

Buenstorf, Guido; Murmann, Johann Peter

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Ernst Abbe's Scientific Management: Theoretical Insights from a 19th Century Dynamic Capabilities Approach

Guido Buenstorf

Max Planck Institute
for Research into Economic Systems
Kahlaische Strasse 10
07745 Jena; Germany
Phone: (+49) 3641-686821
Fax: (+49) 3641-686868
E-mail: buenstorf@mpiew-jena.mpg.de

Johann Peter Murmann

Kellogg School of Management
Northwestern University
Evanston, IL 60208
United States of America
Phone: (+1) 847-467-3502
Fax: (+1) 847-467-3502
E-mail: jpm@northwestern.edu

Abstract: “Scientific management” is the label Frederick Taylor attached to the system of management devised by him. In this article we present our discovery of very different “scientific” management principles that were developed roughly concurrently with Taylorism by German physicist Ernst Abbe, then owner and managing director of the Carl Zeiss optical instruments company. Abbe’s management principles as well as the social philosophy underlying them are accessible to present-day theorists because he laid them down both in the statutes of a foundation he founded and in an extensive commentary on the statutes. These original accounts offer a remarkable opportunity to enrich our current understanding of how managers can create and recreate firm capabilities that allow firms to enjoy a long-term leadership position. Abbe develops an early account for managing a science-based firm and securing its long-term competitiveness, giving detailed prescriptions with regard to the type and scope of a firm’s activities, its organizational setup, and its labor relations. Abbe’s management principles exhibit striking parallels to important contemporary theories of organization such as the *Resource-Based Theory of the Firm* and the related *Dynamic Capabilities Theory of the Firm*, and even today are able to indicate issues that warrant further theoretical elaboration. In this article, we give an outline of Abbe’s thoughts, highlight some of their most characteristic features, and put them into a present-day management theory perspective.

Keywords: Resource-Based Theory of the Firm, Dynamic Capabilities, Scientific Management, Sustainable Competitive Advantage

Ernst Abbe's Scientific Management: Theoretical Insights from a 19th Century Dynamic Capabilities Approach

1. Introduction

“Scientific management” is the label Frederick Taylor (1903, 1911) gave to the system of management developed by him. As is widely known, “scientific management” or “Taylorism” was to develop into one of the most powerful influences on 20th century management practice. In a nutshell, it is based on collecting and centralizing detailed information on the production processes in the firm and on subdividing shop floor activities into the smallest and simplest units of tasks possible. For each of these tasks, detailed instructions about how to execute them were to be given to the worker, thus entirely centralizing decision-making on shop-floor practices and essentially eliminating all worker deliberation and autonomy.

The origins for this article lie in our discovery of very different “scientific” management principles that were developed roughly concurrently with Taylorism by Ernst Abbe. Employed as a physicist at the University of Jena (Germany), Ernst Abbe joined the Carl Zeiss glass works and optical workshop as a R&D scientist and later became the managing director and owner of the famous optical instruments maker as well as its main supplier, the Schott glass company. In 1896 Ernst Abbe created a foundation in the name of Carl Zeiss that would subsequently own the two companies. In the statutes of the Foundation he laid down the guiding philosophy and the principles of management that he had implemented in the preceding two decades (Abbe, 1896). Four years later, Abbe (1900) wrote a long commentary about the statutes’ prescriptions in order to record, for future generations of Foundation leaders, the intentions underlying the statutes.

In this paper we show that, in spite of striking parallels in the biographies of Ernst Abbe and Frederick Taylor, the thrust of Abbe’s “scientific management” is much more closely related to present-day theories of organization such as the *Resource-Based Theory of the Firm* (RBT) (Wernerfeld, 1984; Dierickx and Cool, 1989; Barney, 1991; Peteraf, 1993, Kraatz and Zajac, 2000) and the closely related *Dynamic Capabilities Theory of the Firm* (DCT) (Porter, 1991; Teece, Pisano and Shuen, 1997, Dosi, Nelson and Winter, 2000).¹ As a management theorist, Ernst Abbe found himself in the very rare position that he had significant hands-on experience in guiding a firm but because of his scientific training he was also able to articulate his management

¹ A consensus is emerging that the various resource- and capability-based theories are partially overlapping and highly complementary where they differ.

practices in terms of abstract principles. Even for today's organizational theorists, Abbe's first-hand accounts of social philosophy and management principles offer a remarkable opportunity to enrich our understanding of how managers can create and recreate firm capabilities that allow firms to enjoy a long-term leadership position. This alone provides a compelling reason to analyze Ernst Abbe's management thoughts and investigate whether they can contribute to refining contemporary theory. Abbe's writings also show that fundamental insights into organizational theory were already formulated by practitioners 100 years ago. Developed at roughly the same time, Taylorist scientific management would revolutionize shop-floor practices during the next decades. Abbe's writings show that the potential costs and shortcomings of Taylorist practices realized later were already visible to some of his contemporaries.

In our view Ernst Abbe's management principles, as they are expressed in the statutes of 1896, offer insights that remain relevant for present-day management theorists and practitioners alike. In this article we focus on three features of Abbe's writings that are of particular significance in light of recent developments in management theory. First, Abbe sets out a comprehensive and coherent system of running a science-based company, with a primary orientation toward long-run sustainable growth of the firm. His management principles assign key roles to enhancing the scientific basis of the firm's technology and to fostering the skills of workers. They thus predate later theoretical advances such as the RBT and the DCT. Second, underlying these principles is an evolutionary view of the firm. The organizational prescriptions are not based on a one-shot attempt to engineer the firm's management from scratch, but rather endeavor to codify and specify ongoing practice of the firm's management. Ernst Abbe's writings can thus be seen as first-hand evidence of the existing routines of the firm (Nelson and Winter, 1982, Cohen et al., 1996), which he tries to stabilize for the future. Third, from the principles for securing sustainable competitive advantage, Abbe develops detailed prescriptions for the organization of the company, and the recruitment and decision making procedures of its top-layer of management. Again, these propositions resonate well with present-day capabilities views. In addition, Abbe's documents deal extensively with labor relations. His stance on labor relations has long since earned Abbe a reputation for being an eminent social reformer in Germany (Schmoller, 1906). We argue that this interpretation is incomplete as best. Philanthropy is not the driving force behind Abbe's attitude toward labor relations, rather he argues that the measures adopted by him are for the service of the firm's long-term prosperity. In the larger historical context, Ernst Abbe's writings also indicate that Taylorism was not the only possible prescription

to arrive at around the turn of the 20th century when attempting to find scientifically based management principles.

The article is organized as follows. To place Ernst Abbe's management thought in a present-day context, in section 2 we present a concise summary of some key insights into resource- and capability-based organizational theories as well as some pertinent empirical evidence. Section 3 gives a brief historical overview of the Zeiss firm. In section 4 we present Abbe's fundamental ideas on the nature of the firm and relate them to the contemporary theories. In an analogous way section 5 discusses Abbe's views on how to secure the sustained competitive advantage of the firm as they emerge from the statutes of the Zeiss Foundation and his own comments on them. Section 6 deals with his prescriptions for the organizational setup of top-level management and labor relations. In section 7 we characterize Abbe's legacy for organizational theory and practicing managers and propose that, more than 100 years after they have been devised, his writings still hold some relevant insights for the contemporary reader. Section 8 offers some conclusions.

2. Firms' resources, capabilities and environmental change: a synopsis of recent theories

During the past two decades, scholars working on resource- and capability-based theories of the firm have developed an impressive body of research. These approaches attribute the competitive position of firms to the firm's own assets and capacities more than to industry structure and strategic interactions among competitors. The focus of the analysis is thus shifted away from products and product markets to the inputs used by the firm and the way in which production is organized. In this section we attempt a synopsis of resource- and capability-based approaches, discuss their common premises and point out some challenges in translating their findings into guidelines that can inform practical management behavior and decisions. Our goal in this section is not to write a complete survey of the existing literature. Rather, we want to articulate a coherent theoretical framework that will allow us to discuss with analytic precision the specific proposal made by Ernst Abbe in 1896 about how to manage the Carl Zeiss firm based on a set of key principles.

