High-end disruptive technologies with an inferior performance

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Abstract: The literature on disruptive technologies has previously stated that those innovations often emerge in low-end segments or in new markets and as the performance improves it eventually displaces the old technology. This article aims to explain how and why a technology may prosper in high-end or mainstream markets despite its initially lower performance and does so through three in-depth case studies. The findings suggest that those technologies may compensate the inferior performance by simplifying and removing work for customers. For instance, digital imaging emerged in high-end segments since these customers were willing to trade-off the initially lower image quality in order to remove the usage of film. Based upon these results, the paper concludes that the literature on disruptive technologies needs to maintain a more nuanced view of value and how it is created and distributed inside the customer's organisation.

Keywords: disruptive technology; inferior; performance; Hasselblad; high-end; Facit; digital imaging; IP video surveillance.

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1 Introduction

For many decades, scholars have primarily looked inside the firm (e.g., Tushman and Anderson, 1986) in order to explain why established companies tend to encounter difficulties in the face of technological shifts. Christensen (1997) brought a different perspective upon this issue by looking at the firm's external environment and argued that those technologies which initially underperform according to the demands of mainstream customers tend to be problematic for established firms. Christensen and Raynor (2003) claimed that there are two forms of disruptive technologies, namely those which emerge in low-end segments and in new markets.

Other scholars have stated that previous literature has largely overlooked the issue of high-end disruptive technologies (e.g., Govindarajan and Kopalle, 2006). However, it is not entirely clear how and why a technology with lower traditional performance would emerge in a high-end application or in a mainstream market and more empirical evidence on this phenomenon is needed.

This article explores how and why disruptive technologies may prosper in high-end or mainstream applications despite their inferior performance. It is done by conducting a detailed multiple case study of how three such technologies have emerged in high-end or mainstream segments in different industries.

The remainder of this paper is organised as follows. The next section contains a theoretical exposition and the subsequent section provides a description of the methods used in this paper. Then the case studies are presented and analysed. The final part contains a discussion and some managerial implications.

2 Theoretical exposition

It is well documented today that established firms may encounter difficulties in the face of discontinuous innovation (e.g., Utterback, 1994). A discontinuous innovation can be defined as a major change, related to either a technology or a business model (Veryzer, 1998). Incumbent companies are usually good at innovation under steady, stable circumstances, but when technologies shift or new business models are introduced they can all of a sudden become vulnerable. Frequently, established firms struggle to survive these changes; they lose market share and are displaced by entrants.

Answers to this puzzle have often been sought by looking at supply-side factors and the firm's existing resource base (Cooper and Schendel, 1976; Henderson and Clark, 1990). For instance, Tushman and Anderson (1986) wrote about competence-enhancing and competence-destroying innovations. They argued that innovations which destroy the value of a firm's existing competencies are very difficult to manage, because established firms are bound by traditions, sunk costs and internal political constraints.

Christensen (1997) rejected previous explanations of incumbent failure which had primarily looked inside the firm. Instead, he drew upon resource dependence theory (Pfeffer and Salancik, 1978) in order to explain the decline of established firms. This theory suggests that an organisation is in fact controlled by actors outside the boundaries of the company. Since customers and owners are the key stakeholders that provide a firm with resources, they also impose a great indirect control of the decisions that are taken and how resources are allocated. In addition to this, Christensen (1997) applied the concept of value networks defined as "the context within which the firm identifies and responds to customer's needs, procures inputs and reacts to competitors" [Christensen and Rosenbloom, (1995), p.234] when explaining incumbent failure.

Bower and Christensen (1995) argued that a key determinant of the probability of survival for an incumbent is whether the new technology addresses the preferences of actors in the existing value network. From this theoretical base, they explained the pattern of incumbent failure by making a distinction between sustaining and disruptive technologies. Sustaining technologies have in common that they improve the performance of established products along the dimensions that existing customers' value. Disruptive technologies on the other hand, initially underperform along these dimensions and at the same time, bring new ancillary technological performance attributes to the

market. According to Christensen (1997), they are typically simpler and cheaper than the sustaining technology. The lower traditional performance and the higher ancillary performance make it difficult to find a financial logic in entering the new technology. The established firm finds it irrational to abandon its current, profitable customers in order to develop an initially inferior technology. Incumbent firms are therefore 'held captive' by their most profitable customers and as the performance of the disruptive technology increases, it begins to attract customers and eventually displaces the former technology.

