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# Ernst Abbe's scientific management: theoretical insights from a nineteenth-century dynamic capabilities approach

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'Scientific management' is the label Frederick Taylor attached to the system of shop-floor management devised by him. In this article we present our discovery of very different 'scientific' management principles that, roughly concurrently with Taylorism, were developed by German physicist-turned-manager Ernst Abbe and that are codified in the statutes of the Carl Zeiss Foundation created by Abbe. They exhibit striking parallels to resource- and capability-based theories of the firm, and indicate managerial challenges that warrant further theoretical elaboration. Abbe develops an 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 set-up and its labor relations. We highlight some of the most characteristic features of Abbe's thought, discuss its effects on the development of the firms owned by the Zeiss Foundation, and compare it to and draw out implications for present-day management theory.

## 1. Introduction

'Scientific management' is the label Frederick Taylor (1964 [1903, 1911]) gave to the system of shop-floor management developed by him. 'Scientific management', or 'Taylorism', was to develop into one of the most powerful influences on twentieth-century management practice. In essence, 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.

This article presents a set 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), Abbe in 1866 joined the Carl Zeiss optical

workshop as a R&D scientist. Later he became the managing director and owner of the famous optical instruments maker, as well as of 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. He drafted statutes for the foundation in which he codified the guiding philosophy and the principles of management that he had implemented in the preceding two decades (Abbe, 1989 [1896a]). Four years later, Abbe (1989 [1900]) wrote a long commentary on the statutes' prescriptions to record the intentions underlying the statutes for future generations of foundation leaders.

In this paper we show that despite striking biographical parallels between 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 (Wernerfeld, 1984; Dierickx and Cool, 1989; Barney, 1991; Peteraf, 1993; Kraatz and Zajac, 2001) and the closely related dynamic capabilities theory of the firm (Porter, 1991; Teece *et al.*, 1997, Dosi, Nelson and Winter, 2000). As a management theorist, Ernst Abbe found himself in a rare position: he not only had significant hands-on experience in guiding a firm, but was also able, because of his scientific training, to articulate his management practices in terms of abstract principles. Even for today's organizational theorists, Abbe's first-hand account of management principles offers a remarkable opportunity to enrich our understanding of how managers can create and recreate firm capabilities that allow firms to enjoy a long-term competitive position. Abbe's writings also show that practitioners had already formulated some of the fundamental insights underlying modern organizational theory 100 years ago. Developed at roughly the same time, Taylorist scientific management would revolutionize shop-floor practices during the decades that followed. Abbe's writings show that the limits of Taylorist practices realized later were already apparent to some of Taylor's contemporaries.

In our view, Ernst Abbe's management principles, as they are expressed in the Zeiss Foundation statutes of 1896, offer important insights 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 whose primary objective is to ensure the firm's long-term sustainable growth. Predating later theoretical advances such as the resource-based theory and the dynamic capabilities theory, his management principles assign key roles to enhancing the scientific basis of the firm's technology and fostering the skills of workers. Second, underlying these principles is an evolutionary view of the firm. The organizational prescriptions are not based on a one-shot attempt to (re-)design the firm's practices from scratch, but rather seek to specify and codify ongoing practices that developed over longer periods of time. This aspect of Abbe's writings is valuable for contemporary theorists because he specifies in detail why firms need to change in an incremental manner. Third, from the principles for securing a sustainable competitive position, Abbe develops detailed prescriptions for the organization of

the company, the recruitment and decision-making procedures of its top-level management, and various aspects of labor relations. His orientation toward labor relations has long since earned Abbe a reputation for being an eminent social reformer in Germany (Schmoller, 1913 [1906]). We argue, however, that the creation of a sustainable competitive position for the firm rather than philanthropy is the driving force behind Abbe's attitude toward labor.

Our article is organized as follows. To place Ernst Abbe's management thought in a present-day context, we present in Section 2 a brief summary of some key insights and empirical evidence related to the contemporary resource- and capability-based theories of the firm. 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 the processes through which the firm can secure its long-term competitiveness, 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 set-up of top-level management and labor relations. In Section 7 we use the introduction of laser technology to trace the long-term effects of the principles laid out in the Zeiss Foundation statutes. Next (Section 8) we characterize Abbe's legacy for organizational theory and practicing managers. We propose that, more than 100 years after they have been devised, his writings still hold relevant insights for the contemporary reader. Section 9 concludes with a final appraisal of the differences between Taylor's and Abbe's management philosophies.

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

Resource- and capability-based theories of the firm attribute the competitive position of firms primarily to the firm's assets and capacities rather than to industry structure and strategic interactions among competitors. These theories shift the analytical focus away from products and product markets to the inputs used by a firm and the way in which production is organized. In this section we provide a synopsis of resource- and capability-based approaches.<sup>1</sup> Using central concepts from these approaches, we are able to discuss with analytical precision the specific proposal made by Ernst Abbe in 1896 about how to manage the Carl Zeiss firm. At the same time, relating Abbe's principles for creating and maintaining the competitiveness of the Zeiss company to the capability-based perspective helps to advance the theoretical literature because his principles point to very specific managerial processes and activities.

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<sup>1</sup>A consensus is emerging that the various resource- and capability-based theories are partially overlapping and highly complementary where they differ. Some authors utilize resources and capabilities as largely synonymous concepts. A clearer distinction of the concepts was articulated by Amit and Schoemaker (1993), who suggest that capabilities are defined by the firm's capacity to use its resources in a coordinated way to achieve desired results.

Building on the prior work of Penrose (1995 [1959]), Wernerfelt (1984) reinvigorated the study of resources as crucial determinants of a firm's behavior. He characterizes resources as semi-permanent (tangible and intangible) assets of the firm that have the potential to affect the firm's competitive position. Resources have to be non-tradable, non-imitable and non-substitutable to be of strategic value to the firm and to potentially create a sustainable competitive advantage (Dierickx and Cool, 1989).<sup>2</sup> The firm cannot acquire new resources and capabilities at will. Rather, its present endowment of resources and capabilities conditions its capacity to acquire new ones. Due to their limited adaptability, the accumulation of strategic resources and capabilities requires a consistent, long-term approach, and for this reason becomes a core task of strategic management.

Taking 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 depends on today's resource position, capabilities and activities. Because of different starting conditions, firms are and will remain heterogeneous (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. They suggest (Nelson and Winter, 1982: 99) that the firm's 'memory' is embodied in its routines, i.e. in the regular patterns of organizational processes. Routines cannot be reduced to the level 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. Routines coordinate the behavior of employees because routine-based behavior is predictable by others and enables them to align their own behavior to that of others. The at least partially tacit character of routines limits the scope of both deliberate modification of routines and imitation by competitors.

Firms are heterogeneous for other reasons as well. Highlighting the role of social factors, Kogut and Zander (1996) stress the capacity of firms to provide their employees with an identity, which facilitates coordination, communication and learning, and which also affects the social norms operating within the firm. Witt (1998) adopts a more individualistic viewpoint and emphasizes the cognitive leadership exerted by entrepreneurs who can channel the perceptions of employees. By providing a shared vision or 'business conception' (Witt, 1998: 166), entrepreneurs may enhance the coherence of cognitive frames within the firm. Both contributions thus suggest that heterogeneity may be brought about by differences in how employees perceive the firm's 'meaning' and see their own role in attaining the firm's goals.

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

An important implication of the various contributions is that idiosyncracies in resources, routines, identities and conceptions alone or together may be underlying the specific capabilities of a firm. However, all these causes of heterogeneity are not fully controlled by the firm or instantaneously adjustable, and they cannot therefore be manipulated at will. The firm's existing capabilities therefore condition its ability to acquire new ones.

### 2.1 *Dynamic extensions*

The resource and capability concepts are useful starting points to explore the dynamics of how firms gain and lose their competitiveness. Two issues are central to the theoretical discussion: first, how do the resources and capabilities of the firm come about and how do they evolve over time? And second, which capabilities enable firms to accumulate, maintain and reconfigure strategic resources, and to attain or sustain competitiveness in a rapidly changing environment?