Even though its intellectual origins can be traced further back into the history of management thought (see Penrose, 1959), recent interest in the resources of the firm starts with Wernerfelt (1984). In his analysis, resources are understood as semipermanent (tangible and intangible)

assets of the firm that have the potential to affect the firm's competitive position. As Dierickx and Cool (1989) have pointed out, resources have to be nontradeable, nonimitable and nonsubstitutable to be of strategic value to the firm (i.e. to give rise to sustainable competitive advantage).² These authors emphasize that the accumulation of strategic resources such as customer trust and firm-specific skills requires time, because the rate of adjustment per unit of time is limited. The accumulation of strategic resources thus constitutes a key dimension of strategic management. At times, resources and capabilities appear to be utilized as largely synonymous concepts. A clearer distinction of the concepts was made by Amit and Schoemaker (1993). They suggest that capabilities are defined by the firm's capacity to use its resources in a coordinated way to achieve desired results.

Adopting a resource- or capability-based perspective of the firm presupposes that the firm is an ongoing entity whose past both informs and constrains its future activities. What the firm can and will do tomorrow is not independent of today's position, capabilities and activities. Because of different starting conditions, firms are and will remain heterogeneous, a fundamental assumption on which the RBT is based (Peteraf and Barney, 2003). The basic concept of the firm as an ongoing entity moreover links the resource- or capability-based approaches to evolutionary economics. The continuity of the firm is at the core of the evolutionary theory developed by Nelson and Winter (1982). They suggest (*ibid.*, p. 99) that firms "remember by doing" and have a "memory" that is embodied in the firm's routines, i.e. in the regular patterns of organizational processes. Routines allow for the coordinated behavior of employees because routine-based behavior is predictable by others who can adapt their own behavior accordingly. Insofar as they contribute to the competitive position of the firm, routines underlie the firm's capabilities. The knowledge content of routines cannot be reduced to the knowledge of individual employees. Moreover, much like individual human beings possess tacit knowledge that they cannot express verbally (Polanyi, 1967), the knowledge contained in the firm's routines is frequently not known to its members, but is expressed in their activities and in the firm's performance that they give rise to. This tacit character limits both the deliberate modification of routines and their imitation by competing firms.

There are a number other factors that cause firms to be heterogeneous. Kogut and Zander (1996) highlight the role of social factors. They stress the capacity of firms to provide their

² Barney (1986) has pointed out another condition for strategic resources: Initial expectations on their value have to differ so that some firms are able to acquire them below their (idiosyncratic) value.

employees with an identity, which facilitates coordination, communication and learning, and which also affects the social norms operating within the firm. Adopting a more individualistic viewpoint, Witt (1998) emphasizes the cognitive leadership exerted by entrepreneurs who can channel the perceptions of employees, and thus shape and enhance the coherence of cognitive framing within the firm by providing a vision or “business conception” (Witt, 1998, p. 166). Both contributions thus suggest that heterogeneity may be brought about by differences in how members of the firm perceive its “meaning” and see their own role in attaining the firm’s goals.

Idiosyncracies in resources, routines, identities and concepts can all underlie the specific capabilities characterizing a firm. In addition, all these causes of heterogeneity are not completely and instantaneously under the control of the firm, so that they cannot be manipulated at will. This implies that the existing capabilities of a firm condition its ability to acquire new ones.

Dynamic extensions

Although the basic framework of the RBT is static, in recent years researchers have used the resource and capability concepts as a starting point to explore the dynamics of competitive advantage. Two related issues have been studied: First, which capabilities enable firms to accumulate, maintain and reconfigure strategic resources, and to attain or sustain competitive advantage, in a rapidly changing environment? And second, how do the resources and capabilities of the firm come about and how do they evolve over time?

Teece, Pisano and Shuen (1997) suggest that the firm’s capacity to sustain competitive advantage in a dynamic environment is itself based on particular kinds of capabilities, which are referred to as “dynamic capabilities.” Dynamic capabilities determine the “firm’s ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments” (ibid., p. 516; cf. also Teece and Pisano, 1994); they are, as it were, the capabilities of adapting capabilities. As with resources and capabilities more generally, dynamic capabilities are conditioned by the firm’s past. A firm’s existing stock of resources and its organizational processes (which allow for coordination, learning and reconfiguration) jointly determine the developmental paths open to it. Dynamic capabilities are strategic only insofar as they are “distinctive” (Teece, Pisano and Shuen, 1997, p.524), i.e. they cannot easily be acquired, imitated or substituted by competitors.

The capacity to adapt to a changing environment critically hinges on the cognitive and social factors alluded to above as determinants of firms’ capabilities. According to Cohen and

Levinthal (1990), identifying, assimilating and applying new knowledge (in order to modify organizational processes) poses non-trivial problems to the firm. These activities require that the firm has adequate “absorptive capacities” based on relevant prior knowledge. Absorptive capacities are accumulated as a by-product of research and development and/or manufacturing activities; they are limited in scope. A firm’s absorptive capacities, which depend both on the individual knowledge bases of the firm’s employees and on the way that knowledge is communicated, are therefore a crucial component of the firm’s dynamic capabilities. Lack of absorptive capacities constitutes a technological barrier to the adaptation to environmental change. Social factors may give rise to additional barriers (Kogut and Zander, 1996). Some adaptations that might be called for technologically may not be made because they are incompatible with the normative aspects of the firm’s identity, or they may not even enter the decision makers’ set of relevant actions because of framing effects.

Where do capabilities come from and how do they change over time? Helfat and Lieberman (2002) review the empirical evidence indicating that pre-entry experience helps to account for differences in the capabilities of firms. Helfat and Peteraf (2003) have recently proposed a dynamic extension of the resource-based perspective. In analogy to the product life cycle, they suggest that capabilities, both dynamic and ordinary or “operational” (*ibid.*, p. 999) ones, develop in a regular lifecycle pattern. During the early, developmental stage of this lifecycle, capabilities are enhanced through organizational learning. Differences in team composition, leadership, aspiration levels and environmental factors may cause the effectiveness of learning to differ between firms. In later stages the development of capabilities peters out, and the capabilities reach a steady state of maturity. Internal and external events may disturb the maturity stage and induce a variety of further stages of the lifecycle, ranging from retirement of the capability to redeployment in related markets and recombination with other capabilities.

Focusing on dynamic capabilities, Zollo and Winter (2002) provide a more detailed account of alternative ways in which firms learn. Starting from the routine concept, they argue that dynamic capabilities can, first, be developed semiautomatically “experience accumulation” (*ibid.*, p. 340), based on adapting organizational practice in response to unsatisfactory performance. Two additional learning processes are moreover suggested, which have a more deliberate character and rely on more explicit knowledge. “Knowledge articulation” (*ibid.*, p. 341) is based on verbalizing an organizational process and evaluating its performance. In this way an enhanced understanding of the process is achieved, and modifications of the process are enabled. Even

more demanding is organizational learning through “knowledge codification” (ibid., p. 342). This kind of learning is based on expressing the articulated knowledge in manuals, blueprints, expert systems and the like. Deliberate learning mechanisms are more costly to the firm than experience accumulation. Whether the required investments are warranted depends on the nature of the affected organizational process (infrequency, heterogeneity and ambiguity of the process are suggested to favor deliberate learning mechanisms), as well as on characteristics of the organization and its environment.

Normative implications

The resource- and capability-based theories discussed in the present section are of an abstract, general character. As a consequence, general normative implications can be and have been derived from these theories only at an abstract level. By contrast, the micro-level processes of how to create and sustain (dynamic) capabilities, and the degree to which actual implementation of capability-focused strategies is context-dependent, have not been explored in detail.

Teece, Pisano and Shuen (1997) discuss normative implications of a dynamic capabilities approach with regard to several dimensions. First, the approach suggests an orientation toward creating distinctive resources of the firm rather than toward strategic interaction with competitors. The process of creating resources requires long-term commitment to specific strategies. Second, if capabilities are central to the firm’s competitive position, they are likely to affect entry decisions into markets. In other words, entry is not only (or not predominantly) determined by the characteristics of the market to be entered, but also by characteristics of the potential entrant. This is highly consistent with the empirical findings collected by Helfat and Lieberman (2002) and Murmann (2003). Third, Teece, Pisano and Shuen highlight the need for the firm to define its focus in terms of capabilities rather than products.