Christensen and Raynor (2003) developed this theory further and suggested that there are two forms of disruptive technologies, namely those which emerge in new markets and those that prosper in low-end segments. The same authors also extended the theory by introducing the concept of disruptive business models, i.e., business models that target low-end customers or new markets, can be carried up-market and displace incumbents later on. Ryanair and the concept of low cost airlines can be regarded as one illustration of this notion.

While Christensen's work has shed new light upon the issue of incumbent failure, this theory suffers from a lack of clarity in the used terminology and several scholars have called for a more precise definition (e.g., Danneels, 2004). Govindarajan and Kopalle (2006) provided an expanded conceptualisation of this notion when they suggested that a disruptive technology is a novelty that introduces a different set of performance and price attributes relative to existing products. These characteristics make it unattractive for mainstream customers and as the technology improves along certain parameters it eventually displaces the former product or technology. This definition is broader and could also include disruptive technologies which initially prosper in the high-end or mainstream segments of the market. The authors argue that there are several reasons why high-end disruptive technologies may create a dilemma for established firms. Mainstream customers may not value the new performance attributes, it may have an insufficient initial traditional performance, the market niche is too small and therefore it may not result in any significant profits. However, given its initially lower traditional performance, it is not yet entirely clear how and why such a technology would emerge in high-end or mainstream segments (Danneels, 2004). There seems to be confusion in the literature regarding the seemingly paradoxical issue of high-end and mainstream disruptive technologies. The article aims to fill this gap by answering the following research question: how and why do disruptive technologies prosper in high-end or mainstream segments of the market, despite its lower traditional performance? Before presenting the illustrative case studies, some literature on value and business models is presented, along with the methodology employed in this paper.

2.1 Value creation, appropriation and business models

Economists often refer to utility theory when trying to understand value. Total utility refers to the satisfaction that comes from the possession of a good (Bowman and Ambrosini, 2000). Several scholars have pointed out the subjectivity of value, i.e., a good can be of great value for one individual or firm and be of no use for another one (e.g., von Mises, 1963). In line with this, Menger (1950) made a distinction between use value and exchange value. The exchange value is the paid price whereas the use value is the economic value that the buyer obtains from using the product. A positive difference

between these two measures is regarded as a consumer surplus. Given that buyers may use a product for different purposes, their use value differs and consequently they are willing to pay different prices.

In order to understand why disruptive technologies may prosper in high-end or mainstream segments, it becomes important to look more precisely at what use value they create for customers. Some of the recent work in this area has focused increasingly on the role of the market and the customer. Adner (2002) pointed out that the structure of demand needs to be addressed in order to clarify the nature and effect of disruptive technologies. Furthermore, Adner used the notion of thresholds, defined as critical performance levels that must be met. The functional threshold of a product is the minimum performance that the customer can accept whereas the net utility threshold also takes price into consideration. Slater and Mohr (2006) identified parallels between the work by Christensen (1997) and Moore's book *Crossing the Chasm* (2002) and underlined the importance of finding a nursing market for disruptive innovation.

Though the abovementioned work has contributed to an increased understanding of how disruptive technologies create value, this issue needs to be further addressed. One potential drawback of existing literature is that it has with few exceptions regarded customers as single entities in the value network, with one specific interest, rather than as organisations, which comprise several actors with dispersed utility functions. Many technologies are developed for industrial customers rather than individual consumers and hence, innovations are often sold to organisations, which can be regarded as value networks of their own. Therefore, it may be beneficial to look further into the customer's organisation in order to understand how disruptive technologies create value and prosper in high-end or mainstream segments.

Given that a disruptive technology brings new performance attributes to the market and that value creation is distinct from value appropriation (Chesbrough and Rosenbloom, 2002), the new value may need to be appropriated in a different way. The business model can be regarded as a construct which addresses how a firm creates and captures economic value (Chesbrough and Rosenbloom, 2002). Hence, a better understanding of how disruptive technologies create value is also needed in order to understand the challenges they impose upon incumbent firms and existing business models.

Summing up, while several important contributions have been made by addressing the impact a new technology has on the value network of a firm, more needs to be known regarding how and why disruptive technologies may prosper in high-end or mainstream segments. This in turn calls for a better understanding of how such technologies create economic value. The article addresses this issue by investigating what traditional and new performance attributes the studied disruptive technologies brought to the market and how this new mix created value for customers.

3 Method and research setting

This article is based upon three case studies of technological shifts that have or are currently taking place. Given that the presented research is of an exploratory nature seeking to understand an issue, which has been insufficiently addressed by previous literature, the method is deemed to be suitable. Moreover, the chosen method enables the kind of detailed descriptions that are required in order to address an issue which needs to

be better understood (Yin, 1994). Case studies imply a limited generalisability from the findings (Eisenhardt, 1989). However, the article does not attempt to provide an exhaustive set of answers. Rather, it seeks to explain how and why disruptive technologies with a lower traditional performance may still prosper in high-end or mainstream market segments.

