# Commercialization of Disruptive Technologies:
# Revisiting the Value Network Theory and the Failures of Leading Incumbents in the Hard Disk Drive Industry

In his *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* published in 1997, Clayton Christensen presents his arguments of how and why leading incumbents failed to respond to the technological straightforward changes in the hard disk drive industry and thus went bankruptcy.

There is already a large body of literature explaining firms' success and failures by their technological and organizational capabilities. Beyond these capabilities, Christensen proposes the third theory – the value network theory – to explain why good firms could fail. This paper revisits the failures of such firms in the hard disk drive industry. With a case study of how a prominent hard disk drive manufacturer, Seagate Technology, missed the opportunities to commercialize its 3.5-inch drives in the 5.25- to 3.5-inch form factor transition, this paper aims to provide insights of what the important element in a firm's value network might be to determine its success or failure in technological changes. Contrary to Christensen's analysis which discounts the needs for incumbents to focus on existing business, this paper argues that in the phase of disruptive technological changes, incumbents need to pay even closer attention to the needs of their established customers.

JEL codes:

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| D2 | | Production and Organizations |
| | D21 | Firm Behavior |
| | D23 | Organizational Behavior; Transaction Costs; Property Rights |
| O3 | | Economic Development, Technological Change, and Growth: Technological Change; Research and Development |
| | O31 | Innovation and Invention: Processes and Incentives |
| | O32 | Management of Technological Innovation and R&D |
| | O33 | Technological Change: Choices and Consequences; Diffusion Processes |

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**Commercialization of Disruptive Technologies:
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## 1. Introduction

The hard disk drive industry is a strange industry. It is marked by repeated product transitions towards inferiority, where low-performing disk drives displace the high-performing ones. It is an industry where great firms, having good management teams, staying close with customers and allocating investment to innovations that promised the best returns, often fail. At least that is what the Harvard Business School professor, Clayton Christensen (1997), wants us to believe.

In his *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* published in 1997, Christensen presents his arguments of the technological trends towards lower storage capacity of hard disk drives in the industry history as an example of how established technologies can be disrupted by simple technologies. The disruption by simple technologies has profound impacts on established firms. In the hard disk drive industry, it has seen some major technical transitions in its component technology and format size (called form factor, in inches). The physical size of the disk drives has shrunken from 14 inches to now below 1.8 inches. While these changes in physical sizes were straightforward technologies, most of them were introduced by entrant firms and disrupted the established markets of the superior technologies; most leading incumbents failed to respond to these technological changes and went bankruptcy.

There is already a large body of literature explaining firms' success and failures by their technological and organizational capabilities. Beyond these capabilities, Christensen proposes the third theory – the value network theory – to explain why good firms could fail. This paper revisits the failures of such firms in the hard disk drive industry. With a case study of how a prominent hard disk drive manufacturer, Seagate Technology, missed the opportunities to commercialize its 3.5-inch drives in the 5.25- to 3.5-inch form factor transition, this paper aims to find out the reasons why established firms failed in the form factor transition and provide insights of what the important element in their value network might be to determine the success or failure in technological changes. Contrary to Christensen's analysis which discounts the needs for incumbents to focus on existing business, this paper argues that in the phase of disruptive technological changes, incumbents need to pay even closer attention to the needs of their established customer base.

## 2. Literature Review

The literature on firms' failures often relates to firms' technological and organizational capabilities. Christensen (1997) argues that the two capabilities of firms cannot adequately explain the failures of the leading incumbents in the hard disk drive industry, therefore, he comes up with the third theory, the value network theory, to account for the phenomenon in the industry. The literature on firms' technological and organizational capabilities is summarized below, followed by a brief review of the value network theory. This paper in turn argues that without specifying what in a firm's value network leads to the firm's success or failures, the theory lacks any explanatory power.

### *(a) Technological and Organizational Capabilities*

One explanation for why firms fail to respond to some certain technological changes points to the types of innovations required to overcome the changes. Henderson and Clark (1990) suggest that in a successful product development, firms require two types of knowledge – component knowledge and architectural knowledge, which could yield very different types of innovations from the conventional radical-incremental distinction. Component knowledge refers to the knowledge about the core design concepts and the way in which they are implemented in a particular component. Architectural knowledge is the knowledge about the ways in which the components are integrated and links together into a coherent whole. The common components of a hard disk drive include platter (the media where data are stored), read-write head (which moves above the surface on the platter to read and write data on it), motor (which drives the rotation of platters) and actuator (which positions the read-write head over the platter) etc. The knowledge about the design of each of these components is the component knowledge. Architectural knowledge refers to how these components relate to each other.

