000). This clearly shows that the model is quite well able to predict firm competitiveness. Next, we compared the model predictions with a random walk model. The random walk model assumes that this year's market share change equals last year's market share change. Our model also clearly outperforms the random walk model, which has a correlation with actual values of only .34 (p=.022).

Table 1 Results from Pearson's correlation

		Real market share change	**Random walk model**	**System dynamic model**
Real market share change	Pearson Correlation	1		
	Sig (2-tailed)			
	N	45		
Random walk model	Pearson Correlation	.340*	1	
	Sig (2-tailed)	.022		
	N	45		
System dynamic model	Pearson Correlation	.612**	.371*	1
	Sig (2-tailed)	.000	.012	
	N	45	45	

*. Correlation is significant at the .05 level (2-tailed), **. Correlation is significant at the .01 level (2-tailed)

4 CONCLUSIONS

The objective for this study was to use create a system dynamic model that simulates the market share development between the years 1997-2007. The simulation model is based on dynamic RBV, which was seen as a significant development step to the criticized resource based view. The created dynamic model was tested in the mobile handset vendor business and the results gave support for the model. This chapter contains the analysis on the implications of these findings towards the identified problem areas in the empirical RBV theory.

The first identified empirical challenge was the measurement of resources, which has been problematic, as the RBV does not offer explicit tools or processes to identify and measure a firm's resources. In addition, the central theoretical concepts of the RBV, such as the VRIN framework and causal ambiguity make the identification and measurement of resources implicitly challenging. To overcome these issues, the measurement of resources was executed by adopting the dynamic approach to the RBV. This means that the focus in measurement is shifted from the problematic direct measurement of the firm's stock of resources to measuring the in- and outflows of resources over time. The firm's resource stock at a single time step is then derived by estimating the level of resources accumulated over time. The model was based on the simplified dynamic RBV framework which builds on classification between a firm's active and passive resources. The connected flows that were identified were exploration that increases the firm's total resources and exploitation that allows the firm to activate its resources to its products. In addition, both resource stocks are similarly affected by erosions that decrease the firm's resource stocks. The challenging task of resource accumulation based on these flows was implemented with system dynamic modeling. The numeric measurement of the in- and outflows was executed by using objective output proxies. Patenting activity was identified as a measurable proxy for the firm's exploration activities, and product launches were used to identify exploitation activities. The benefit from using proxies is that they offer a systematic way to measure a phenomenon, enabling comparable measurement between different firms by measuring the actual performance of the firm.

The second identified empirical challenge was the generalizability of the research findings. This problem was identified, because a built-in challenge in RBV theories as the value of resources is strongly dependent on the competition within the industry. On the basis of the literature, the way to counter this problem is a careful selection of the case sample. The research was conducted in the mobile handset vendor business. This industry can be classified as a fast developing high technology industry, which as such does not represent an average industry. Thus the generalizability of the results from this perspective is questionable. However, the use of the proposed research framework can be adapted according to the input data, and is not tied to any specific industry. The adaptability is achieved by using relative and industry level measures to model the system behavior. Thus the framework adjusts to the competition surroundings, making the model generally applicable in other industries.

The final challenge in empirical RBV research is to adopt a research design that is not based on *ex ante* rationalization of resources, but to predictions of the phenomenon. The modeling in publication 6 was executed by using data available at the chosen time step. As such, the firms' market shares in the next time step are modeled with older data. The model produced effectively 10 market share predictions for each company over the inspection period. The statistical analysis of market share change confirmed that the model had statistically significant predictive ability.

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Appendix A.

Name of indicator	Formula	Description
CI Citation index	$CI_{c,i} = \frac{\sum_{k=1}^{m_{c,i}} \sum_{j=i}^{2005} n_{c,k,i,j}}{m_{c,i}}$	Indicates the quality of a firm's patents and therefore the quality increase of their capabilities. Logic assumed that, the more citations a patent gains, the better it is in terms of quality. *Used in: Resource accumulation*
RCI Relative citation index	$RCI_{c,i} = \frac{CI_{c,i}}{\left(\frac{\sum_{c=1}^{C} CI_{c,i}}{C}\right)}$	Used to estimate the amount quality of firm's patents related to the firm's strategic position in technological capability. *Used in: Resource accumulation*
TCT Technology Cycle Time	$TCT_i = \frac{\sum_{c=1}^{C} \sum_{k=1}^{m_{c,i}} \left(\frac{\sum_{r=1}^{R_{c,i,k}} pub_{c,i,k} - ref_{c,i,k,r}}{R_{c,i,k}}\right)}{\sum_{c=1}^{C} m_{c,i}}$	Indicates the renewal rate of technological capabilities by revealing the average age of citations made to prior patents. Industry-specific TCT is calculated as an industry average and used in measuring capability erosion. The smaller the TCT, the higher the erosion. Firm-specific TCT, instead, measures the relative novelty of a firm's capabilities. A smaller TCT compared to that of competitors' improves capability addition. *Used in: resource addition and resource and capability erosions*
FTCT Firm specific technology cycle time	$FTCT_{c,i} = \frac{TCT_i}{\left(\frac{\sum_{k=1}^{m_{c,i}} \left(\frac{\sum_{r=1}^{R_{c,i,k}} pub_{c,i,k} - ref_{c,i,k,r}}{R_{c,i,k}}\right)}{m_{c,i}}\right)}$	Describes the firm's TCT compared to the industry average TCT. If the firm is able to produce patents with better TCT, the quality of its patents is assumed to rise. *Used in: Resource accumulation*
Exploration-exploitation ratio	$EI_{c,i} = \frac{\left(\frac{m_{c,i}}{l_{c,i}}\right)}{\left(\frac{\sum_{j=i-3}^{i} \sum_{c=1}^{C} \left(\frac{m_{c,j}}{l_{c,j}}\right)}{3 \times C}\right)}$	Indicates the firm's exploration-exploitation balance compared to industry's 3 year average to identify resource shortages. Inverse number is used in capability reconfiguration. If the index or inversed index is >1 the number is assumed to be 1 as there is no resource shortage. *Used in: Resource accumulation* *Used in: Capability reconfiguration*
c = company C = total number of firms i,j = year $m_{c,i}$ = total no. of patents k = patent $n_{c,k,i,j}$ = total no. of citations		$pub_{c,i,k,r}$ = publication date of a patent $R_{c,i,k}$ = total number of references to a patent r = reference $l_{c,j}$ = total no. of product launches $ref_{c,i,k,r}$ = publication date of a reference