Resources and capabilities have diverse origins. A substantial and growing body of empirical evidence suggests that an important subset of the firm's capabilities derives from the pre-entry experience accumulated by founders and from experience that the firm gained through earlier activities (for a review, see Helfat and Lieberman, 2002). To make sense of the changes that capabilities undergo over time, 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 tend to develop according to a regular life cycle pattern. During the early, developmental stage of their life cycle, capabilities are enhanced through organizational learning. The effectiveness of the learning process differs between firms because of differences in team composition, leadership, aspiration levels and the environment that the firm faces. In later stages the development of capabilities peters out. Capabilities reach a steady state of maturity. Internal and external triggering events may destabilize the maturity stage and induce a variety of further stages of the life cycle, ranging from retirement of the capability to redeployment in related markets and recombination with other capabilities.

Teece *et al.* (1997) suggest that the firm's capacity to attain and sustain its competitiveness in a dynamic environment is itself based on particular kinds of 'dynamic' capabilities. Dynamic capabilities determine the 'firm's ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments' (Teece *et al.*, 1997: 516; cf. also Teece and Pisano, 1994); they are, in short, 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 *et al.*, 1997: 524) in that 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 earlier in the section on the 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. Most importantly, they are limited in scope largely because they depend both on the limited individual knowledge bases of the firm's employees and on the way that knowledge is communicated and coordinated within the firm. A firm's absorptive capacities are, therefore, a key component of its dynamic capabilities. The more limited a firm's absorptive capacities are, the less likely a firm will be able to adapt to a changing environment.

Zollo and Winter (2002) suggest that firms acquire dynamic capabilities in three fundamentally different kinds of learning processes. Starting from the routine concept, they argue that dynamic capabilities can, first, be developed semi-automatically by 'experience accumulation' (Zollo and Winter, 2002: 340) operating upon the adaptation of organizational practice in response to unsatisfactory performance. They identify two additional learning processes, which have a more deliberate character and rely on more explicit knowledge. 'Knowledge articulation' (Zollo and Winter, 2002: 341) is based on verbalizing an organizational process and evaluating its performance. Verbalization allows for an enhanced understanding of the organizational process and facilitates modification of the process. The most demanding form of organizational learning is based on 'knowledge codification' (Zollo and Winter, 2002: 342). In this kind of learning process, the articulated knowledge is expressed in manuals, blueprints, expert systems and the like so that it becomes more widely and readily available within the firm and the potential for future modifications is enhanced. Zollo and Winter indicate that there are tradeoffs between the different forms of organizational learning. The more deliberate learning processes are more costly to the firm than experience accumulation. Whether the required investments are warranted depends on characteristics of the organization and its environment, but most importantly on the nature of the affected organizational process. Deliberate forms of organizational learning are most suitable for the modification of organizational processes that occur infrequently and exhibit heterogeneity and ambiguity.

## *2.2 Normative implications*

Resource- and capability-based theories are of an abstract, general character. For this reason, the normative implications that were derived from these theories likewise have been very general in nature. Teece *et al.* (1997) articulate some fundamental normative implications of the dynamic capabilities approach that contrast with the industry structure and strategic interaction perspectives. They suggest that to achieve

a sustainable competitive position, a firm must focus on creating distinctive resources, which presupposes a long-term commitment to specific strategies. A firm moreover must define its focus in terms of capabilities rather than products. Finally, because capabilities are central to a firm's competitive position, they have to be thoroughly evaluated when a firm considers entering new markets. In other words, entry decisions should not be only (or predominantly) based on the characteristics of the market to be entered but also on the characteristics of the potential entrant. This position is highly consistent with the empirical findings reported by Helfat and Lieberman (2002) and one of us (Murmman, 2003).

The capability-based perspective also has strong implications for the appropriate scope of a firm's activities. Recall that 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 pressures, capability considerations justify only specific forms of diversification, with the appropriate scope of the firm depending on how broadly its capabilities are applicable. Coherent diversification into related activities and markets is called for when capabilities are generic, whereas single-product firms are superior in situations with specific capabilities. When previously differentiated capabilities converge, Teece *et al.* (1994: 24) see various forms of inter-corporate relationships such as joint ventures as the most appropriate vertical and horizontal organization of firm boundaries along the value chain.

Based on case study evidence, Argyres (1996) shows that gains from using superior outside capabilities can outweigh transaction costs stemming from potential opportunism in make-or-buy decisions. Jacobides and Winter (2003) argue that if a firm's capabilities are unevenly distributed over the value chain, these imbalances may—when faced with competitive pressures from other firms with differently distributed capabilities—favor specialization in specific stages. Vertical specialization may be caused by the prior acquisition and improvement of specific capabilities, and it may also enhance subsequent learning. On the other hand, when there are interdependencies between learning at different stages of the activity ('systemic innovation'; Langlois, 1992: 182), integrated firms can be expected to be better innovators than specialized ones.

### *2.3 Shedding new light on the micro foundations*

In contrast to the general normative implications of the resource- and capability-based theories sketched above, the micro-level processes of how to create and sustain (dynamic) capabilities have received little attention. Similarly, the extent to which the actual implementation of capability-focused strategies is context-dependent has largely remained an open question. In light of these gaps in the theoretical literature, Ernst Abbe's first-hand account of his management principles offers a remarkable opportunity to enrich our understanding of how managers can create and recreate

firm capabilities that allow firms to enjoy a long-term competitive position. As we will detail below, the management principles outlined in the Zeiss Foundation statutes appear to the present-day reader as if they were devised as a specific implementation of the capability-based perspective. To better understand Abbe's approach to creating firm capabilities, some background information on the company for which the principles were devised is helpful. Before we outline and examine the principles in more detail, we will for this reason provide in the next section a brief historical sketch of the Carl Zeiss firm.

### **3. Carl Zeiss optical works, 1846–2005: a brief history of the firm**

In 1846 Carl Zeiss founded a mechanical workshop in Jena, a small German university town.<sup>3</sup> His choice of location was not coincidental: being a native of nearby Weimar, Zeiss had completed an apprenticeship as a mechanic in Jena. During this time, he attended lectures in mathematics and physics. Moreover, he gained practical experience in the use of microscopes while being an intern at the university's institute of physiology. In line with his personal experience, Zeiss justified his application to open a mechanical workshop in Jena by pointing out to the authorities the opportunities for contacts with university scientists.

Zeiss began to produce simple 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 manufacture assembled microscopes was to try various combinations of lenses until their individual imperfections mutually compensated and the combination yielded satisfactory optical quality. This procedure required long periods of experimentation for each single microscope produced. It also gave rise to large variations of product quality. Zeiss was convinced that microscopes could be made on a more systematic, analytical basis if the physical laws governing the optical properties of materials and geometries were understood and properly applied. When his own attempts of developing mathematic models for the construction of microscopes failed, he searched for a more knowledgeable partner. He found one in the young university physicist Ernst Abbe.