Depending on which type of knowledge an innovation has an impact on, the consequences for firms can be very different. An innovation can reinforce or overturn either component or architectural knowledge of firms adopting it, or both, thus a simple radical-incremental innovation dichotomy would fail to capture such impact. Therefore, to expand the radical-incremental innovation dichotomy, Henderson and Clark (1990) bring in two more types of innovation – modular (or component-level) innovation and architectural innovation. Figure 1 summarizes all four different types of innovations according to Henderson and Clark's model. The horizontal axis depicts innovations' impact on components, while the vertical axis on linkages between core concepts and components.

Modular innovation (or component-level innovation) refers to the innovations that improvement occurs in individual components, but the underlying core design concepts, and the links between them remain the same. That is, modular innovation destroys firms' component knowledge. Architectural innovation is the innovation that changes a product's architecture but leaves the components, and the core design concepts that they embody, unchanged. In this sense, architectural innovation destroys firms' architectural knowledge. This type of innovation is not unrelated to component knowledge. It is often triggered by a change in component, such as size, that creates new relationship between components in the established product. In the hard disk drive example, replacing old oxide platter media with new thin-film platter in a hard disk drive would be a component-level innovation because it simply overturns the existing component knowledge of the platter. While introducing new form factor drives would be an architectural innovation because, for instance, the position of the motor in an 8-inch drive is different from that in a 5.25-inch drive, thus destroying the architectural knowledge of how motor and the other components relate to each other (Christensen, 1993:550, footnote 18).

Following this framework, incremental innovations tend to build on established firms' existing architectural and component knowledge, thus their core competencies, making them more competitive in the market. On the contrary, radical innovation overturns established firms' both existing architectural and component knowledge, and thus their existing capabilities, creating them challenges.

To understand why firms are better in handling one type of innovation than another, Henderson and Clark (1990) then go on to explore how architectural and component knowledge are managed within firms. They point out that in the initial phase of a product development, architectural knowledge of the product is usually unstable because different firms compete on and confuse about the system and how components should be put together. Once a dominant design is established, and a single architecture is generally accepted, firms normally cease to study the alternative configurations of the established set of components due to limited resources. Architectural knowledge of the product within the firm is thus stable. At this stage, firms will instead concentrate their resources on building component knowledge, meaning competing on researching and developing particular components.

All these four types of innovations reflect firms' technological capabilities, because architectural and component knowledge are mostly enhanced by engineering efforts. However, architectural and component innovations are more a result of firms' organizational capabilities. As Henderson and Clark (1990) point out, most established firms are better at managing component knowledge than architectural knowledge due to the communication channels, information filters and strategies that firms adopted in product development. It is because effective firms often organize different groups of engineers focusing on different components. In the hard disk drive example, an effective disk drive maker may organize separate work groups in platter, read-write head, motor and actuator etc in order to improve the corresponding component knowledge. Communication channels between work groups are usually fixed, and therefore this kind of organization structure usually facilitates component-level innovations. When architectural change of the products is required, these firms often fail to respond because its organizational structure impedes them to handle architectural innovations.

In Christensen's early analysis of the hard disk drive industry (Christensen, 1993), he observed that most of the component-level innovations (such as introducing new head/ platter media technologies) were pioneered by incumbents, while the architectural innovations (such as new form factor drives) by entrants, while incumbents lagged behind. Christensen argues that although the architectural innovations led by the entrants were straightforward because most employed widely available proven components, its impact was industry-shaking.

*(b) Value Network Theory*

Christensen argues that because firms' technological and organizational capabilities cannot adequately explain the failures of the established firms in the hard disk drive industry, he proposes the third theory – the value network theory. A value network refers to the context within which the firm identifies and addresses customers' needs, procures inputs and reacts to competitors. It determines the perceptions of the economic value of new technologies, and the perceptions in turn shape the rewards firms expect to obtain from developing the new technologies.

As firms gain experience within the value network, they build up capabilities, settle organization structures and cultures tailored to their own network. It suggests that the longer the firms have been in a given network, and the more successful they have been, the less eager they are to compete with firms in other networks because their abilities and financial incentives to create new market applications and thus new value networks are constrained by their existing value network.

Applying the theory to the hard disk drive manufacturers, it means that the established firms are unlikely to value new form factor drives that did not fit the existing network. It is because producing different form factor drives entails different cost structure and marginal profits. For instance, 14-inch drive manufacturers could make profits in their value network with the gross margins of about 60 percent, while 8-inch drive manufacturers of only about 40 percent. Therefore, 8-inch drives were seen as financially unattractive in the value networks of 14-inch drives manufacturers (Christensen, 1997:38). Even worse, developing 8-inch drives would mean weakening the established value network of 14-inch drive makers because the new technologies would cannibalize sales of the established technologies. Therefore, most new form factor drives were developed by entrant firms because they were free from any value network constraints.