A fourth normative issue that is derived from a capability-based perspective is particularly relevant in the context of this paper: the appropriate scope of a firm’s activities. The firm’s scope has both a horizontal dimension (diversification, i.e. the breadth of the product spectrum) and a vertical one (integration, i.e. the depth of production). With regard to the horizontal dimension, Teece et al. (1994) argue that under strong competitive pressure, only specific forms of diversification are justified on the basis of capability considerations, which depend on how broadly the firm’s resources and capabilities are applicable. They propose that coherent diversification is called for when capabilities are generic, whereas single-product firms are to be

expected in situations with specific capabilities. As a third case, Teece et al. discuss a situation where previously differentiated capabilities converge. In this situation, various forms of inter-corporate relationships or “network firms” (Teece et al., 1994, p. 24) such as joint ventures are most promising.

Other contributions have explored the role of capabilities (in addition to the more traditional transaction cost considerations) in vertical integration decisions (Langlois, 1992). Based on case study evidence, Argyres (1996) shows that gains from using superior outside capabilities can outweigh transaction costs based on potential opportunisms in make-or-buy decisions. Jacobides and Winter (2003) suggest that if a firm’s capabilities are unevenly distributed over the value chain, these imbalances may – under competitive pressure from other firms with different distributions – favor specialization in specific stages. Vertical specialization may both be caused by and enhance learning, i.e. acquisition and improvement of capabilities. On the other hand, when there are interdependencies between learning at different stages of the activity (“systemic innovation”, Langlois, 1992, p. 182), integrated firms would be expected to have superior innovative performances than specialized ones.

A framework to evaluate the historical case study

The above synopsis of key contributions to the resource- and capability-based theory allows us to discuss analytically the specific proposals made by Ernst Abbe in 1896 about how to manage the Carl Zeiss firm. In the remainder of this paper, we present, based on the statutes of the Carl Zeiss Foundation, a set of managerial principles that, although developed more than 100 years ago, appear as if they had been devised as a specific implementation of the capability-based perspective. The Zeiss case is moreover special in that the rationale underlying the management principles has been made public, so that we have first-hand information about them today. Given both the subsequent success of the firm and scarcity of work on how to translate the theoretical insights of the capability-based perspective into managerial processes, studying Abbe’s principles for creating and maintaining the superior capabilities of the Zeiss companies is important and promising in its own right. As we will show below, the theoretical framework outlined above provides us with a yardstick to evaluate the principles laid down in the Zeiss Foundation statutes. At the same time, the historical material points to ways in which the capability-based approach can (and we think should) still be developed further by articulating ideas about the managerial processes that create strong organizational capabilities. Before we can outline and discuss the

principles themselves, we provide, in the next section, a brief historical sketch of the firm for which they were devised.

3. Carl Zeiss Optical Works, 1846—2003: A Brief History of the Firm

In 1846 Carl Zeiss founded a mechanical workshop in Jena, a small German university town.³ His choice of location was not coincidental: Being a native of nearby Weimar, Zeiss had completed an apprenticeship in mechanics in Jena. During this time he had attended lectures in mathematics and physics. He had moreover gained practical experience in the use of microscopes as an intern at the physiological institute. In line with his personal experience, Zeiss justified his application to open a mechanical workshop in Jena by pointing to the opportunities for contacts with university scientists.

Zeiss began to produce basic microscopes in 1847. Firm historians suggest that he was reluctant to make more sophisticated microscopes assembled from two optical systems because he personally disliked the trial-and-error methods required for their production. Given the low quality of available glass and the imprecise methods used for grinding lenses, the only possible way to produce assembled microscopes was to try a variety of lenses until their imperfections mutually compensated and yielded a satisfactory optical quality. This procedure required long periods of experimentation for each single microscope produced and gave rise to large variations of product quality. Zeiss was convinced that microscopes could be made on a more systematic, analytical basis by understanding and applying the laws governing the optical properties of materials and geometries. After his own attempts at using mathematic models for the construction of microscopes had failed, he tried to find a more knowledgeable partner. By the mid-1860s, he found one in the young university physicist Ernst Abbe.

Abbe's involvement in Zeiss' optical workshop began in 1866. He first introduced changes in the organization of production that increased the division of labor and specialization of workers, and he also constructed new measurement instruments. Both measures helped to increase the precision of component production. Abbe then proceeded to develop an analytical theory of the microscope. That theory made it possible to compensate for varying glass quality by modifying the geometry of the lenses. In 1872 the first microscopes produced on the basis of his theoretical findings were sold. The production of microscopes in the Zeiss workshop increased

³ This section draws heavily on Hellmuth and Mühlfriedel (1996).

steadily afterwards, and by the end of the decade, sales exceeded capacity. In 1876 Zeiss invited Abbe to become a partner in the workshop. Abbe henceforth held an ownership stake in the firm.

When Abbe had understood the physical principles that underlie the various kinds of optical reproduction errors, the remaining factor limiting the optical quality consisted in the available materials. Individually correcting the different kinds of errors to achieve high-fidelity imaging would have required glass types with different optical properties than the ones available. To improve upon that situation, Abbe, after 1879, joined forces with the glassmaker Otto Schott. He financially supported Schott and in 1882 helped him establish an experimental laboratory for research into optical glass. Schott's task resembled Abbe's earlier research into the physical laws of microscopy. He needed to find out what chemical compounds produced what kinds of glass, and to learn how to modify the chemical composition of the melt such that glass with the desired properties could be produced. By 1883 Schott had made sufficient progress to start industrial production of special glass for optical instruments, and the laboratory was turned into a commercial company jointly owned by Zeiss, Abbe and Schott. Industrial-scale production of the new optical glass qualities began in 1885. The new glass varieties allowed the construction and production of microscopes at a quality level that had never been realized before. These instruments became an instant commercial success and enabled the Zeiss firm to grow into a sizable enterprise. Within 15 years, employment rose from 82 to 615 employees from 1880 through 1895 (Hellmuth and Mühlfriedel, 1996, p. 135).

A crucial turning point was reached in 1888 when Carl Zeiss died. After the founder's death, Abbe first led the company jointly with the former's son, Roderich Zeiss. However, because of serious conflicts between them, in 1891 Abbe convinced the younger Zeiss to withdraw from the company. This experience with problems stemming from personal ownership of a company had far more profound implications, however. It motivated Abbe to put the Zeiss company, and his 50 per cent share of the Schott glass works, into the hands of an impersonal ownership. To this end he founded the Carl Zeiss Foundation whose statutes were approved by the state government in 1896.

After establishment of the Foundation the Zeiss company continued to grow rapidly. New lines of business were started, which all belonged to the broader field of optical technologies: camera lenses, measurement instruments, astronomical instruments as well as, with increasing importance for the company's revenue, binoculars and other military equipment. Zeiss developed into a leading optical firm with worldwide activities; its Jena employment increased to 4,748

workers in 1913 (Walter, 2000, p. 33). During World War I, total revenues increased fivefold, with the share of revenue stemming from sales to the military eventually reaching 90 per cent (Florath, 1997, p. 46). After the end of World War I, the launch of innovative new products facilitated the conversion to civilian production, so that the pre-war production volume was soon reached again. In 1933 Zeiss' employment in Jena was at the pre-war level, in spite of hyperinflation and the great depression in between. Further growth was again based on military demand when the Nazi government came to power and post-World War I weapons restrictions were no longer adhered to.

The extensive production of military equipment turned the Zeiss plants into priority targets for allied bombings in World War II. After the war, the Zeiss company found itself located in the small part of Germany that was occupied by U.S. forces, but was later handed over to the Soviets in return for the Western sectors of Berlin. Yet the Americans did not want to leave Zeiss to their emerging Cold War antagonists. In June 1945 they evacuated 126 managers, scientists and engineers of Zeiss and Schott, and also numerous technical documents, to the American occupation zone. From this date two Zeiss firms existed: one in Oberkochen (Western Germany), one in the then East German Jena. The Jena firm was further struck by Soviet restitution claims, dismantling of production facilities, and socialization. In spite of the vastly different environmental conditions, both firms re-developed into leading producers of optical products with surprisingly similar product programs and innovation activities (Kogut and Zander, 2000). They were in conflict over the rights to brand names and trademarks. In 1971 both firms agreed to each limit their activities to different regions of the world market. When Germany was reunified in 1990, Carl Zeiss Jena lost its Eastern European markets, while it was not competitive in the West. In 1991, Carl Zeiss Oberkochen took over the traditional business lines of Carl Zeiss Jena, and its some 2,800 employees (Becker, 1997, p. 254). It acquired single ownership of Carl Zeiss Jena GmbH in 1995. Currently, in 2004, the Carl Zeiss Group is a global player in optical technologies, with a staff of 14,000 employees worldwide and a 2003 revenue of more than €2 billion.