Abbe's involvement in Zeiss's optical workshop dates back to the year 1866. He first introduced changes to the shop-floor organization of production that increased the division of labor and specialization of workers. He also constructed new measurement instruments. Both measures helped to enhance the level of precision attained in component production. Abbe then proceeded to develop an analytical theory of the

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<sup>3</sup>In the next few paragraphs we draw heavily on Hellmuth and Mühlfriedel (1996).



microscope. That theory made it possible to compensate for varying glass quality by modifying the geometry of the lenses. The first microscopes produced on the basis of his theoretical findings were sold in 1872. Output of microscopes in the Zeiss workshop increased 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 optical quality consisted in the available materials. Individually correcting different kinds of errors to achieve high-fidelity imaging would have required glass types with different optical properties than were available at the time. To overcome this obstacle, Abbe joined forces with 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 how to modify the chemical composition of the melt so that glass with the desired properties could be produced. By 1883 Schott had made sufficient progress to envisage industrial production of special glass for optical instruments. For this purpose Schott's 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 quality levels that had never been realized before. These instruments became an instant commercial success and enabled the Zeiss firm to grow into a sizable enterprise. During the 15-year period from 1880 to 1895, the number of employees rose from 82 to 615 (Hellmuth and Mühlfriedel, 1996: 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 Zeiss's son, Roderich. However, serious leadership conflicts developed between them, and in 1891 Abbe convinced the younger Zeiss to withdraw from the company. This experience with problems stemming from personal ownership of a company motivated Abbe to put the Zeiss company, as well as his 50% share of the Schott glassworks, into the hands of an impersonal owner, the Carl Zeiss Foundation. The transfer of firm ownership to the foundation allowed Abbe to specify the rights and obligations of future managers in detail. It was an organizational innovation that would later serve as a model for like-minded German entrepreneurs, most notably Robert Bosch, and earned Ernst Abbe an honorary doctor from the University of Jena's law department.

After establishing the foundation, the Zeiss company continued to grow rapidly.<sup>4</sup> New lines of business were started, all belonging to the broader field of optical technologies:

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<sup>4</sup>We focus in the remainder of the article on the Zeiss firm. The Schott glassworks had a similar history, including a temporary split-up into two independent firms in East and West Germany after 1945.

measurement instruments, photographic lenses and cameras, and astronomical instruments, as well as, with increasing importance for the company's revenue, binoculars and other military equipment. As Zeiss developed into a leading optical firm with worldwide activities, Jena employment increased to 4,748 workers in 1913 (Walter, 2000: 33). During World War I, total revenues increased fivefold, with the share of revenue stemming from sales to the military eventually reaching 90% (Florath, 1997: 46). When the war was over, the launch of innovative new products (such as optical instruments for precision metering) facilitated the conversion to civilian production, allowing the firm to soon reach its pre-war production volume. In the subsequent years Zeiss managed to grow into Germany's dominant optics firm. Its Jena employment fluctuated substantially in the turbulent 1920s, but even after shrinking due to the Great Depression, employment in 1933 stood at pre-World War I levels. After 1933, further growth was again based on military demand as the Nazi government no longer respected the post-World War I weapons restrictions imposed on Germany.

At the end of World War II, Zeiss found itself located in the small part of Germany that was occupied by US forces but was to be handed over to the Soviets in return for the Western sectors of Berlin. Because the American authorities did not want to leave Zeiss to their emerging cold war antagonists, they deported 126 managers, scientists and engineers of Zeiss and of Schott to the American occupation zone in June 1945 (Hermann, 1989: ch. 1). Numerous technical documents were also removed from Jena and taken to the USA in the hope of transplanting know-how to American industry. At this point, there were two Zeiss firms in existence: one in Oberkochen (West Germany) and one in Jena (East Germany). The Jena firm was further struck by Soviet restitution claims, the dismantling of 94% of its production facilities, the deportation of further 275 leading firm members to the Soviet Union<sup>5</sup> and finally socialization (Mühlfriedel and Hellmuth, 2004: ch. 2). Despite vastly different environmental conditions, both the Western and the Eastern firm re-developed into leading producers of optical products with surprisingly similar product programs and innovation activities (Kogut and Zander, 2000). When Germany was reunified in 1990, Carl Zeiss Jena ran into enormous troubles because it lost the Eastern European markets and was not competitive in the West. In 1991, Carl Zeiss Oberkochen took a majority position in the newly founded Carl Zeiss Jena GmbH, which pursued the core traditional business lines of the Jena firm and had some 2,800 employees (Becker, 1997: 254). By acquiring the shares initially held by the state of Thuringia, Oberkochen in 1995 acquired sole ownership of the Jena firm. Currently the Carl Zeiss Group is a global player in optical technologies, employing 13,500 people worldwide and reaching a revenue of over €2 billion. It is still owned by the Zeiss Foundation and governed by the foundation's statutes of 1896.

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<sup>5</sup>The deported included some 36 scientists, 100 construction engineers and 130 production workers. They were allowed to return to Jena in 1951.

#### 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% share in the Schott glassworks to the Carl Zeiss Foundation. It took him another four years to complete the first draft of the foundation's statutes. After discussing the draft with the key managers of both companies, he presented a revised version to the state government of Sachsen-Weimar, which approved it in October 1896 (Hellmuth and Mühlfriedel, 1996: 189). The statutes consist of 122 paragraphs in nine sections, plus a 14-paragraph appendix containing regulations for 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: the principles for running a science-based firm; the nature of successful organizational change; and selection and development of human resources at all levels of the organization. We begin by analyzing Abbe's 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 firm's 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 was based on a crowd of people gathering *ad hoc*; rather in such an organization everything continues to operate that has been gradually accumulated over a long period in the form of valuable drives, special installations, planned schooling, regulated ties and marketing channels. (Abbe, 1989 [1900]: 342)<sup>6</sup>

Abbe draws an interesting implication from his emphasis on the firm's historically accumulated organization. He proposes that a part of the firm's yield cannot be attributed to the effort of individual workers and shareholders, but is simply due to the ongoing existence of the organization itself. Consequently, this part of the firm's yield cannot legitimately be claimed by its present members. Its legitimate recipient is the organization itself, in this specific case, the Carl Zeiss Foundation as the impersonal owner of the Zeiss and Schott firms (Abbe, 1989 [1896a]: 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 environments in which they operate.

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<sup>6</sup>All translations from Abbe (1989 [1896a]) and (1989 [1900]) are ours.

Abbe's characterization of the firm as non-reducible entity is clearly incompatible with some present-day theories of the firm in economics, including the notion that a firm is a nexus of contracts (Fama and Jensen, 1983). For Abbe the 'continuity of all activities' is made possible by the ongoing existence of the organization based on the lasting impact of work carried out by earlier organization members. Note that 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. Studying in detail how routines originate and remain in place as the repository of the firm's capabilities becomes, from this vantage point, a promising path for identifying the locus of the firm's 'non-reducible nature' 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 codify established practice, beginning in the preamble where Abbe (1989 [1896a]: 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, commenting on the prescribed organizational set-up 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. Abbe concludes his general remarks on the design of the organization 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 through 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, 1989 [1900]: 335)

Second, in addition to this reliance on prior experience, Abbe enforces a similarly gradualist approach on his successors. The very fact that he gives them such detailed binding prescriptions in the statutes severely limits the discretion of future managers. This effect is further pronounced by the checks and balances contained in the provisions for cooperative management that we discuss in more detail later.

The evolutionary approach taken by Ernst Abbe is notable because it predates by several decades similar positions taken by eminent social theorists. Remember that he lived in an age marked by a pervasive belief in the possibility of radical change, the credo of Taylorism being merely one example. 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. What is more, these authors did not encompass planned organizations such as firms in their critique of grand design. Hayek even stressed a fundamental distinction between an individual organization, which in his view can be centrally planned and controlled, and the spontaneous order of an entire economy, which in his view is much too complex to be centrally designed or controlled. Abbe's insight that individual firms are also complex systems that can be damaged by initiating radical change became widespread only in more recent times (Winter and Szulanski, 2001).

Gradualism, however, is clearly a double-edged sword. It may preserve the coherence of an 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. Abbe is aware of this risk and deals with it in two ways. On the one hand, as a measure of last resort, changes to the statutes are made possible, although only under very special circumstances and with a clause allowing for such changes to be challenged in court. On the other hand, Abbe realizes that the fundamental trade-off between coherence and adaptability is unavoidable. His decision is to emphasize the organization's coherence over its adaptability, being fully aware that this decision may entail costs in the future.