The explanatory power of the value network theory is doubtful for at least two reasons. First, the concept seems non-falsifiable. The "value" in the value network can be anything one can name, ranging from organizational structures, cultures, to customers' needs, vertical and horizontal linkages etc. Unless all the possible "values" in a given network are measured and quantified, one cannot weigh a given network over another to make any conclusion that whether a new technology is financially attractive in a given network or not. Second, the theory does not explain differences among individual firms into the development of new technologies. For instance, both Seagate and Rodime were leading manufacturers in the 5.25-inch drive markets in the late 1980s. The value network theory would predict that they would both perceive the new 3.5-inch drives as financially unattractive to their own value networks, because the leading manufacturers in the 5.25-inch drive market would generally not find the 3.5-inch drive market appealing due to the different revenue structures. However, Rodime managed to be the first to introduce 3.5-inch drives in the industry while Seagate lagged behind the transitions for two years.

This paper thus argues that without specifying the important element in a firm's value network, the theory cannot explain adequately firms' failures in the hard disk drive industry either. The purpose of this paper is to revisit such failures, look for alternative explanation and explore what in a value network of an established firm that is important to keep the firm motivated in developing new technologies.

## 3. Research Methodology

The study uses both quantitative and qualitative data sources to look at the hard disk drive industry. The prime data source on the hard disk drive industry of this paper is the same as that of most other studies, including that of Christensen (1993 and 1997). This is the *Disk/Trend Report*, the leading market research publication in the worldwide disk drive industry. The *Disk/Trend Report* tracked the disk drive industry from 1976 to 1998 and reported detailed information on industry-wide disk drive shipments and revenues, market trends, estimated application classification in different market segments and product performance specifications (such as capacity, size, head/media technology, access time, transfer rate, introduction year etc.) of every disk drive model intended for computer data storage which was in new production or announced by manufacturers.

While *Disk/Trend Report* only provides quantitative data such as product performance specification and aggregate sales figures, this paper relies on other secondary sources to study firms' marketing and decision-making strategies. Documents such as yearbooks, websites and annual reports of the leading firms, computer magazines and press archives are studied.

This paper focuses on the hard disk drive industry from 1986 through 1988. The choice of this timeframe is due to the fact that these are the years where industry shakeout was most prominent. The total number of hard disk drive manufacturers peaked at 75 in 1985 but declined to 58 in 1988. This decline could reflect that there was an industry shakeout, possibly due to disruptions.

Disk drives in the 1980s targeted at least one of three major markets: captive, original equipment manufacturers (OEM), and plug-compatible manufacturers (PCM). In the captive drives market, manufacturers produced drives internally or through a subsidiary of the computer manufacturer, and they sold primarily for use with the computer system offered by the same manufacturer. Drives sold to the OEM market are drives produced by independent disk drive manufacturers to the OEM of computer systems, who in turn install drives in their computing products and sell them to end-users. Drives sold through PCM are sold directly to end-users. Throughout the 1980s, only markets for captive and OEM drives were sizable. No shipments to the PCM market were recorded in the low capacity ranges. By 1988, captive and OEM drives accounted for 21 and 79 percent of the total market. Because captive drives were supplied and demanded in house, and the purpose of this paper is about the interaction between the technological development and the market demand, all captive drives are excluded from the *Disk/Trend* dataset.

As the *Disk/Trend* data of 1986 through 1988 indicates, the number of disk drive models introduced or produced by 60 disk drive manufacturers in 1986, 63 in 1987 and 58 in 1988 totaled 520, 711 and 800. After dropping captive drives and drives below 2.5 inches from the data, the number of disk drive models is reduced to 459, 622 and 699.

## 4. Findings

Christensen (1997) argues that the reasons why the established firms in the hard disk drive industry lagged behind in the form factor drive transitions when compared to the entrants pointed to (a) firms' capabilities in handling architectural and component-level innovations and (b) firms' perception of the different revenue structures between the existing and new business and the fears of sales cannibalization of the existing business. By looking at the quantitative data in the *Disk/ Trend Report*, this paper aims to verify the two causes, and thus argues that they are not supported by the empirical evidence in the industry.

*(a) Capabilities in developing architectural and component-level innovations*

In his earlier study of the hard disk drive industry, Christensen (1993) argues that because of the organizational structure that firms established over time, established firms tend to be good at component-level innovations to sustain product improvement; while entrants are good at introducing architectural innovations, such as developing smaller form factor drives.

However, McKendrick, Doner and Haggard (2000:284-5) have already corrected this claim. In fact, among the three form factor transitions (from 14- to 8-, from 8- to 5.25- and from 5.25- to 3.5-inch) in the 1980s and 1990s, only the 5.25-inch format was clearly introduced by entrants. Therefore, asking why incumbents failed in developing architectural innovations seems to be a false question, because entrants apparently had no advantages over incumbents in this type of innovations.

Also, while it might be true that most component-level innovations were introduced by incumbents, they were actually executed by entrants. Drawing data from *Disk/Trend Report* 1987-89, Table 1 compares the percentage of drives using thin-film media disk, which was one of the component-level innovations in the media, among leading incumbents and entrants. The majority of entrants indeed entered the market with drives using thin-film media disks, while leading incumbents were less aggressive in introducing thin-film media disks to the market.