This brief overview of the history of Carl Zeiss Jena provides the necessary background information on the firm to appreciate the significance of the statues for the Carl Zeiss Foundation as abstract an account of the firm's management principles.

4. The firm as a non-reducible, evolving entity

In 1891 Abbe transferred his ownership of the Zeiss optical workshop as well as his 50 per cent share in the Schott glass works to the Carl Zeiss Foundation. It took him another four years to complete the first draft of the Foundation's statutes. Upon discussing the draft with the key managers of the companies, he presented a revised version to the state government of Sachsen-Weimar. It was approved by the state officials in October 1896 (Hellmuth and Mühlfriedel, 1996, p. 189). The statutes consist of 122 paragraphs in nine sections, plus a 14-paragraph appendix containing the statutes of the Foundation's university fund (see below), totaling almost 70 printed pages. In addition, Abbe wrote an extensive commentary of another 58 pages in which he explains the motives behind the statutes' prescriptions. The statutes specify in detail the organization of both the Foundation itself and its companies, the management principles for the companies, and the way in which their profits are to be spent. In our discussion of the statutes, we focus on the three issues that we identified in the introduction. We begin by analyzing his view of the nature of the firm.

For Abbe, the firm is a non-reducible entity whose existence is independent of its constituent parts. The organization is prerequisite to the ordered interaction and collaboration of its members. In addition, the ongoing existence of the organization is crucial because it allows for earlier achievements and skills to have a permanent effect on present-day performance, i.e. for preserving the firm's capabilities. In his comments on the statutes, Abbe reasons as follows:

...in such an organization, economic work does not begin anew in each year, as if it depended on a crowd of people gathering *ad hoc*; rather, all continues to operate that a long past has gradually created in terms of valuable drives (*Antrieben*), special installations, planned schooling, regulated connections and marketing channels (Abbe, 1900, p. 342).⁴

Abbe draws an interesting implication from his emphasis on the firm's organization. He proposes that since a part of the firm's yield cannot be attributed to the effort of individual workers, but is owed to the ongoing existence of the organization itself, this part of the firm's yield cannot legitimately be claimed by its present members. Rather, its legitimate recipient is the organization itself, in the concrete case, the Carl Zeiss Foundation as the impersonal owner of the Zeiss and

⁴ All translations from Abbe (1896) and (1900) are ours.

Schott firms (Abbe, 1896, p. 280). In return, the Foundation is obliged to use its share of the firms' yield to help safeguard its future development by improving the industrial, scientific and local environment in which they operate.

Abbe's characterization of the firm as non-reducible is clearly incompatible with some of the present-day theories of the firm in economics, including notions such as the firm as a nexus of contracts (Fama and Jensen, 1983). A more affirmative way to relate Abbe's view of the firm to contemporary reasoning starts from his recognition of the "continuity of all activities" that is made possible by the ongoing existence of the organization, and of the lasting effect of earlier firm members' performance. This position bears striking parallels to the routines concept that figures prominently in evolutionary economics (Nelson and Winter, 1982, ch. 5) and that, as has been argued in section 2, is closely related to the capabilities-based approach. The concept of routines (or organizational processes) as the repository of the firm's capabilities thus allows the more specific specification of the locus of the "non-reducible nature" of its organization that is alluded to by Abbe.

In arguing that the firm's capabilities are gradually created over time, Abbe moreover suggests that the firm is evolutionary in character. This view of the firm's nature translates into the management prescriptions developed in the statutes in two ways. First, the provisions of the statutes reflect actual prior practice in the Zeiss firm, which is an implicit statement in favor of gradualist, evolutionary management principles. At several places in his comments, Abbe emphasizes that provisions in the statutes are nothing but the codification of established practice. The first such statement is found in the preamble, where Abbe (1896, p. 263) emphasizes that the statutes contain "warranties for the continuing validity of the principles that have until now been followed in the management and administration of the firm". Similarly, in commenting on the organizational setup of the Foundation's firms, he states that it follows from his almost 30 years of experience with his own firms, as well as from his knowledge of various other companies. He concludes his general remarks on the organizational setup by noting that

...all this corresponds in principle to the arrangements with regard to the management of the present foundation-owned companies that in part have existed for a long time, and in part have developed during the past four years [after Roderich Zeiss had left], and thus have in their key elements been tested in lengthy experience. The provisions [...] thus serve the sole purpose of fixing and more

precisely specifying what has been actual practice without formal regulation until now (Abbe, 1990, p. 335)

Second, in addition to this reliance on prior experience, Abbe enforces a similarly gradualist approach on his successors. The very fact that in the statutes he gives them such detailed binding prescriptions already implies gradualism as it limits the discretion of future managers. This effect is further pronounced by the checks and balances contained in the provisions for cooperative management (see below).

The evolutionary approach taken by Ernst Abbe is quite notable because it antecedes similar positions taken by eminent theorists by several decades. After all, his was an age of unshattered belief in the possibility of radical change, which is reflected not least by the credo of Taylorism. The classic rejections of grand societal designs such as Popper's (1945) call for piecemeal social engineering and Hayek's critique of constructivism in designing institutions (Hayek, 1973) came decades after Abbe's writing. And they did not encompass planned organizations such as firms in their critique of grand design, but might even, as Hayek did, stress the contrast between the planned organization that may be subjected to central planning and central control on the one hand and the spontaneous order which cannot be properly designed but has to evolve on the other. The insight that firms as well are complex systems that may be damaged by radical change (even if it aims at improving them) became widespread only in more recent times (Winter and Szulanski, 2001).

Gradualism is a double-edged sword. It may preserve the coherence of the organization, but it also risks creating excess inertia. The insistence on gradualism and the *ex ante* specification of organizational and managerial details necessarily entails a loss of adaptability to changing environmental conditions, and Abbe is aware of this risk. He handles it in two ways. On the one hand, as a measure of last resort, changes to the statutes are made possible, although under severe restrictions only and with a clause allowing for such changes to be challenged in court. On the other hand, Abbe deems the trade-off between coherence and adaptability to be unavoidable. His decision is to emphasize the organization's coherence, and he accepts the blame for any damage to the Foundation and its firms that might arise from that decision.

In light of the recent literature, something more specific can be said about the method chosen by Ernst Abbe to imprint his management principles on the future of the Foundation-owned firms. Although the principles codified in the Zeiss Foundation statutes operate at a more basic level than the capabilities highlighted in the discussion of Zollo and Winter (2002, see

section 2 above), the considerations of these authors can fruitfully be applied to the present context. The strategic decisions on which Abbe's writing focuses would appear to be highly infrequent, heterogeneous and ambiguous. In terms of the criteria adopted by Zollo and Winter to choose among the various forms of learning, the codification strategy chosen by Abbe would thus appear sound. At the same time, Ernst Abbe went beyond a mere codification of the firm's routines in that we went to great lengths to explicitly state their purpose. Just by writing down the existing routines and prescribing them to future managers, he would not have communicated their purpose. By contrast, the comments on the Carl Zeiss Foundation statutes, as well as other written and spoken statements in which Abbe made his view of the firm and his management principles public, help to identify the intentions underlying his prescriptions. From the present-day perspective, this can be characterized as an attempt to hand over his own vision or "business conception" (Witt, 1998) to his successors to come. Abbe also takes conformity to the vision put forward by him as the yardstick for deciding whether specific changes later made to the statutes are allowable or not. If necessary, this is to be adjudged in court "with appropriate consideration of the founder's presumable intentions" (Abbe, 1896, p. 318). Codification of the routines *cum* articulation of the underlying vision is thus the method by which Abbe tries to preserve the firms' capabilities for the future.