With his provisions for later changes to the statutes, moreover, Abbe finds an ingenious way to allow for some adaptability whilst safeguarding continuity and imprinting 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), their general arguments illuminate what Abbe observed in managing the Zeiss company. The strategic decisions on which Abbe's writing focuses are 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 makes sense. Ernst Abbe, however, went beyond a mere codification of the firm's routines in that he went to great lengths to explicitly state their purpose and thereby channeled the process through which fundamental change would have to proceed in the future. By just writing down the existing routines and prescribing them to future managers, he could 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. This enables him to hand down his own vision or 'business conception' (Witt, 1998) to his successors. Codification of the routines *plus* articulation of the underlying vision is thus the method by which Abbe tries to preserve the firms' capabilities for the future.

Conformity to Abbe's vision is then put forward as the yardstick for deciding whether or not future changes to the statutes will be allowable. If necessary, this is to

be adjudged in court ‘with appropriate consideration of the founder’s presumable intentions’ (Abbe, 1989 [1896a]: 318). Thus, even in the case that changes are required to preserve the viability of the firm, a ‘higher-level’ continuity is enforced for these changes. The practical implications of this provision will be seen in Section 8 below.

## 5. Prescriptions for safeguarding the competitiveness of firms

### 5.1 Long-term orientation

The Carl Zeiss Foundation is dedicated to economic, scientific and social purposes. Its overarching economic objective is to safeguard the long-term viability of its firms (Abbe, 1989 [1896a]: 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 1989 [1896a]: 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, 1989 [1900]: 342). This long-term orientation is analogous to the focus on capability development as a mechanism for ensuring long-term competitive advantage in the capabilities theory of the firm. Abbe makes this long-term orientation operational in a number of specific provisions, which can provide contemporary scholars with intriguing ideas on how to theorize about the micro-processes of capability development.

### 5.2 General competitive strategy

Teece *et al.* (1997) have highlighted the distinction between models of strategy that trace a firm’s economic success to market power and models that locate economic success in superior capabilities. 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. Abbe’s attitude toward the optical industry as a whole is to promote the state of the art rather than to outfox competitors by erecting entry barriers and manipulating the rules of the game. Zeiss always had competitors, but Abbe seems to have taken it for granted that as long as the foundation-owned firms could preserve their strong technological position, they would be able to rely on their capabilities to develop superior products and processes rather than on cutting prices or obstructing competitors. Maintaining its innovative capacities is at the center of his vision of the Zeiss firm. Again, Abbe derives this position from past practices followed at Zeiss. In a speech made in 1896, Abbe claims that the firm had entered new markets only when, based on its own R&D efforts, it

could offer a product that differed from those of the incumbent firms (Abbe, 1989 [1896b]: 84–85).

### 5.3 *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 formulated: optics, glass-making, instrument making and connected industries. Diversification is accordingly limited to related diversification. Drawing on his decades of experience in managing a science-based firm, Abbe formulates the same strategic principles as Teece *et al.* (1994), who 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, the statutes contain no restrictions with regard to the scale of activities, but explicitly allow for new domestic and foreign branches, and for the formation of new firms or the takeover of existing ones—provided these are active in the allowable range of industries. It is interesting to note that while apparently Abbe sees no need to explain the rationale underlying the restrictions in terms of scope, he does discuss in other parts of his writings the potential risks—loss of oversight and coherence—inherent in expanding the scope of the firm. 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.

Further restrictions on the scope of foundation-owned firms apply within the set of allowable industries. The firms can only be active in those industry segments that are characterized by a close science–technology relation in products and/or processes. 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. 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.

### 5.4 *Shop-floor skills*

In addition to specifying the range of the firms' activities, the statutes prescribe the type of work to be done. 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, 1989 [1896a]: 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. Abbe here 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: 187).

The emphasis on qualified labor is explicitly characterized as a counterbalance to the ‘routine tendency of pure factory work’ (Abbe, 1989 [1896a]: 282). This does not imply that Abbe categorically objects to mass production and increased division of labor. As noted in the historical overview, the first organizational change he initiated in the optical workshop was to increase the specialization of individual workers. Similarly, the firm later adopted mass-production methods in suitable product categories, and it was at the forefront in standardizing products and parts to generate scale effects. Rather than being blind to the benefits of the division of labor, Abbe realized that the useful and potentially unavoidable expansion of factory work comes at a cost—the 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. Providing the necessary absorptive capacities of the firm and building new organizational capabilities 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 its production to changing environments. The insistence on preserving and fostering shop-floor skills resonates well with recent arguments about the importance of shop-floor level innovation and learning by doing (see e.g. Lazonick, 1990).

### *5.5 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, 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. These measures are not only driven by philanthropic considerations but are also motivated by the desire to promote the foundation’s broader interests.

It seems evident that the foundation-owned firms would benefit from the promotion of their industries, particularly since 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, 1989 [1896a]: 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 actual measures taken to support the local working population also included educational activities—such as the establishment of a public library—with positive spillovers for the firms. 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 altruistic motives alone. For Abbe, the success of the optical workshop and the glassworks is based on Carl Zeiss’s early insight that



close contact to science provides a powerful basis for technological progress. Promotion of science for Abbe also means to promote science-based industry because the interaction with science enables and induces the firms to develop new products and processes, thus recreating their capabilities. This perspective on science shows up both in the statutes and in the accompanying regulations of the 'university fund', the foundation's vehicle for the support of science. First, the support is focused on the University of Jena, thus generating a natural advantage for the foundation's firms. Second, the university fund regulations restrict the foundation's subsidies to mathematics and the sciences, plus those other disciplines having a 'close relation to the interests of the Carl Zeiss Foundation' (Abbe, 1989 [1896a]: 323).

The concrete science support activities of the foundation reflected this position because it deliberately used the university fund to shape the university's research orientation in a way congenial to the interests of its firms (Hellmuth and Mühlfriedel, 1996: 297–298). For example, the foundation financed a new institute for the physicist Adolph Winkelmann, with whom Otto Schott conducted collaborative research on the optical properties of glass. In addition, Ernst Abbe ensured that Gottlob Frege, an authority in pure 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. 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. Yet 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 are significant because they go beyond the essentially defensive framing of dynamic capabilities as enabling the firm to react to environmental change that is widespread in present-day theorizing. The funds paid out by the Zeiss Foundation effectively endogenize the scientific basis of the technology commercialized by its firms. In this way, the foundation and its firms initiate environmental change rather than merely react to it, providing some degree of control over the direction the change takes. At the same time, the active steering of university research puts the foundation-owned firms in a superior position for absorbing the ensuing results, adding to their competitive strength. Of course, creating the scientific foundations 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.

## 6. Top-level management and labor relations

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

### 6.1 Team leadership

The team leadership principle is clearly visible in the way the top management of foundation-owned companies is set up. The top management teams of these firms have to consist of three to four members with equal rights, who are to make their decisions with unanimity. According to Abbe, only leadership by a collective body can ensure 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 glassworks.

Except for general oversight by an external foundation commissioner appointed by the regional government, the autonomy of the top management team is safeguarded by the statutes. Further provisions enhance 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 dismissed prematurely but serve until their retirement. Any contractual obligations of top management team members, other than the ones laid down in the foundation’s statutes, are declared void. The rationale underlying the independence of managers is to safeguard their internal and external authority. Abbe argues that for leaders to be trusted by employees, it has to be generally known that their decision-making does not reflect third-party interests foreign to the firm.

### 6.2 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 are to continue their regular activity in their field of expertise. Otherwise, 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, 1989 [1900]: 339).

These requirements for the top management team reflect the crucial role of knowledge in Abbe’s management principles. 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. The provisions in the Zeiss Foundation statutes indicate how this concern can be translated into managerial practice. They try to ensure that the communication of individual knowledge from the technical, scientific and business realms extends into the top management team itself. In this way, the hazard that an entire domain of relevant expertise might be excluded from top-level decision making is kept in check. 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. Moreover, 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 forces them to keep up to date in their professional field, thus keeping their absorptive capacities workable in a dynamically changing environment. The provision consequently constitutes a concrete process proposal for safeguarding the dynamic capabilities of the firm.