The observation about the different levels of thin-film media disk usage among incumbents and entrants needs some technical elaborations. The capacity of a disk drive measures how many megabytes of data can be stored on the disk. In principle, to increase the capacity of disk drives, manufacturers could either increase the size of the disks, or pack data more densely in a unit disk area (which is the measured as areal density). From a larger form factor to a smaller one, the size of disks shrink, therefore manufacturers have to find ways to increase the areal density of the disks in order to make their products competitive in the market. One way to increase the areal density is to improve the component knowledge of the recording media technologies. Thin-film disk (as opposed to the old oxide disk technologies) is one of those component-level innovations. Thin-film disk on average can sustain three times higher areal density than the old oxide disk. Other advantages of using thin-film disks over old oxide disks include less disk noise and improved reliability. Thin-film disks are however much more expensive to manufacture than oxide disks (*Computerworld*, 29 November 1982).

Table 2 shows the trend of thin-film disk usage in different form factor drives in 1986-88. Smaller form factor drives tended to employ thin-film disks than the larger form factor ones did. It suggests that although downsizing the size of disks entailed overturning firms' architectural knowledge, it was triggered by component-level innovations – changing of recording media technologies in order to sustain the capacity performance of disk drives.

This finding could perhaps provide hints on why the form factor transitions proved difficult for the leading incumbents – it was because the established firms lagged behind the entrant firms to incorporate the essential component-level innovation in the form factor transitions.

*(b) Revenue Structure and Sales Cannibalization*

Christensen's value network theory argues that different revenue structures and sales cannibalization between the existing and new technologies are the reasons why the established firms were reluctant to move to the new form factor drive format. However, these may not be true. Smaller form factor drives were not necessarily financially unattractive to established firms. Drawing from the data in Christensen's (1997:15), the cost per megabyte of an 8-inch drive was $50, while that of a 5.25-inch drive was $200 – the 5.25-inch drive market was certainly higher-end. Also, manufacturing a 5.25-inch drive was cheaper than an 8-inch as well, because the smaller disk size was much easier to manufacture. Due to this, manufacturers could in principle sell a megabyte at a higher price but lower cost.

As the *Disk/ Trend Report* data shows, almost all the leading firms in the hard disk drive industry have participated in more than one market segments with more than one product architectures during the studied period. Coincidently, most firms who exited the disk drive market during the period had very narrow product diversity. Table 4 shows the comparison of the product lines between leading firms and exit firms in 1986. The value network theory would predict that the more successful the disk drive manufacturers were, the less likely they would develop new technologies in the lower-end market segment because the cost structure of producing new technologies was too low to be financially attractive within the value network of the firms. The theory would further predict that these firms would not produce two competing technologies within the same market segment because it would mean sales cannibalization. Findings in Table 4 are contradictory to the sales cannibalization hypothesis.

The question remains; if the different revenue structures and the sales cannibalization between the existing and new technologies were not the main obstacles for the established firms in adopting the new technologies, why did the firms lag behind the form factor transition? The following section presents a case study to explore the failures of one of the major leading players in the 5.25-inch drive market, Seagate Technology.

## 5. Case Study – Seagate Technology

Seagate is often cited as the metaphor of how leading incumbents failed to respond to disruptive technologies due to the constraints of its value network (see

Christensen and Rosenbloom, 1995). It was the first to introduce the industry-first 5.25-inch hard disk drive and it pioneered the 8- to 5.25-inch form factor transition. However, it lagged significantly in the 5.25- to 3.5-inch form factor transition. The puzzle was that given Seagate was so aggressive in developing new technologies, why did it overlook the potential of the 3.5-inch drive market? This sub-section outlines Seagate's corporate history and Christensen's arguments in the failures of Seagate in the 5.25- to 3.5-inch form factor transition, and then provides answer to the above question.

In October 1979, Finis Conner, from Shugart Associates which was then the leading floppy disk drive firm, observed that desktop PC users were adding multiple 5.25-inch floppy drives to their systems and they needed more storage capacity. He therefore approached Alan Shugart, the then president of Shugart Associates, with an idea to sell 5.25-inch hard disk drives with larger capacity and faster speed. In late 1979, Shugart and Conner left Shugart Associates and co-founded Seagate Technology. A year later, Seagate introduced the industry-first 5.25-inch drives to the market, and it soon became a hit. The market for 5.25-inch hard disk drives soon took off. By 1982, 8 percent of the desktop PCs sold were installed with 5.25-inch hard disk drives (*Computerworld*, 17 December 1984b). Seagate was once the largest independent manufacturer in the 5.25-inch drive market.