5. Prescriptions for safeguarding sustainable competitive advantage

A long-term orientation

The Carl Zeiss Foundation is dedicated to economic, scientific and social purposes. The overarching economic goal of the Foundation is to safeguard the long-term viability of the foundation-owned firms (Abbe, 1896, p. 264). To attain this goal, the Zeiss Foundation statutes demand that the firms are not to maximize short-term profits, but rather to increase their long-term "total economic yield" (*wirtschaftlicher Gesamtertrag*, Abbe 1896, p. 280). This provision is explicitly set in contrast to the alleged behavior of joint stock companies. In Abbe's own interpretation, the respective paragraph demands that the Foundation pursue the "best possible development of the specific forces of organization and the best possible increase in the specific economic advantages flowing from it" (Abbe, 1990, p. 342). This long-term orientation is analogous to the focus on sustainable competitive advantage prevalent in the capability-based perspective. It is operationalized in a number of specific provisions.

Scope of firm activities

The Zeiss Foundation statutes restrict the scope of permissible activities of Foundation-owned firms. They are limited to the industries in which the existing firms were active when the statutes were devised: optics, glass making, instrument making and related industries. These limits to the range of activities that the firm may engage in resonate well with the implications for diversification derived from the capability-based perspective. As was outlined above, Teece et al. (1994) argue that related diversification can preserve the coherence of the firm, provided the capabilities of the firm are generic so as to provide a rationale for diversification in the first place. By contrast these authors see no rationale for unrelated diversification. The empirical evidence on the transferability of capabilities to new markets provides strong support to this position (Helfat and Lieberman, 2002).

It is less clear that Abbe's *ex ante* specification of industries in which the Foundation-owned companies may be active is a useful approach to the diversification issue. It may be justified, however, if one takes the absorptive capacities of the firm into account. The absorptive capacity argument suggests that the assimilation of external knowledge is a non-trivial problem and depends on a background of related prior knowledge. Under these conditions a long-term commitment of the firm to specialize on a limited range of fields of expertise is obviously called for. From this perspective, the *ex ante* specification may be interpreted as Ernst Abbe's suggestion on how to handle the problem of absorptive capacities.

Restrictions are made only with regard to the scope of activities, but not with regard to scale. Quite to the contrary, the statutes explicitly allow for new domestic and foreign branches, and for the founding of new firms or the takeover of existing ones – provided these work in the set of allowable industries. Interestingly, Abbe sees no need to explain the rationale underlying the restrictions, whereas he does discuss the potential risks inherent in allowing expansion, i.e. the potential loss of oversight and coherence. There are, moreover, no provisions in the statutes calling for specialization in specific stages of the value chain. In principle the statutes allow for unlimited vertical integration.

Close-to-science industry segments

Further restrictions on the scope of Foundation-owned firms apply within the set of allowable industries. Firms can only be active in those industry segments that are characterized by a close

science-technology relation in products and/or processes. The statutes prohibit even the purely financial engagement of the Foundation in firms that are not covered by these regulations. Consequently the opportunistic exploitation of short-term profit opportunities that do not add to the long-term position of the Foundation-owned firms is prohibited.

This limitation of activities to the science-technology nexus is even more congenial to the capability perspective than the restriction in terms of allowable industries, since it defines the Foundation-owned firms as being science-based. More than the *ex ante* specification of industries, this amounts to an *ex ante* specification of the nature of capabilities to be sought, and the kind of strategy to be pursued, by the Foundation-owned firms.

Shop-floor skills

In addition to specifying the range of the firms' activities, the statutes prescribe the type of work to be done in Foundation-owned firms. As much as possible, firms are to be active in those segments of their industries that require "technically sophisticated individual labor" (*technisch hochstehende Einzelarbeit*; Abbe, 1896, p. 281), even if these segments are not very attractive otherwise. To interpret the intentions underlying this provision, it is helpful to consider an earlier document of 1891 in which Abbe had outlined the strategy of the Foundation. In this document, Abbe characterizes qualified labor as a "school of refined technique" that "provides an opportunity to keep a larger number of capable technical and also scientific employees in the workshop's service" (quoted in Hellmuth and Mühlfriedel, 1996, p. 187).

The emphasis on qualified labor is in striking contrast to the principles of Taylorism. It is explicitly characterized as a counterbalance to the "routine tendency of pure factory work" (Abbe, 1896, p. 282). This does not imply that Abbe objects to mass production and increased division of labor. As we noted in the historical overview, his first contribution in the optical workshop was to increase the specialization of individual workers. Rather than being blind to the benefits of the division of labor, Abbe seems to hold that the useful and potentially unavoidable expansion of factory work comes at a cost – loss of individual skills – and thus requires deliberate counterbalancing measures.

The central role for qualified labor in Foundation-owned firms appears to be complementary to the provisions codifying the scope of activities in safeguarding the absorptive capacities of the firm. To provide the necessary absorptive capacities of the firm is seen as a task that is not restricted to the clerical and managerial levels of the firm but extends to the shop floor.

It enables the firm to quickly adapt production to changing environments. The insistence on preserving and fostering shop-floor skills resonates well with what we know today about the importance of shop-floor level innovation and learning by doing enabled by a thorough understanding of the job (see Lazonick, 1990).

Support of science

Beyond the realm of the firms it owns, the Zeiss Foundation is to further the interests of the industries in which its firms are active, i.e. optics and precision mechanics,⁵ to engage in non-profit activities to the benefit of the working population in and around Jena, and to support research and teaching activities in mathematics and the sciences. In part these measures are based on social policy considerations. At the same time, they are motivated by the intention to promote the Foundation's broader interests, and they are to be pursued in close relation to the Foundation-owned firms.

It seems evident that the first of these goals, advancement of the respective industries, would be to the direct benefit of the Foundation-owned firms. In addition, the statutes explicitly state that measures taken to attain this goal may be linked to the firms' activities or even be executed by the firms themselves (Abbe, 1896, p. 309). The firms are thus directly involved in the Foundation's broader activities to promote the progress of the industries, even though these activities are not to be limited to the immediate interest of the Foundation-owned firms.

Similarly, the concrete measures taken to support the local working population also included activities – such as the establishment of a public library – which likely had positive effects for the firms, as they enhanced the education of the workers. This is entirely consistent with Abbe's emphasis on shop-floor skills. Most interesting from the capability perspective, however, is the provision made for support of basic science by the Zeiss Foundation. This provision is clearly not motivated by purely altruistic motives. For Abbe, the success of the optical workshop and the glass works is based on Carl Zeiss' early insight that the close contact to science provides a powerful basis for technological progress. He considers the presence of the university as a causal factor underlying the rise of precision mechanics in Jena (Hellmuth and Mühlfriedel, 1996, pp. 159, 172). Promotion of science for Abbe also means to promote science-based industry, as the interaction with science enables and induces the firms to develop new products and processes and

⁵ Abbe (1896) refers to these industries as *feintechische Industrien*. This term has no obvious counterpart in present-day German industry classifications.

thus to recreate their capabilities. This perspective on science shows up both in the statutes and in the accompanying statutes of the “university fund,” the Foundation’s vehicle for the support of science. First, the support is concentrated on the University of Jena, thus generating a natural advantage for the Foundation’s firms. Second, the support of science is to be in line with the Foundation’s broader goals. The university fund statutes restrict the Foundation’s subsidies to mathematics and the sciences, plus those other disciplines having a “closer relation to the interests of the Carl Zeiss Foundation” (Abbe, 1896, p. 323).

Practical science support activities reflected this position, as the Foundation deliberately used the university fund to shape the university’s research orientation (Hellmuth and Mühlfriedel, 1996, p. 297f.). For example, Abbe ensured that Gottlob Frege, an authority in higher mathematics, was supported by the university fund. Overcoming the fierce opposition of the university’s physics department, he also helped physicist Felix Auerbach, who was Jewish, to become a professor. The Foundation moreover financed a new institute for the physicist Adolph Winkelmann, with whom Otto Schott conducted collaborative research on the optical properties of glass. Quite uncommon among German universities were two chairs that were established in 1902 following Abbe’s suggestion and that closely combined science and technology: the institute of technical physics and applied mathematics, and the institute of technical chemistry.