### 6.3 *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 needs to be familiar with its most important matters and its culture. Persons foreign to the firm would be incapable of making decisions on the basis of sound personal judgment. In turn, the individual manager also has to be known to the other managers.

This emphasis on personal continuity shines new light on the reasoning in Edith Penrose's (1995 [1959]) 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 accumulated within the firm. Newly hired managers therefore do not immediately increase the stock of managerial know-how available to the firm; on the contrary, they initially reduce that stock, because managerial know-how is required to socialize them into the firm. The provision in the foundation statutes decouples the Penrosian concern for personal continuity from the growth of the firm. Moreover, it adds an individualistic perspective to the argument. In addition to knowledge concerns, continuity is also required to enable individual managerial authority, mutual trust and the ability to form joint expectations in the management team. This aspect of continuity is illustrated by Abbe's 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's 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 employees have in management's capabilities (Hellmuth and Mühlfriedel, 1996: 182). Implicit in this accusation is the conviction that authority has to develop on the basis of individual performance and that it cannot be mandated from above. Abbe's writings again provide an interesting suggestion on the micro-level on how to build firm capabilities. For regular employees to cooperate to the best of their abilities with management, managers need to earn their authority based on merit.

#### *6.4 Autonomous and responsible workers*

Under Abbe's leadership, the Zeiss firm introduced a workers' council and enacted various social policy measures, such as an entitlement to old-age pensions and the eight-hour work day. Philanthropic motives only provide a limited explanation of labor relations and social policy measures implemented at the Zeiss firm. Rather, these measures were seen as win-win situations, benefiting both workers and the firm (a similar point has been made by Plumpe, 1997). Abbe himself (1989 [1896a]: 347) expressed the conviction that the past treatment of workers—which is reflected by the statutes' provisions—was a decisive factor in the success of the foundation-owned companies.

Abbe was not the only nineteenth-century factory owner in Germany who was concerned about improving the welfare of workers. His stance on labor relations, however, differed radically from other reformist approaches in that it was based on changing the relationship between the firm and its employees at the fundamental, constitutional level. The crucial point 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 regard to its employees, Abbe stresses as a goal the 'improvement of their personal and economic *legal* situation' (Abbe, 1989 [1896a]: 264, our italics). In his explanation 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 this field of activity or may do so in the future' (Abbe, 1989 [1900]: 331).

The rationale underlying the 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, 1989 [1900]: 348). This intention also shows in the section of the Zeiss Foundation statutes that deals with provisions on labor relations. It prohibits all forms of personal subordination of workers to their principals. A separate paragraph explicitly grants workers the free exercise of individual and civil rights, including the right to representation of their interests individually and in groups. Workers' councils in the foundation-owned companies are entitled to be heard on all matters. These clauses are in striking contrast to common practice at that 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 employees assume responsibility for their work. In Abbe's view, labor relations at Zeiss had in the past provided the firm with a large number of conscientious, dedicated, reliable and upright employees. He was likewise convinced that the labor relations practiced at Zeiss would be essential for the firm's future. For the kind of work done at Zeiss, he argues (1989 [1900]: 350), personal involvement, deliberation and 'far more than merely dutiful diligence' are indispensable to maintain the technical standards once achieved, and even more so to raise them. For Abbe, worker responsibility and involvement, however, could not be prescribed by the constitution of the firm, but had to emerge from the workers' own motivation, fostered by suitable factual institutions and interactions in the firm. Treating workers respectfully and granting them personal autonomy are prerequisites for their assuming responsibility of their work. Abbe realized that skilled labor is not just an issue of education and training, but also one of motivation.

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 expected that treating the workers as autonomous, responsible individuals would 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. In Section 8 we will provide more evidence on the processes by which Zeiss coordinated motivated individual workers into firm capabilities and thereby helped secure the firm's long-term competitive position.

## 7. The statutes' effects on the Zeiss firm's long-term performance

We have shown above how the detailed prescriptions laid down in the statutes of the Carl Zeiss Foundation anticipate important insights of present-day management theories. The ultimate criterion to evaluate the soundness of Abbe's management principles, however, lies in their impact on the development of the foundation-owned firms. *Prima facie* evidence clearly suggests that their impact was beneficial. By the end of the 1920s, Zeiss had developed into the dominant firm in the German optical industry as well as a global leader in its markets (Sassmannshausen, 2003: 235). Despite an extremely difficult subsequent history, Zeiss—and similarly Schott—has survived and prospered to the present day, and is globally competitive in its fields of activity. In this section, we first present evidence showing that the foundation statutes had a lasting impact on the development of the Zeiss firm. Then we argue that their provisions were causally related to the firm's subsequent success.

### 7.1 *The lasting impact of the foundation statutes*

There is strong evidence that throughout its history the fate of the Zeiss firm and the activities of its managers were substantially shaped by the provisions of the foundation

statutes. (We focus here again on Zeiss, but what we say holds equally for Schott. Both companies today continue to be fully owned by the Zeiss Foundation.) This indicates that, by codifying it in the statutes, Abbe successfully communicated his vision to later firm members. The historical record also indicates that Zeiss managers as well as workers valued this vision and that they followed the prescriptions of the statutes out of conviction rather than necessity. The critical junctions in the firm's history show the internalization of Abbe's principles most clearly.

The continuity of the firm was challenged several times in the turbulent history of twentieth-century Germany. Both the Nazi regime and later the East German socialist government tried to bring Zeiss under their control. Not surprisingly, both were eventually successful in destroying the firm's independence and in minimizing the role of the foundation statutes. Nonetheless, in doing so they faced unusual opposition. In 1945 as well as in 1990, efforts to re-establish the statutes in their original form were top priorities of the Zeiss members (Mühlfriedel and Hellmuth, 2004: 6, 345).

In the early days of the Nazi government in 1933–1934, the Zeiss management and workers succeeded in getting the first Nazi-appointed foundation commissioner replaced by a more knowledgeable and less oppressive one. Legislation mandating that all companies had to be run by a single 'leader' with practically unlimited power was initially ignored, at least in the internal dealings at Zeiss. The firm moreover supported a number of Jewish employees and regime critics (Walter, 2000: ch. 4). After the liberation in 1945, all changes made to the statutes during the Nazi years were immediately reversed. In socialist post-World War II East Germany, a first attempt to socialize the firm in 1947 was successfully countered by an unlikely coalition composed of party representatives at Zeiss, elected workers' representatives and the regional government. The opposition to socialization was eventually broken, and both the Zeiss and Schott firms were socialized the following year. But the relationship between Zeiss and the socialist state remained tense, as the *esprit de corps* of many Zeiss employees was stronger than their affinity to the socialist ideology. During the republic-wide insurgency on June 17, 1953, Zeiss workers were at the forefront of the protests in Jena. Re-establishing the foundation statutes in their original form was one of their political demands (Hermann, 1989: 66).

The beginnings of the Western Zeiss firm in Oberkochen likewise indicate the continuing impact of Abbe's legacy. The firm was originally founded as a subsidiary of Zeiss Jena, and since many of the leading scientists and engineers were in the West, it was expected to do the bulk of future R&D for Zeiss Jena. When the Eastern Zeiss firm was socialized, however, the Western management and employees saw themselves as the 'true' keepers of the Zeiss tradition. Rather than freeing themselves from the constraints posed by the statutes in organizing a legally new firm, they established a West German Carl Zeiss Foundation that became the owner of the Oberkochen Zeiss firm. The governance of both the Zeiss firm and the new foundation was based on Abbe's original statutes. The rights and benefits guaranteed in that document were granted to the workers of the Western Zeiss firm, including those who migrated from Jena to Oberkochen.

This is strong evidence that, more than 50 years after they had been devised, the provisions of the statutes were still seen as valuable by the managers and employees.