5.25-inch remained a standard form factor for desktop PCs, until a Scottish hard disk drive manufacturer, Rodime, introduced the 3.5-inch form factor in 1983. Engineers in Seagate were claimed to be the second to introduce the 3.5-inch drive prototypes in the industry. In 1984, less than two years after Rodime introduced the industry-first 3.5-inch drive, Seagate succeeded in developing its first 3.5-inch drive and brought the prototypes to customers, notably IBM and some value-added resellers of desktop PC, for product evaluation.[1] However, Seagate's customers showed little interest because the low capacity of the new drives could not address their needs. Seagate's customers were demanding 40 to 60MB, but Seagate's 3.5-inch drive could only provide 10MB; they preferred the older 5.25-inch drives. As a result, Seagate's manager lowered the sales estimates for the new 3.5-inch drives, and slowed down the new product development (Bower and Christensen, 1995:48; Christensen, 1997:20-21).

The market for 3.5-inch drives began to grow then and disk drive manufacturers started to rush in the market. In 1986, NEC, MiniScribe, Tandon, Rodime, Lapine and Plus Development together shipped about 850,000 pieces of 3.5-inch drives, accounting for about 20 percent of the low-end desktop PC market (*Disk/Trend Report*, 1987). In February 1987, Seagate eventually introduced its first 3.5-inch drives to the market. But in an interview in June 1987, Shugart, the then

[1] Christensen (see Christensen, 1997:20-21 and Bower and Christensen, 1995:48) said Seagate tested its 3.5-inch drive prototype with its customers in 1985. This paper suspects that the date was wrong because Seagate actually *announced* specifications and pricing of its 3.5-inch drives in 1984, the product evaluation with its customers might have happened well before that (*Computerworld*, 12 November 1984). This paper further doubt whether Seagate was the second to introduce the 3.5-inch drive prototype, because there were other disk drive manufacturers such as Control Data Corporation and Lapine who had announced their 3.5-inch products in the press before Seagate did (*Computerworld*, 30 May 1983 and 2 July 1984).

chairman and the chief executive officer of Seagate, admitted that Seagate still could not get any OEM contracts for its 3.5-inch drives (*Computerworld*, 1 June 1987).

The above story of how Seagate missed opportunities of new technologies leads Christensen to conclude that Seagate was held captive by its customers in the face of technological changes – its decision to develop or not to develop new technologies was based on its value network constrained by its existing customers, not on its organizational and technological capabilities. Christensen and Rosenbloom (1995:248) said,

> "In retrospect, it appears that Seagate executives read the market – at least their own market – very accurately. Their customers were manufacturers and value-added resellers of relatively large-footprint desktop personal computers such as the IBM XT and AT. With established applications and product architectures of their own, these customers saw no commercial value in the reduced size, weight and power consumption, and the improved ruggedness of the 3.5-inch products."

This explanation, however, does not seem to depict the whole picture. By the time Seagate overlooked the 3.5-inch drive market, IBM was its major customer and accounted for more than 60 percent of Seagate's sales. Was IBM oblivious to and saw no commercial value in the 3.5-inch products? In 1985, the same year Christensen said Seagate tested its 3.5-inch drive prototype with its customers, the press already reported that IBM was considering installation of high-performance 20MB 3.5-inch drive in its IBM PC AT (*Infoworld*, 15 April 1985). By late 1980s, IBM even produced all 3.5-inch drives internally at its manufacturing plant at Fujisawa, Japan (*Disk/Trend Report*, 1987).

In retrospect, Seagate did indeed *not* seem to have read the market – not even its own market – accurately. Its customers, notably IBM, clearly wanted 3.5-inch drives, but their capacity requirement was what Seagate's 3.5-inch drives could not meet. Christensen explicates the failures of Seagate by his value network theory, that Seagate's tie with its established customers was too strong that it kept Seagate from moving to the new market. The response of IBM to the new market, however, suggests the opposite – Seagate's tie with its established customers was not strong enough to bring them together to the new market.

The fundamental issue was that the OEM marriage between Seagate and IBM has been weakened in the face of the 5.25- to 3.5-inch drive transition. By 1987, IBM only accounted 22 percent of Seagate's revenue, down from 60 percent in 1984. IBM was the pioneer and it introduced many industry-first technologies (including the first hard disk drive) in the industry. However, it rarely manufactured drives for its low-end systems because buying from independent manufacturers like Seagate proved more cost-effective. The late 1980s has seen changes because IBM has been able to meet much of its own demand with its disk drive plants in Rochester, Minnesota and Fujisawa, Japan. Many of its OEM contracts with disk drive manufacturers during that period mostly served for back-up purpose. The slowdown of sales from the system companies like IBM was not atypical in the late 1980s. Other system companies like Digital Equipment Corporation (DEC, now part of Hewlett-Packard, HP) and HP were getting more proficient at making their own peripherals and thus relied less on independent peripheral manufacturers like Seagate.