In practice, then, the Foundation’s “science policy” was at the same time applied industrial policy. To be sure, the statutes kept the support of science outside the direct influence of the Foundation-owned companies, and they prohibited any attempt to exclude competitors from its potential benefits. At the same time, the money from the university fund helped to continue the direct science-technology interaction that had characterized the Zeiss firm right from the beginning.

The support of science and the active steering of the local university’s research agenda go beyond the essentially defensive problem of reacting to environmental change on the basis of dynamic capabilities. The scientific basis of the Foundation-owned firms is effectively endogenized, which allows the Foundation and its firms to initiate change rather than merely to react to it. Of course, creating the scientific foundations required for the firm’s product and processes is exactly what Zeiss and Abbe did when they established the scientific basis for designing and manufacturing microscopes. In this respect as well, the Zeiss Foundation statutes codify prior practice of the Zeiss firm.

General orientation

Teece, Pisano and Shuen (1997) have suggested a useful distinction between models of strategy that are based on the exploitation of market power and strategic interaction with competitors on the one hand, and models of strategy calling for superior efficiency of the firm on the other. In terms of this classification, Abbe's view of the firm clearly belongs to the latter category. In both the Zeiss Foundation's statutes and Abbe's comments on them, competing firms are hardly mentioned at all. And the general perspective with regard to the industry level is to promote the state of the art rather than to behave strategically vis-à-vis competitors. This position cannot simply be explained by the lack of competition of the Foundation-owned firms. The optical workshop in particular was always subject to competitive pressures from other optical instruments producers. However, Abbe seems to have taken it for granted that as long as they can preserve their strong technological position, the Foundation-owned firms should also in the future be able to pursue a strategy based on using their capabilities to develop superior products and processes rather than the competitive struggle based on cutting prices, restricting competition, or obstructing competitors.

6. Top-level management and labor relations

Right after stating the essential goals of the Foundation, the statutes contain detailed prescriptions for the organizational setup of its companies, and for the selection and behavior of top-level managers. Several guiding principles can be abstracted from these rules. We discuss them under the headings of team leadership, expertise and continuity. Afterwards we discuss the labor relations envisaged by Ernst Abbe.

Team leadership

The *team leadership* principle is clearly visible in the way the top management of Foundation-owned companies is set up. Top management teams of these firms have to consist of four members with equal rights, who are to make their decisions with unanimity and who are collectively liable for damages arising from them exceeding their responsibilities. Abbe deems it necessary to have a collective body leading the firm, since it is only in this way that it can be ensured that the multiplicity of interests and the diversity of expertise that exist in the firm are represented at top echelons of decision-making. The coherence between the separate Foundation-

owned companies is fostered by the provision that at least one top management team member of the optical workshop must also be on the top management team of the glass works. For Abbe, this is a matter of handling the particularly interdependent fields of glass making and optical instrument making, but also a more general matter of the unity of the Foundation's strategy.

The top management team is to decide all matters of regular business activity independently of the Foundation. However, the Foundation's commissioner (*Stiftungskommissar*) is assigned extensive advisory and supervisory functions that are specified in detail in the statutes. He functions as a mediator between the Foundation and its firms and has to be consulted in all exceptional matters. Further provisions safeguard the independence of managers. Only lifetime employees can be named members of the top management team. Moreover, although top management team membership may be temporally restricted *ex ante*, top management team members cannot be named "until revoked" nor may they be dismissed prematurely. Any contractual obligations of top management team members other than the ones written down in the Foundation's statutes are declared void. The rationale behind the independence of managers is to safeguard their internal and external authority. Abbe argues that for leaders to be trusted, it has to be generally known that they do not have to consider any interests in their decisions other than those of the firm itself.

Expertise

To be named a top management team member, the respective person has to be an expert with regard to the scientific, technical or business interests of the firm. At least one top management team member is required to possess scientific expertise relevant to the firm. Even after having been named, top management team members have to continue their regular activity in their field of expertise. Otherwise, so the argument given for this clause goes, managers would "soon lose the living contact with the practical activity of their firm and increasingly become subject to the danger of handling their matters in a formalistic way" (Abbe, 1900, p. 339).

The provision that the top management team needs to assemble experts from the different relevant domains of knowledge, and that in particular it needs to contain scientific expertise, can again be justified theoretically by reference to the firm's absorptive capacities. Cohen and Levinthal (1990) argue that the firm's absorptive capacities depend both on the individual knowledge bases of its members and the way they are communicated within the firm. In terms of this concept, Abbe's provisions demand that the communication of knowledge bases from the

technical, scientific and business realms has to extend into the top management team itself. In this way, the threat that an entire domain of relevant expertise might be excluded from top-level decision making seems to be kept in check. Moreover, the requirement of having at least one scientist on the top management team helps to ensure the ongoing capacity of the firm to understand and incorporate recent scientific developments, and to modify its products and processes accordingly. The provision that top management team members have to remain active in their original field of expertise is the dynamic counterpart of the absorption problem – it may help them to keep up to date in their professional field and thus to keep their absorptive capacities workable in a dynamically changing environment. The provision thus constitutes a concrete measure for safeguarding the dynamic capabilities of the firm. It implicitly acknowledges the need for ongoing change in the firm.

Continuity

Continuity in management is enforced by the rule that individuals can become members of the top management team only after they have served in leading positions of a Foundation-owned firm for no less than two years. To lead a firm, argues Abbe, an individual requires knowledge of its most important matters and of its culture. Persons foreign to the firm would be incapable of making decisions on the basis of sound own judgment. They would either have to rely on the experience of other managers, i.e. not make an own judgment, or they would be in danger of making bad decisions. In turn, the individual manager also has to be known to the other managers.

The emphasis on continuity in the Zeiss Foundation statutes resonates well with the theoretical reasoning in Edith Penrose's (1995) theory of the growth of the firm. Penrose argues that efficient firm growth is limited by the availability of managerial know how. According to her, managerial know how cannot be purchased on markets because it is dependent on specific experience made within the firm. Newly hired managers therefore do not immediately increase the stock of managerial know how available to the firm. Quite to the contrary, new managers initially reduce that stock, because managerial know how is required to socialize the new managers into the firm.

Abbe deemed also continuity necessary in individual leadership. This is illustrated by his conflict with Roderich Zeiss prior to the latter's departure from the firm. In the midst of this conflict, in a letter to Roderich, Abbe complains about the unsteadiness of the younger Zeiss'

decision making. He regards it as extremely dangerous for the firm – not only because unsteady management compromises the capacity to act in crises, but also because it undermines the trust that the employees have in the management’s capabilities (Hellmuth and Mühlfriedel, 1996, p. 182). Implicit in this accusation is the conviction that authority has to be based on merit.

Autonomous and responsible workers

Ernst Abbe has long been recognized as a eminent social reformer in Germany, not least because he gave up his personal ownership of the Zeiss company and early on introduced a worker’s council and social policy measures such as an entitlement to old-age pensions and the eight-hour working day at the company (Schmoller, 1906). It would be wrong, however, to simply portray Abbe as a philanthropist. This position is contradicted by the justification he himself gave for his activities. Even in the realm of labor relations and social policy within the firm, philanthropic motives only provide a limited explanation of the practices implemented at the Zeiss firm. At least in part, the measures taken can be seen as win-win-situations to the benefit of both workers and the firm (a similar point has been made by Plumpe, 1997). Abbe himself (1896, p. 347) expresses his conviction that the past treatment of workers – which is reflected by the statutes’ provisions – was a decisive factor for the success of the Foundation-owned companies. Although at the time Abbe was not the only firm owner in Germany who was concerned with improving the welfare of workers, his position on labor relations was fundamentally different from other reformist approaches in that it was based on changing the relationship between the firm and its employees at the fundamental, constitutional level.

For the present discussion, Ernst Abbe’s basic view of workers, visible in the Zeiss Foundation’s statutes as well as the ongoing practice within its firms, is more important than actual social policy measures. The crucial point here is that the statutes give workers enforceable rights vis-à-vis the Foundation and the management of its firms. At the very beginning of the statutes, when stating the responsibilities of the firm with regards to its employees, Abbe stresses, as a goal, the “improvement of their personal and economic *legal* situation” (Abbe, 1896, p. 264, *our italics*). In his explanations of the statutes he adds:

...the purpose of my endeavors is not at all to promote charity in my field of activity, but solely to improve the legal situation of all those who entered in this field of activity or may do so in the future. (Abbe, 1900, p. 331).