The continuing impact of the statutes' provisions is also reflected by the product portfolio. Throughout its history Zeiss has concentrated its activities on optical instruments and precision mechanics. Based on the early production of microscopes, a broad line of scientific and measurement instruments was developed. Binoculars, photographic lenses and later cameras were added as additional important parts of the optics product portfolio. The same holds for spectacles, ophthalmologic instruments and planetariums. Occasional ventures farther away from its traditional focus, for example into automobile lighting, tended to be less successful (Sassmannshausen, 2003: 188–189). In addition, Zeiss upheld the close relationship to science postulated in the statutes. The firm has always employed large numbers of scientists, and has always had (except for the later years of the East German Zeiss firm) a scientist in its top-level management team. In addition, the firm continued to cooperate with research institutions and scientific users. For example, the ultra-microscope was developed jointly with Richard Zsigmondy and the slit lamp for ophthalmology jointly with Allvar Gullstrand, both of whom would later win Nobel prizes (Walter, 2000: 62, 124). In the post-World War II turmoil, the Western Zeiss firm ended up in the rural Oberkochen, with no university or other research facility close by. The firm nonetheless maintained its close relationship to science. It established extensive research departments and employed large numbers of scientists so that at times the Oberkochen facilities were dubbed an 'optical university' (Hermann, 1989: 275). Already in 1946 Zeiss scientists had started to publish a new academic journal called *Optik*. Consistent with Abbe's principles, results of fundamental significance were made public through this journal. It published 44 articles by Oberkochen staff in its first four volumes (Köhler, 1983: 23).

Zeiss has a similarly strong record with regard to its emphasis on shop-floor skills. Between the wars, the firm established specialized workshops for the practical education of apprentices, and also a firm-owned vocational school. Financial support was given to employees who attended technical schools and universities. Historical evidence for the 1930s shows that Zeiss employed a higher share of skilled workers than its competitors (Walter, 2000: 94–98). The importance of skilled labor for the success of the firm was also highlighted in a 1946 report by the US occupation authority:

Whatever varying influences may affect the success of the Zeiss Corporation, it is certain that the skill of its workers is a factor of considerable value, if not of overriding importance. This firm has for generations attached great value to the adequate training of its personnel, and it would appear that no untrained worker is admitted to the factory (quoted in Walter, 2000: 293).

## 7.2 Consequences of the statutes

Notwithstanding the verdict of the US authorities, it is possible that the firm's success was not enabled by the provisions made by Ernst Abbe but was due to quite different

factors, and perhaps even in spite of the restrictions made in the Zeiss Foundation statutes. This possibility cannot be ruled out with absolute certainty, but we find it hard to square with the historical record for a number of reasons.

First, the history of the Zeiss firm has been studied extensively. Even though their research has not specifically focused on this issue, company historians seem to agree that the firm benefited from Ernst Abbe's legacy (Hermann, 1989: 328; Walter, 2000: 3–17; Neunhöffer, 2001: 125; Sassmannshausen, 2003: 233). Second, from 1945 to 1990 there was not only one Zeiss firm but two, and both firms were highly successful in their respective economic and political environments. The Eastern Zeiss firm in Jena was a rare case among high-tech firms in the Eastern bloc in that at least some of its products (e.g. planetariums) were competitive on a global scale. In terms of their autonomy, political environments and economic opportunities, the West and East German Zeiss firms operated under quite different sets of circumstances. That their performance nonetheless was similar suggests a continuing impact of their common past and the pursuit of the same basic strategy that dated back to Ernst Abbe and was codified in the Zeiss Foundation statutes. Kogut and Zander (2000) have provided an in-depth analysis of the innovation activities of the two Zeiss firms. They show that both firms had strikingly similar patent portfolios and they interpret the strong showing of the Eastern Zeiss firm as evidence that socialist firms could have substantial technological capabilities. This finding is in line with qualitative evidence that Zeiss Jena managed to develop products in modern fields such as semiconductors and lasers, although at very high costs and rarely catching up to the Western state of the art. Third, the historical material available on Zeiss can be used to probe into the detailed effects of the statutes' provisions on particular episodes in the firm's history. In this way, the performance consequences of Abbe's management principles can be better identified, even though more thorough historical research specifically dedicated to this purpose will be required to reach a final verdict. In the remainder of this section, we will examine the consequences of Abbe's emphasis on activities at the frontier of scientific research in the context of the two Zeiss firms' adoption of laser technology.

### *7.3 The introduction of laser technology*

Laser technology is ideal to examine the consequences of Ernst Abbe's management principles on business practices in the more recent past. The laser was the most significant innovation in optical technology after World War II, and with the laser scanning microscope (LSM) it found a useful application for one of Zeiss's core products. In addition, the introduction of laser technology after 1960 falls into the period when there were two separate Zeiss firms in East and West Germany—hence we can rely on two observations rather than just a single one. Finally, the development of laser scanning microscopes by both Zeiss firms has been studied in detail in a doctoral dissertation authored by a long-term Zeiss employee (Neunhöffer, 2001), providing us with the empirical basis for a sound comparison.



When the first workable laser was developed in the USA in 1960, there was widespread initial enthusiasm about this revolutionary optical technology. Given their corporate vision as leaders in the optical industry, it was mandatory for both Zeiss firms to develop capabilities in laser technology. Both firms quickly became involved in laser research and development activities, and each managed to present a workable experimental laser by 1962 (Albrecht, 1996). Subsequently, the primary intention of both firms was to integrate the new technology into their existing product lines rather than trying to become full-fledged producers of the whole range of laser sources.

The Western Zeiss firm drew on internal scientific capacities as well as external contacts to leading German laser researchers to develop its first (ruby) laser (Albrecht, 1996). A 'physics laboratory' devoted to basic science had been established in Oberkochen in 1956; it quickly reacted with its own efforts to the presentation of the world's first laser in 1960. Laser research in Oberkochen was well connected to academic research. For example, Zeiss Oberkochen obtained the rubies for its laser from Karlsruhe physics professor Horst Rothe, to whom the laboratory had close contacts and who presented his first laser in 1961 (Albrecht, 1996). After successfully developing its own laser, Zeiss Oberkochen concentrated its further product development on applications in military measurement technology. Research activities were limited to dye lasers and resulted in the introduction of commercial dye lasers in 1972 (Köhler, 1983: 100–2).

While the Western firm could obtain laser sources from a variety of international and domestic suppliers, embargoes and lack of convertible currency ruled out the option of purchasing Western lasers for Zeiss Jena, and supplies from the Soviet Union were limited. It was thus even more important for the Eastern firm to develop its own laser sources. In doing so, Zeiss Jena was in a strategic position because its powerful director of research, Paul Görlich, was at the same time an honorary professor at the University of Jena, as well as co-director of the Institute of Optics and Spectroscopy in Berlin, which were the two leading institutes in East German laser research (Albrecht, 2001). The firm managed to exert substantial political pressure on the university to enlist it in production-relevant research. It also drew on the pool of knowledgeable university researchers to fill its own ranks. In 1964 Zeiss Jena presented its first commercial gas and solid state lasers. It also began development of a laser spectral analyzer that became a substantial commercial success outside the socialist countries.

In both West and East, the laser euphoria soon gave way to frustration with the problems encountered in applying laser technology to practical purposes. The Western Zeiss firm gave up its production of dye lasers in 1974. It retained some development of laser sources for military equipment, but otherwise relied on purchased lasers for its component needs. Zeiss Jena stopped marketing its gas lasers in 1967, but continued production for its own component needs. Moreover, the firm upheld a number of research projects and cooperative efforts with academic institutions as well as other firms. Through this continued involvement in laser research, it managed to preserve its absorptive capacities in laser technology despite the scientific and economic isolation in which it operated. According to one analyst, with its early and ongoing

involvement in laser technology the firm followed the principles laid out by Ernst Abbe in the Zeiss Foundation statutes, and thus sustained its traditional corporate vision even in the socialist environment (Neunhöffer, 2001: 52).