These weak ties of Seagate with its customers could also be reflected from its conventional approach of product announcements – it first announced new products, and then started to find customers for them. Evidence was that Seagate first announced the product specifications and pricing of its new 3.5-inch drives in 1984, however, it did not get any OEM contracts for these drives until late 1987. On the contrary, Conner Peripherals, one of the leading manufacturers of 3.5-inch drives in late 1980s, never announced new products until it secured customers for the products and was shipping products to them (*The San Francisco Chronicle*, 6 November 1990). This reveals that Seagate's established customers did little to help it decide what new technologies to develop, and refutes Christensen's saying that Seagate was held captive by its established customers and it only developed what its customers needed.

The above explains why Seagate missed to commercialize and sell its new 3.5-inch drives to its *established* customers. The performance of Seagate's products could possibly explain why it could not get any *new* customers for its 3.5-inch drives within three years they were announced. Seagate's first 3.5-inch drives had only 10MB, while the others available in the market at the time had over 20MB at a comparable price.[2] In fact, Seagate's products did not seem to be attractive by technological means. For instance, while ranking the 52 hard disk drive manufacturers according to the disk drive with the highest areal density each offered as of 1986, Seagate ranked only twenty-sixth, just average in the market (see Table 3). The average performance of Seagate's products (despite its leading position in the industry) could be revealed from its skeptical attitudes towards new technologies. In 1987, when the industry was already moving to the thin-film disk media to replace the older oxide technology, the majority of the drives Seagate shipped still used the oxide technology. In an interview, Shugart explained that "[t]here's so much information available on oxide disks that you can make long-range projections. There's not enough known about the thin-film media yet. Over a period of time, there will be enough accumulated that technologists can make some projections for long-term reliability" (*Computerworld*, 1 June 1987). Was Seagate oblivious to the new thin-film disk technologies? It apparently was not. In 1984, Seagate acquired Grenex, a sputtered thin-film magnetic media developer, as part of its vertical integration strategy to improve its product performance (*Computerworld,* 10 December 1984).

For Seagate, it was just one thing to be strong in research and development, while another to actually have superior products introduced to the market. In this regard, Shugart explained, "[w]e're a volume manufacturer, so the technology we execute is different than what they might be working on in research and development. It has to be a big enough market before we will get into it… Just because we don't manufacture it doesn't mean we can't do it" (*Computerworld*, 1 June 1987). The technological gap between research and product development was not uncommon in the industry, because what most leading incumbents struggled was to drive the production cost down, rather than to improve their product performance. Table 3 compares the highest areal density of drives announced or produced by hard disk

[2] MiniScribe, for instance, offered its Model 8425 disk drive which had 25.6MB at $600 in 1985 (*Computerworld*, 13 May 1985).

drive manufacturers in 1986 and their market share. The technological capabilities of firms did not seem to relate the success of firms (in terms of market share). An analyst in the industry once commented, "in this industry, it's one thing to have products and another to have relationships…Once you are selling to them, it's hard to be dislodged unless you really screw up" (*The San Francisco Chronicle*, 6 November 1990).

In fact, when the market was healthy, Seagate and the other volume manufacturers enjoyed low production cost and stayed very competitive in the market. However, when the market demand slowed down, either by the erratic buying pattern of IBM as mentioned, or a general slowdown of the computer market growth, it posed major difficulties for volume manufacturers like Seagate. It is because the strengths of these large manufacturers in volume production became a major liability when the sales of hard disk drives fell. Evidence was that in the mid-1980s, there was an unexpected slowdown of desktop PC market, Seagate and other leading disk drive manufacturers thus suffered from inventory problems. In 1988, Seagate announced production cutbacks, employee laid off and aggressive pricing in order to tackle the excess inventory problem. Seagate's dumping of products also created a chain reaction to other disk drive manufacturers like Control Data Corporation and Micropolis (*The New York Times*, 23 August 1988). It is because Seagate's product dumping has put direct pressure on the markets of its competitors, who in turn had to follow. The product dumping has squeezed margins on the other drives.

For Seagate, production cost outweighed product performance in firms' product development strategies and customer needs. It is because in the industry where OEM manufacturers were the major customers, it was more important to ensure reliable and sufficient supply of disk drives, than the high performance of the products. Therefore, in the face of technological change, leading incumbents could not respond to the changes because product performance was not what they had been committed to.

In sum, as the case of Seagate shows, the failures of leading incumbents in developing new technologies were not due to the unattractiveness of the revenue structure of the new business or their fears of sales cannibalization of the existing business. It was also not due to their strong ties with the existing customers, as Christensen argued. Instead, this paper argues that their failures were attributed to their sacrifices of product performance for volume production. In the phase of disruptive technological changes, the established incumbents could not progress because of their failures to meet the needs of the existing customers.

## 6. Concluding Remarks

This paper summarized the literature on firms' technological and organizational capabilities, and Christensen's proposed value network theory to account for firms' failures in technological changes. It argued that the value network theory is inadequate to explain the failures of the leading hard disk drive manufacturers in commercializing disruptive technologies.