In this context Abbe's reaction to a petition filed by employees in 1904 is illustrative. The petitioners had asked to base pensions on an interest-bearing fund in lieu of the pay-as-you-go system that underlaid the Foundation's pension statutes. In rejecting this request, Abbe once more stresses that "not capital goods, but the living organization of the Zeiss works, the sum of the forces, capabilities, experiences and traditions united in them, have to be the carrier of the Foundation and its liabilities" (quoted in Hellmuth and Mühlfriedel, 1996, p. 294). He moreover laments that the petition indicates its authors' ignorance of his intentions, as it asks for the kind of pension system common in other firms – a system that for Abbe amounts to no more than a "pittance, crumbs from the rich man's table" (ibid.). By contrast, Abbe

...had dared to make the first practical attempt at worker legislation and had endeavored to grant to workers not only the participation in some kind of capital yields, but an enforceable right to pensions, support for surviving dependants, unemployment insurance (by means of dismissal settlements), vacation, the right of political activity etc. [...] In this, he had however given the spiritual (*ideell*) promotion of the working class priority over its more or less secure material welfare. (ibid. p. 295)

The rationale underlying social measures is thus to emancipate workers, to increase their personal autonomy by replacing the "public law of proletarians" by a "better private law of workers and clerical staff" (Abbe, 1900, p. 348). This intention also shows in the Zeiss Foundation statutes' section with provisions on labor relations. The statutes dismiss all forms of personal subordination of workers to their principals. A separate paragraph explicitly grants to workers the free exercise of individual and civil rights, including the right to representation of their interests individually and in groups. Workers' representations in the Foundation-owned companies are entitled to be heard on all matters. These clauses are in striking contrast to the common practice at the time, when social democratic or union activities were regarded as legitimate reasons for the dismissal of workers.

As a counterpart to worker autonomy came the expectation that they assume responsibility for their work. For Abbe, labor relations at Zeiss were a source of past success, as they enabled the firm to keep a large number of conscientious, dedicated, reliable and upright employees. And what is more, Abbe was convinced that this effect of labor relations is essential for the very survival of the firm. For the kind of work done at Zeiss, he argues (1900, p. 350),

personal involvement, deliberation and “far more than merely dutiful diligence” is indispensable for maintaining the technical standards once achieved, and even more so, for increasing them. Worker responsibility and involvement cannot be prescribed by the constitution of the firm, but has to emerge from the workers’ own motivation, fostered by suitable factual institutions and interactions in the firm.

The introduction of the eight-hour working day at the Zeiss firm in 1900 nicely illustrates the complex labor relations prevalent at the firm. The eight-hour day was agreed to by the management under the condition that working days were strictly kept to by workers, that there would only be two breaks and no eating or drinking during work time, and the ban on paid work outside the firm would be enforced. This intensification of the workday raised fears among the workers that supervision might become oppressive. Abbe’s closest colleague at the time, Siegfried Czapski, tried to dismiss such fears by means of an appeal to workers’ responsible behavior. He declared that “[i]f it proved necessary to purchase time clocks and lock the gates, then we would say we have a work force here that is not mature for the eight-hour day, then we would simply have to abolish it again” (quoted in Hellmuth and Mühlfriedel, 1996, p. 267).

Abbe’s emphasis on the importance of skilled labor for the capabilities of the firm thus finds its counterpart in the motivational effects of the labor relations envisaged in the Zeiss Foundation statutes. Based on his experience in the Zeiss firm, Abbe expects that treating the workers as autonomous, responsible individuals will yield a long-term benefit to the firm by increasing their interest in their work and their willingness to contribute more than minimal efforts to the firm. The implicit psychology of this approach to motivation finds support in present-day motivational theories (Frey, 1997).

7. Theoretical insights derivable from this 19th century scientist and manager

Throughout this article we have stressed the intriguing parallels between the management principles developed by Ernst Abbe and contemporary capability-based theories. In our view the Zeiss Foundation statutes are an early predecessor of the capability-based view, which constitute a surprisingly complete and internally consistent set of provisions of how to run innovative, science-based firms. As such, the documents authored by Ernst Abbe could be seen as no more than an interesting historical curiosity, a footnote to the history of management thought. It seems

to us, however, that Abbe's management thought is more than that. Abbe's writings allow us to add insights to the capabilities theory of the firm by articulating ideas about the processes that seem to create and sustain a firm's dynamic capabilities. In this section, in addition to outlining these ideas, we will also discuss the limitations and omissions that we see in Abbe's theory of the firm.

One important characteristic of the Zeiss Foundation statutes is that they go beyond a concept of dynamic capabilities as a mere adaptation to the firm's environment. Through the measures to be taken by the Zeiss foundation, the environment in which its firms operate is significantly modified. Given that the Zeiss Foundation operates in a small-town setting, it has substantial leverage in upgrading its environment. (The outcomes of its activities are clearly visible in its native Jena even today.) Most significant in this context is the call for the direct support of science by the Zeiss Foundation. We sketched out earlier how the support of science was turned into industrial policy by the Zeiss Foundation. The means expenditure in Jena by the Foundation helped to establish first-rate university departments in disciplines such as physics and mathematics, which allowed the Foundation-owned firms both to draw on the local academic knowledge base and on the supply of university graduates.

It is interesting to compare the approach taken by Ernst Abbe and the Zeiss Foundation to the roughly concurrent attempts of the German chemical firms to shape their environment. Murmann (2003) has documented how successfully the lobbying of chemical firms shaped the institutional setup in which the firms operated. Zeiss focused on directly influencing the citizens, community leaders and public officials responsible for Jena, and did not rely on the activities of industrial associations and the like. This approach allowed Foundation-owned firms to directly benefit from the money spent by the foundation on the support of science. Given the focus on funding local research activities and the absence of local competitors, the localized character of spillovers kept externality effects in check.

The literature on dynamic capabilities has emphasized the need for the firm to adapt to its competitive environment. The historical material suggests that firms can do better than merely adapt; they can and do – within limits, – actively shape their environment. Acknowledging this capacity suggests that the evolutionary selection heuristic often used in the literature is incomplete. The firm is not subjected to a perfectly exogenous selection environment. Rather, the firm and its environment have a coevolutionary relationship (Murmann, 2003). This

coevolutionary aspect of dynamic capabilities, its preconditions and its likely effects have not found the attention they deserve in the existing literature.⁶

Second, the codification *cum* articulation strategy utilized by Ernst Abbe to perpetuate his management principles adds an interesting aspect to the discussion of deliberate capabilities learning (Zollo and Winter, 2002). We have argued above that Abbe's approach conforms to the criteria suggested for codification to be beneficial. There is, however, an inherent risk in codification, i.e. that the codified processes over time are detached from their original purpose, and are increasingly perceived only as unnecessary and annoying restrictions. As will emerge below, this tendency is also observable with regard to the recent history of the Zeiss Foundation statutes. Ernst Abbe chose to make the purpose of the codified provisions explicit. By articulating the intentions underlying them, he added meaning to the individual provisions and thus facilitated their subsequent interpretation. Clearly stating the science-based character of the Foundation-owned firms, and embedding them in the science support activities of the Foundation itself, provided further guidance with regard to the firms' identity. These measures seem suitable as instruments to enhance the acceptance of the provisions, and to provide a yardstick for later evaluations of whether they are still valid.

Finally, the Zeiss case suggests an interesting perspective on the relationship between capability and agency theories. For Ernst Abbe, the emphases on worker skills and on worker responsibility were two sides of one coin. He trusted that workers, treated as responsible agents, would live up to their intellectual capacity and deliver the quality of work required in a successful science-based firm. Due to the codification of labor relations in the Zeiss Foundation statutes, workers could moreover expect them to be preserved in the Foundation-owned firms. Similar to citizens of a state under the rule of law, they were given specified, reliable rights. It seems to us that the legal status of workers vis-à-vis management was one secret behind Zeiss' dynamic capabilities. On the basis of their guaranteed rights, workers and managers could work toward the common goal of trying to adapt the firm to new technological and competitive situations without constantly fearing that the other party would try to extract a disproportionate share of the value created by the firm.