At the Western Zeiss firm, development of laser scanning microscopes began in the late 1970s. The firm combined its own capabilities in microscope technology with purchased laser components. Commercial production of the LSM from Oberkochen—the first commercial laser scanning microscope worldwide—was taken up in 1983. It became a commercial success when improvements were made in close cooperation with Johan Ploem, a pioneer in fluorescence microscopy at the University of Leiden (Netherlands) who had been provided with a prototype. The successful introduction of the LSM indicates that Zeiss Oberkochen had acquired sufficient competence in laser technology to perceive and exploit the opportunity present in developing an LSM. It seems to have benefited from the concentration on the firm's traditional competences in conjunction with the ongoing contact with scientific users.

The Eastern Zeiss firm in Jena had identified the opportunity of linking laser technology and microscopy before the Western firm. Beginning in 1974, a Zeiss physicist in Jena studied the feasibility of producing LSMs. At the time of these theoretical efforts, Zeiss Jena was at the frontier of the fledgling LSM technology. The firm was subsequently able to keep up with the international scientific advances and to perceive technological opportunities arising from them. It had a team of researchers that kept track of the emerging technology, even though it was unwilling or unable to enter the actual development of these microscopes before 1986 (Neunhöffer, 2001: 72–76). When the decision to develop its own LSM was finally made, the reunification of the two Zeiss firms after 1990 soon marked the end of the project. At that time, only a prototype existed in Jena, whereas hundreds of Oberkochen's second-generation LSMs had been sold, and the third-generation models were being introduced. The Jena prototype included some features, however, that were missing from the Oberkochen models. As part of the ensuing corporate restructuring, a joint LSM development team was created by merging members of the previous teams in Oberkochen and Jena. According to the team leader, who came from Oberkochen, this merger generated synergies by combining the superior theoretical knowledge of the Jena staff with the stronger experience in practical product development accumulated in Oberkochen. Zeiss claims global leadership in laser scanning microscopy today.

The development of LSM technology illustrates the strengths of a strategy based on close interaction with science, technological leadership and concentration of core capabilities in optical technologies, as it is codified in the Zeiss Foundation statutes. But this science-based approach alone could not guarantee long-term success in all markets that the firm decided to enter. A striking case are photographic cameras, a market in which Zeiss was once a global leader, but then lost out to international competitors because it lacked the capabilities to adapt to changes in consumer preferences. (From the inception of the firm, Zeiss's marketing capabilities were focused on scientific instrument users. The only other major consumer product categories Zeiss was

active in are binoculars and spectacles, in which the optical components form almost the entire product and which, therefore, stay very close to Zeiss's core capabilities.)

Zeiss first entered the camera business in 1900. In 1926, the firm merged its camera subsidiary with three major competitors into the Zeiss Ikon AG. This new firm subsequently developed a number of milestone innovations, including the world's first built-in distance meter (1932) and photoelectric exposure meter (1936). Before and after World War II, Zeiss Ikon, together with its German competitors Leica and Rollei, dominated global camera markets. The firm proved incapable, however, of reacting to the radical, demand-related changes that started in the 1950s, when the camera market bifurcated into the high-end single lens reflex cameras (SLR) and low-end pocket cameras. The new designs catered to two different kinds of customers, and each was superior to the earlier viewfinder design for their respective audience (Windrum, 2004). Zeiss Ikon clearly had the technological capabilities to develop a product for the changed market conditions. It even introduced one of the first SLR cameras. Zeiss Ikon and the other German camera makers, however, did not pursue the new designs as single-mindedly as the Japanese competitors. The Japanese were able not only to produce at lower cost but also to come up with a series of incremental innovations that fully exploited the potential of the new designs. Unable to appreciate quickly enough the enormous demand changes taking place in the consumer camera market, Zeiss Ikon did not sufficiently reallocate its organizational resources to the new camera designs and rapidly lost its market leadership. In 1971, the firm had to withdraw from the camera market altogether (Hermann, 1989: ch. 18), restricting itself from now on to supplying optical lenses to other camera manufacturers.

## **8. Theoretical insights for today from a nineteenth-century scientist-manager**

Containing an astonishingly complete and internally consistent set of provisions of how to run innovative, science-based firms, the Zeiss Foundation statutes articulate principles of management that bear striking similarities to the capability-based theory of the firm. But Ernst Abbe's management principles go well beyond the contemporary literature on dynamic capabilities. The principles provide us with new insights by articulating ideas about the processes that create and sustain a firm's dynamic capabilities, and thus help to further develop the capabilities theory of the firm. In this section we will outline some of these ideas that deserve further appraisal by contemporary theorists. We will also discuss limitations and omissions that we see in Abbe's thought.

### *8.1 Insights for present-day research*

The Zeiss Foundation statutes 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.

Abbe realized that the Zeiss Foundation, given that it operates in a small-town setting, has substantial leverage in upgrading its environment. (Zeiss continues these policies to this date, and even a first time visitor to Jena will not miss the influence the firm has had on the civic institutions in the city.) Most significant in this context is the call for the direct support of science. We sketched out earlier how the support of science was turned into industrial policy by the Zeiss Foundation. The funds spent in Jena by the foundation helped to establish first-rate university departments in disciplines such as physics and mathematics, and to initiate academic programs tailored to the needs of the foundation-owned firms and their industries. As a consequence, the foundation-owned firms could draw on the local academic knowledge base as well as on the supply of qualified university graduates.

Analyzing the rise of the Germany synthetic dye industry from 1857 to 1914, one of us (Murmans, 2003) has previously documented how the lobbying efforts of synthetic dye firms shaped the institutional set-up in which the firms operated. Zeiss took a somewhat different approach than the synthetic dye firms. It focused on influencing the citizens, community leaders, and public officials responsible for Jena, and did not rely on the activities of industrial associations and the like. The most likely reason for the difference is that in the case of synthetic dye industry, the most important dye innovations during the first 25 years of the industry were created in university laboratories. In the case of Zeiss, the innovations were made in the laboratory of the firm, drawing upon the theoretical expertise of a university scientist. As a consequence, more of the knowledge required to improve optical technology stayed within the firm. This also meant that the foundation-owned firms could benefit more exclusively from the money spent by the foundation on the support of science, particularly since the support was focused on Jena where Zeiss had no direct competitors.

The literature on dynamic capabilities has emphasized the need for the firm to adapt to its competitive environment. The Zeiss case lends additional support to the pattern found in the synthetic dye industry (Murmans, 2003). Rather than merely adapt, firms can and do—within limits—actively shape their environment, particularly on the local level. This coevolutionary aspect of dynamic capabilities, its preconditions and its likely effects deserve attention in future research.<sup>7</sup> To get a more precise estimate on how important shaping the environment was for the success of Zeiss, it would be fruitful to compare the efforts of the Zeiss with those of other optical firms both in Germany and in foreign countries. Studies of other science-based industries are also necessary to evaluate the generality of this finding.

Second, the codification strategy adopted by Ernst Abbe to perpetuate his management principles adds an interesting aspect to the discussion of deliberate capability Learning (Zollo and Winter, 2002) and invites more reflection on the process by which capabilities are created and maintained. We have argued above that Abbe's approach conforms to Zollo and Winter's criteria for codification to be beneficial.

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<sup>7</sup>The issue is touched upon in Teece *et al.* (1994: 16), but it is not systematically explored.

Yet codification inherently entails the risk that over time the codified processes are detached from their original purpose, and are increasingly perceived only as unnecessary and annoying restrictions. 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 expressing 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. A key task for management is to align the goals of all the people working for the organization. It seems to us that what the foundation statutes accomplished is to lay out meta-goals that organizational members came to identify with and that hence facilitated goal-alignment among the employees of the Zeiss Foundation firms. The meta-goals embodied by the foundation statutes were broad enough to allow for channeled change in the products made by the firms, but they were sufficiently narrow so that the firms would not lose the advantage of an accumulated knowledge base.