Using the same case study – Seagate Technology – as in Christensen's work, this paper arrived at a very different conclusion from Christensen's. It provided insights of what matters in firms' value network in determining the success or failure of the established firms. While the value network theory maintains that the late response of Seagate to commercialize its 3.5-inch architecture innovations was due to its historically strong ties with its established customers, this paper argued that the opposite was true. Seagate failed to move to the 3.5-inch drive market in time not because it has concentrated too much of its resources on its existing customers who did not want the new technology at all. The established customers of Seagate clearly wanted to switch to the 3.5-inch architect. It was Seagate who failed to maintain the strong ties with its customers by maintaining its product performance to a satisfactory level as required by its customers, thus keeping it from moving to the new 3.5-inch market.

Indeed, there were inherent characteristics of the hard disk drive industry that complicated the analysis. First, the hard disk drive market was not stand-alone, but was highly dependent on the computer market. Second, the OEM customers in the hard disk drive market were themselves capable to manufacture hard disk drives. These two factors have made market demand unpredictable for hard disk drive manufacturers, who in turn were unable to control price in the market. Third, fierce competition in the industry also translated into an extremely short product life-cycle, manufacturers competed mostly on cost by scaling-up production. The end result was that these inherent characteristics of the industry served as a nature system to select volume manufacturers as winners, disregarding the technological and organizational capabilities of these firms. When the market was healthy, the system ran seemingly well. However, when the market was unpredictable, the system broke down and volume manufacturers failed because their strengths in volume production turned into a liability. Dumping and industry shake-out were common throughout the industry history. When volume production could no longer differentiate among firms, technological and organizational capabilities mattered. Volume manufacturers who were not committed to product performances thus failed. The failures of some volume manufacturers created an illusion that "good" firms could fail – the foremost observation of Christensen was seemingly a false one.

Without discounting the value network theory, the purpose of this paper aims to deepen the understanding of firms' value network in determining their success or failures in the phase of technological changes. Unlike Christensen who maintains that the established firms' failures are attributed to their over-serving the existing customers thus leaving room for entrants to attack the market in the bottom-up manner, this paper argues that the existing customers' need must not be missed in order for established firms to get over the simple technological changes. Indeed, the notion that firms fail simply by being too close to their customers is counter-intuitive and not evident in any industry. Future research on disruptive technologies should focus more on how established firms should address the needs of their existing customers in order not to be disrupted during technological changes.

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**Figure 1 Henderson and Clark's Framework for Defining Innovations**

| Linkages between Core concepts and Components | | Core Concept: Reinforced | Core Concept: Overturned |
|---|---|---|---|
| | Unchanged | Incremental Innovation | Modular Innovation<br>(or Component-level Innovation) |
| | Changed | Architectural Innovation | Radical Innovation |

*Source:* Henderson and Clark, 1990.

**Table 1 Comparison between Leading and Entrant Firms Using Thin-Film Media Drives**

| Manufacturers | % of Thin-Film Media | Manufacturers | % of Thin-Film Media |
|---|---|---|---|
| **Leading Firms:** | | **Entrant Firms:** | |
| Maxtor | 100% | Areal Technology | 100% |
| Rodime | 89% | Comport | 100% |
| Micropolis | 82% | Goldstar Telecom | 100% |
| Seagate Technology | 76% | Prairietek | 100% |
| Priam | 67% | Samsung Electronics | 100% |
| Tandon | 64% | Western Digital | 100% |
| Miniscribe | 61% | Magnum Technology [c] | 80% |
| Control Data | 56% | Kalok | 75% |
| NEC | 43% | Kyocera | 67% |
| Plus Development | 33% | Mitsumi Electric | 0% |
| Microscience International | 25% | | |
| Quantum | 22% | | |
| Fujitsu | 0% | | |
| Hitachi | 0% | | |
| Storage Technology | 0% | | |

*Notes:*

(a) Firms are listed in decreasing order of their percent of drives using thin-film media.

(b) Leading firms refer to those who had significant (>4%) market share in one or more capacity segments in 1986. Entrant firms are those who started (or resumed) disk drive production in 1987.

(c) Magnum Technology exited in 1988.

**Table 2 Percentage of Hard Disk Drives Using Thin-Film Disks by Form Factors in 1986-1988**

| | 1986 | 1987 | 1988 |
|---|---|---|---|
| **3.5"** | 75.00% | 89.13% | 90.91% |
| **5.25"** | 51.52% | 58.66% | 70.67% |
| **8"** | 29.55% | 37.84% | 40.00% |
| **14"** | 17.14% | 7.69% | 5.88% |