Anecdotal evidence indicates that this kind of "cognitive leadership" (Witt, 1998) was successful. Zeiss employees (or "Zeissians," as they refer to themselves) have always tended to show an unusually close identification with their firm and to perceive themselves as an "elite" among

⁶ The issue is touched upon in Teece et al. (1994, p. 16), but it is not systematically explored.

fellow workers. During the time when Germany and Zeiss were divided, the strong identification of Zeiss workers was present in both the Western and the Eastern firms. More generally, the complementary relation between worker skills and worker motivation presumed in Abbe's management principles would imply that tight monitoring regimes may be incompatible with an emphasis on shop-floor skills and worker motivation. Industries relying on different types of labor qualification may accordingly require different kinds of governance. This hypothesis is testable and seems worthy of empirical efforts to us.

What is missing in Abbe's theory of the firm?

Perhaps the most radical provisions in the Zeiss Foundation statutes are the restrictions on the scope of the firms' activities. We argued above that the limitations to scope may be justified on the grounds of the firms' absorptive capacities. Conspicuously absent are analogous vertical restrictions (except for the general provision to keep close to science). It appears that Abbe did not recognize the potential to attain competitive advantage by focusing on specific stages of the value chain.

A related concern is the potential inertia that may arise from the emphasis on gradualism and continuity. It has been argued that in times of more radical "architectural" (Henderson and Clark, 1990) change, incumbents frequently find it hard to make the required modifications to their products and processes. In other words, their dynamic capabilities fail. In spite of the efforts made in the Zeiss Foundation statutes to preserve dynamic capabilities, there are no well-defined instruments that would help the firms to deal with situations when change is more rapid than they can accommodate by gradual learning. It is possible that allowing for radical change while generally adhering to gradualism is not a feasible strategy. If this is so, one has to make a choice between gradual and radical change, which is what Ernst Abbe explicitly did. However, there may be ways to reconcile the two, for example by setting up particular experimental "niches" in the firm that proceed in less gradual ways. No such considerations are to be found in Abbe's writings.

Finally, the present discussion begs the question of what effects the detailed prescriptions laid down in the Carl Zeiss Foundation's statutes had on the development of the Foundation-owned firms. *Prima facie* evidence suggests that their effect was beneficial: Both the Zeiss and Schott companies are among today's world leaders in their respective fields of activity, in spite of a history of sometimes rather adverse environmental conditions. They are still owned by the Zeiss

Foundation, and the statutes continue to be in effect. In addition, Jena, the place where the history of Zeiss began, is one of the few places in East Germany today that has managed to come out of the transition from state socialism with a non-negligible industrial sector and with a substantial number of entrepreneurial ventures. Many of them are in high-technology sectors, and many are direct or indirect Zeiss spinoffs. It can safely be assumed that the present development benefits from skills fostered in the Foundation-owned firms. Without more profound empirical research it is not possible, however, to decide whether the success of the Foundation-owned firms and the industrial development in Jena was possible *because* of the provisions made by Ernst Abbe, because of quite different factors, or perhaps even *in spite* of the restrictions made in the Zeiss Foundation statutes.

The long-term performance of the Foundation-owned firms notwithstanding, the present Zeiss management clearly feels restricted rather than enabled by at least parts of the statutes (Bertram, 2002). Of major concern are the limitations in capital-market transactions that result from the legal status of the Foundation and its firms. Particularly during the stock market boom of the late 1990s, the Zeiss management felt disadvantaged because it could not use its own stock to buy into other firms and to organize joint ventures. Accordingly, the Foundation statutes were recently changed to allow for turning the Zeiss and Schott firms into two independent, public companies (Zeiss, 2003). Supported by the present commissioner of the Zeiss Foundation, the firm's management argues that this change is necessary to keep the firm competitive in today's environment, and that it therefore does not contradict Ernst Abbe's original intentions. The present management's position, which is highly controversial among the stakeholders of the firm and has been challenged in court, finds some support in the analysis of Teece et al. (1994, see also section 2). In recent decades, the firm's environment has changed in that the optical industry has become more closely intertwined with other fields such as biotechnology and semiconductors. In this situation of "converging evolutionary paths," the analysis of Teece et al. (1994) favors "network firms" characterized by partial equity holdings and joint ventures over vertical integration. This is exactly the kind of institutional arrangement that the present Zeiss management argues is necessary. In any case, the present conflict over the Foundation statutes indicates the limits to the gradualist approach prescribed by Ernst Abbe. Conceivably, the lifecycle argument advanced by Helfat and Peteraf (2003) is applicable here, and the respective provisions of the Zeiss Foundation statutes are no longer suitable as the basis of the capabilities envisioned by their author more than 100 years ago.

We plan to study these issues more thoroughly in future work. In particular, we will carry out a very detailed investigation of the impact that the codification of the Zeiss company's routines had on the subsequent development of the firm. The articulation of Abbe's vision in the Foundation's statutes provides a unique opportunity to do this research. In our view the history of Zeiss was a "natural experiment" (Kogut and Zander, 2000) right from the beginning, not only after World War 2 when the firm was split in two. To date scholars have analyzed only a very small part of the "data" generated by this marvelous "natural experiment."

8. Some concluding remarks on the management ideas of Abbe and Taylor

In this article, we presented the management concepts devised by the German physicist, entrepreneur and social reformer, Ernst Abbe. With their emphasis on sustainable competitive advantage based on the firm's capabilities and their recognition of the importance of shop-floor skills and worker involvement, the general thrust of the principles developed by Abbe is surprisingly well in line with some present-day management theories. Their gradualist nature does more justice to the evolutionary character of the firm than the calls for revolutionary changes frequently made in Abbe's days. In addition, some of the specific provisions derived from the general principles, for example with regard to shaping the environment in which the firm operates, even go beyond the prescriptions of established theory.

We framed the discussion by juxtaposing his thought to the concepts developed by Frederick Taylor at roughly the same time. Frederick Taylor and later Henry Ford, with his introduction of the assembly line, are the emblematic pioneers of modern production methods: mass production of standardized commodities in factories with extreme degrees of division of labor and an almost complete centralization of responsibility and decision making. In concluding this article, it is now time to come back to the comparison with Taylorism. Does Taylor's contemporary Ernst Abbe provide us with an alternative vision for managing a firm? Our answer to this question is a qualified "yes." The answer is affirmative because of two factors. One is that Abbe, based on his lengthy experience in practical management matters, realized the limits to a management approach which attempts to be "scientific", but turns out to be mechanistic because it fails to appreciate the differences between a physical or technical system and a social organization, i.e. a collective of human agents that each have their own intentions and their own knowledge. It is not that Abbe did not realize the potential benefits of divided labor and learning

by doing based on specialization. As we have reported above, successful “rationalizing” production in Zeiss’ workshop anteceded his success in developing the scientific foundations for optical instrument-making. Furthermore, in Abbe’s later years, some production lines at Zeiss, for example mass production of military binoculars, utilized Taylorist concepts rather than the “challenging individual labor” favored by him. Abbe, however, realized that Taylorism implies a loss of worker skills and of worker involvement that may, in the long run, be harmful for the company, and he actively attempted to create a bulwark against its universal introduction even in the long run. Our second reason for an affirmative answer is that Abbe, just as Taylor, did develop a way to introduce science in modern industry, albeit on a different level. He uses science to rationalize product development and product design rather than the actual production process.

But why do we want to qualify our “yes” to the question of this section? Because Abbe was of course active in an industry different from those in which Taylor and Ford introduced their new production methods. Microscopes were not mass produced like automobiles, and the existing technology would not have allowed Taylorism to be pushed to the extreme in the optical industry. Abbe wrote the statutes of the Zeiss Foundation as a guideline for managing its firms, which were to remain science-based. He might not have advocated his own management principles as a general model applicable to the high-volume production of standardized commodities. Rather, he expected the significance of factory production to increase further, and repeatedly referred to the special character of the optical industry that made a different approach necessary there. From a present-day perspective, one may perhaps be a bit bolder, since Taylorism has been found not to be incontestable even for mass production such as in the automobile industry. The extensive discussions of the Toyota system (Clark, et al, 1987), which in many ways is more compatible with Abbe’s approach to management than with Taylor’s, seem to support this view.

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