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 the same coin. He trusted that workers, when treated as responsible agents, would live up to their intellectual capacity and provide the high-quality work required in a successful science-based firm. Given the codification of labor relations in the Zeiss Foundation statutes, workers could moreover trust them to be preserved in the future. 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 the dynamic capabilities of the Zeiss firm. 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. The historical record indicates that this kind of 'cognitive leadership' (Witt, 1998) was successful. Zeiss employees (or 'Zeissians', as they often refer to themselves to this day) have always tended to show an unusually close identification with their firm and to perceive themselves as an 'elite' among working class people. We have outlined above how the strong identification of Zeiss workers helped preserve the firm during the most adverse stages of its history. The motivational force on employees created through their identification with the organization clearly deserves more attention from scholars of process management. (For an excellent overview of the literature on process management, see Bower *et al.*, 2005).

At a more theoretical level, the complementary relation between worker skills and worker motivation presumed in Abbe's management principles suggests that tight monitoring regimes may be incompatible with an emphasis on shop-floor skills and worker motivation. We hope to stimulate additional research on this question. Furthermore, industries relying on different types of labor qualification may accordingly

require different kinds of governance. The shift toward knowledge-based products and processes could thus come with a shift toward greater worker autonomy and worker involvement. This hypothesis is not only intriguing but also empirically testable.

### *8.2 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. 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 more fundamental concern is the potential inertia that may arise from the emphasis on gradualism and continuity. Henderson and Clark (1990) have provided some evidence that in times of more radical and 'architectural' change, incumbents frequently find it hard to make the required modifications to their products and processes. Many firms do not seem to have the necessary dynamic capabilities to deal with radical changes in their environment. Despite the efforts made in the Zeiss Foundation statutes to preserve dynamic capabilities, they lack well-defined instruments that would help the firms to deal with situations when change is more rapid than they can accommodate by gradual learning. Abbe clearly believed one has to make a choice between gradual and radical change. Many strategy scholars believe it is possible to do better than that, 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.

Moreover, as Abbe anticipated, codified provisions likely outlive their usefulness at some point in time. At least from the perspective of Zeiss's top management, this situation has indeed come to pass with some of the statutes' provisions, particularly in regard to the legal structure of the foundation-owned firms. Two contentious issues are the joint and several liability of Zeiss and Schott provided for in the statutes, and the provision that the firms may not be turned into joint-stock companies. In 1989 managers still characterized the joint and several liability as beneficial for the firms because it allowed temporary crises affecting one of the firms to be buffered (Hermann, 1989: 254–255). More recently, however, top management came to regard the respective provisions as dangerous, particularly in view of potential lawsuits in the USA. Top management also came to the conclusion that the legal status of the foundation and its firms was an obstacle in capital-market transactions. The Zeiss management felt that potential partners in international alliances and acquisitions could be deterred by the firm's unfamiliar legal structure. At the same time, an increasing reliance on joint ventures and acquisitions was seen as necessary to retain competitiveness and achieve sustainable growth through related diversification (Bertram, 2002; Preuss, 2004).

Based on these considerations, rather drastic changes were made to the statutes in 2004, allowing top management to turn the Zeiss and Schott firms into two independent,

public companies. As one would expect, these changes were highly controversial among the firms' stakeholders and have been challenged in court. As specified by the foundation statutes, the court decided upon the changes based on whether or not they violated Ernst Abbe's original intentions. In the end, the court sided with the firms' management that, supported by the commissioner of the Zeiss Foundation, argued that the changes were consistent with Abbe's intentions. Top managers pointed out that Abbe's statutes made it their duty to keep the firms competitive in their present-day environment and protect them from new kinds of legal hazards. It is important to note that most of the statutes were not changed and continue to guide the management of the foundation companies. In particular, the foundation retains sole ownership of the Zeiss and Schott firms and therefore can enforce Abbe's wishes to ensure their long-term viability.

The issues sketched in the present section warrant much more thorough discussion than we can provide in this paper. As we hope to have shown here, the articulation of Abbe's vision in the foundation's statutes provides a unique opportunity to do this research. In our view, the Zeiss company amounted to a 'natural experiment' (Kogut and Zander, 2000) right from the beginning, not only after World War II 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'.

## **9. Some concluding remarks on the management ideas of Abbe and Taylor**

In closing, we want to return to our initial juxtaposition of Ernst Abbe's management ideas and the concepts developed by Frederick Taylor at roughly the same time. 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. Does Taylor's contemporary Ernst Abbe provide us with an alternative 'scientific' vision for managing a firm?

We certainly believe so—even though we recognize that a degree of Taylorism is fully compatible with Abbe's principles. We see two key differences in their visions. One is that Abbe, based on his lengthy experience in practical management matters, realized the limits to a management approach that attempts to be 'scientific' but is completely mechanistic in its orientation. By contrast, Taylorism failed to appreciate the differences between a physical or technical system and a social organization, i.e. a collective of human agents who each have their own intentions and their own knowledge. Abbe clearly realizes the potential benefits of divided labor and learning by doing based on specialization. As reported earlier, he introduced organizational changes in Zeiss's workshop along these lines even before he developed the scientific

foundations for optical instrument making. 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. Similarly, Zeiss subsequently was an early adopter of time and motion studies and rational shop-floor organization. Taylor's associate Gilbreth, for example, conducted time and motion studies in the Zeiss firm in 1911 (Walter, 2000: 58). Abbe and his successors realized, however, that the loss of worker skills and of worker involvement might in the long run be harmful for the company, and they actively attempted to create a bulwark against the universal introduction of Taylorist methods. Shop-floor organization was for this reason complemented by educational measures to foster worker skills and education (Walter, 2000: 114).

Second, Abbe, just as Taylor, developed a way to introduce science to modern industry, albeit on a different level. The key difference is that Abbe used science to rationalize product development and product design rather than the actual production process.

How much Taylorism is compatible with Abbe's management philosophy clearly depends on the particular industry. Abbe was active in an industry that differed from those in which Taylor and Ford introduced their new production methods. Microscopes were not mass-produced like automobiles. The existing technology would not have allowed Taylorism to be pushed to the extreme in the optical industry. Also recall that Abbe wrote the statutes of the Zeiss Foundation as a guideline for managing its firms, which were to remain science-based. We do not know whether he would have advocated the same management principles for high-volume production of standardized commodities. In any case, Abbe expected the significance of factory production to increase further, and repeatedly referred to the specific character of the optical industry that made a special approach necessary there.

But more than 100 years after Abbe and Taylor articulated their management principles, considerable evidence has accumulated that Taylorism, with its emphasis on centralizing all decisions in the hand of managers and giving a worker the smallest task possible, is not the most efficient system of production even in what was its showcase industry: automobile manufacturing. One of us recently visited a Toyota factory in Japan to take a look at the company's famed production system (for excellent descriptions of the system, see Clark *et al.*, 1987; Fujimoto, 1999). Taylor would be pleased to see that Toyota employs a large cadre of production engineers who carefully plan every single motion on the long assembly lines. But he would be surprised to learn that workers give the engineers many of the ideas for improving the efficiency of the assembly line. Without question, the most shocking discovery for Taylor would be that at any moment an individual worker is empowered to bring the entire production line to a halt when he or she discovers a defect in one of the cars moving through the assembly line. Idling everyone on the line is Toyota's way of forcing workers to detect and analyze the causes for production problems the moment they occur. Toyota has found that the short-term efficiency losses associated with letting workers slow



down or even stop the entire assembly line are more than offset by the long-term efficiency and quality improvements this production method entails. Abbe would undoubtedly smile upon hearing that Toyota relied on the skills of individual workers to become the most efficient, and before long probably the largest, automobile manufacturer in the world.

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