*Source*: *Disk/Trend Report*, 1987-89

**Table 3 Highest Areal Density in 1986**

| | Manufacturer | Highest Areal Density | Sign. Market Share | | Manufacturer | Highest Areal Density | Sign. Market Share |
|---|---|---|---|---|---|---|---|
| 1 | Pertec | 43666560 | | 27 | Tandon | 20875904 | Yes |
| 2 | Maxtor | 43476096 | Yes | 28 | Micropolis | 19794000 | Yes |
| 3 | Cardiff Peripherals | 41054673 | | 29 | Brand Technology | 19564740 | |
| 4 | Toshiba | 37069760 | | 30 | Mitsubishi Electric | 19240048 | |
| 5 | NEC | 34572000 | Yes | 31 | Miltope | 19200000 | |
| 6 | Hewlett-Packard | 32595000 | | 32 | Toya Soda | 18534000 | |
| 7 | Control Data | 32565296 | Yes | 33 | Microscience | 18450000 | Yes |
| 8 | Century Data | 29934800 | | 34 | Peripheral Tech | 18015441 | |
| 9 | Seiko Epson | 28748700 | | 35 | Fuji Electric | 17620200 | |
| 10 | Hitachi | 26858000 | Yes | 36 | Quantum | 17520000 | Yes |
| 11 | Conner Peripherals | 26772000 | | 37 | Plus Development | 17477488 | Yes |
| 12 | Northern Telecom | 26296416 | | 38 | Miniscribe | 15999600 | Yes |
| 13 | IBM | 25920000 | | 39 | YE Data | 13450800 | |
| 14 | Vermont Research | 25385403 | | 40 | Matsushita | 13421249 | |
| 15 | Ibis | 24608000 | | 41 | Sony | 12720000 | |
| 16 | Fujitsu | 24446765 | Yes | 42 | Storage Technology | 12192000 | Yes |
| 17 | Ricoh | 24288000 | | 43 | Alpha Data | 11700000 | |
| 18 | Rodime | 24288000 | Yes | 44 | Shinwa Digital | 11250650 | |
| 19 | Lexikon | 24108000 | | 45 | Tokico | 10676000 | |
| 20 | Alps Electric | 23779360 | | 46 | Data-Tech Memories | 10643802 | |
| 21 | Priam | 23377360 | Yes | 47 | Xebec | 10496000 | |
| 22 | Siemens | 23332517 | | 48 | Sagem | 7800000 | |
| 23 | JVC | 23271090 | | 49 | Tulin | 6560000 | |
| 24 | Memorex | 22453200 | | 50 | Teac | 6168600 | |
| 25 | Newbury Data | 22414500 | | 51 | Cogito | 5375400 | |
| 26 | Seagate Technology | 21021666 | Yes | 52 | Josephine County Tech | 2076300 | |

*Source*: *Disk/Trend Report*, 1987-89

*Notes:*

(a) Firms are listed in decreasing order of their highest areal density found in all drives they produced.

(b) Sign. Market Share column measures whether the market share of the firm is significant (>4%) in at least one market segment. Market shares across segments cannot be compared, so no detailed figure is listed here.

(c) The total number of hard disk drive manufacturers listed here do not equal to the actual total number of hard disk drive manufacturers because some did not report complete product specifications and thus their highest areal density cannot be calculated.

**Table 4 Comparison of Product Variety between Leading and Exit Firms in 1986**

| | <30MB | 31-100MB | 101-300 MB | 301-500 MB | 501MB-1 GB | >1GB |
|---|---|---|---|---|---|---|
| ***Leading Firms:*** | | | | | | |
| Control Data | | 5 | 5,8 | 5.8 | 8,14 | 8,14 |
| Fujitsu | 3,5 | 3,5,8 | 5,8,14 | 5,8,14 | 8,14 | 14 |
| Hitachi | 3,5,8 | 3,5,8 | 5,8 | 5,8 | 8,14 | 8,14 |
| Maxtor | | 5 | 3,5 | 5 | 5 | |
| Microscience International | 3,5 | 3,5 | 5 | | | |
| Miniscribe | 3,5 | 3,5 | 5 | 5 | | |
| NEC | 3,5 | 5 | 5,8 | 8 | 8,14 | 8,14 |
| Priam | | 5,8 | 5,8,14 | 5,8 | | |
| Rodime | 3 | 3,5 | 5 | | 8 | |
| Seagate Technology | 3,5 | 3,5 | 5 | | | |
| ***Exit Firms:*** | | | | | | |
| Cogito | 5 | | | | | |
| Data-Tech Memories | | 5 | | | | |
| Newbury Data | | 3,5 | 5 | 5 | | |
| Nixdorf | | | 5 | 8 | | |
| Shinwa Digital | 3,5 | | | | | |
| Sony | 5 | 5 | | | | |
| Toya Soda | | | 5 | | | |
| Tulin | 3 | 3,5 | 5 | | | |
| Vermont Research | | | | | 8 | |

*Source*: *Disk/Trend Report*, 1987-89

*Notes:*

(a) Leading firms refer to those who had significant (>4%) market share in one or more capacity segments in 1986. Exit firms are those who terminated disk drive production in 1987 or 1988.

(b) 3 = 3.5” 5 = 5.25” 8 = 8-9” 14 = 10-14”

(c) Firms are listed in alphabetical order.