The cases come from the calculator, camera and video surveillance industries and they are all related to a displacement of analogue or mechanical technology by microelectronics, i.e., digital technology. The industries and corresponding companies were targeted since they all have in common that the technology had disruptive characteristics (see Table 2 for further information), but did not prosper in low-end segments or in new markets as predicted by the disruptive innovation framework (Christensen and Raynor, 2003). The first electronic calculators, as well as the first successful applications of digital imaging and IP-based, digital surveillance (IP video) all emerged in either the mainstream market or in high-end applications. Additionally, these technologies had an inferior performance along those dimensions that have been valued historically by mainstream customers. Digital imaging initially offered a lower image quality, electronic calculators started off as bigger and more expensive and IP surveillance had a lower image resolution and a higher price in the beginning. Hence, these shifts offer an opportunity to understand how and why disruptive technologies may prosper in high-end or mainstream applications, despite a lower traditional performance. Another reason for choosing these cases is that incumbent firms have struggled in these transitions, despite the fact that their customers initially demanded the technology. Hence, the pattern of displacement is different in these cases from the one described by Christensen (1997). Therefore, they present an interesting opportunity to address how and why a disruptive technology does not initially prosper in low-end or new market segments as postulated by previous theory.

In these three different industries, one corresponding company has been targeted. This was done in order to obtain insights into how these technologies have been commercialised in their early phases and how those firms tried to overcome the problem of offering a product with lower traditional performance. All the targeted firms were operating in high-end or mainstream segments. Table 1 below provides a summary of the gathered data.

Table 1 An overview of the data used in the different cases

Company and industry	*Interviews*	*Secondary data*
Hasselblad and the shift to digital imaging.	30 interviews, follow-up questions and discussions of in total approx. 100 hours.	Minutes from board and top management meetings 1989–1995. Internal PMs, strategic documents and mail conversations.
Facit and the displacement of mechanical calculators.	Six interviews, totalling approx. 20 hours.	All minutes from board and top management meetings during 1964–1972. PMs, internal investigations and reports from this period.
An entrant firm that has driven the shift to IP Video.	Seven interviews of in total approx. 15 hours.	None.

Table 2 An overview of the investigated companies and how the disruptive technologies created value

Disruption	*Studied firm*	*Time period*	*Traditional performance*	*Price*	*Ancillary performance*	*Value proposition*	*Changes in the value network*
The displacement of analogue video surveillance by digital, internet cameras (IP video).	A European entrant firm which has driven the shift and grown rapidly over the studied time period.	1996–2007	For a long time, the new technology offered worse image quality in terms of resolution and displayed images per second.	Network cameras have up until 2005 with few exceptions been more expensive.	Easier installation since fewer wires are needed. The cameras can be made more intelligent.	Improved video surveillance at a lower total cost of ownership.	IP video is sold to the same customers, but to IT departments instead of security departments. Thus, a change inside the customer's organisation has taken place.
From film-based photography to digital imaging.	Hasselblad, a high-end incumbent firm which is famous for outstanding image quality.	1990–2005	Hasselblad's analogue photos corresponded to about 36 megapixels, the first digital versions in the mid 1990s offered 4–6 megapixels.	Digital cameras were significantly more expensive up until the late 1990s.	Simpler production of pictures. Images could be viewed instantly and captured at no cost.	A simplified workflow enabled an improved handling and images that are good enough.	Sold initially to Hasselblad's traditional high-end segment of studio photography.
The substitution of mechanical calculators by electronic calculators.	Facit, a Swedish manufacturer of office furniture, typewriters and mechanical calculators.	1964–1973	Electronic calculators offered similar computing capabilities initially, but became better towards the mid-1970s.	In 1966, electronic calculators were about twice as expensive, but the price went down rapidly during the studied period.	From the late 1960s and on pocket calculators introduced portability and simplicity as new attributes.	Similar up until the rise of pocket calculators. Then factors like simplicity, price and portability were introduced.	Electronic calculators were sold to the same customers up until the rise of pocket calculators. Those were instead sold via bookstores and retailers in order to generate larger volumes and reach mass markets.

Former CEOs, R&D managers and people in charge of commercialisation were approached with open-ended and semi-structured interview questions. Since these companies are public, CEOs and people with strategic responsibility could be identified. A snowballing technique was used in order to find additional respondents. Given that two of the cases (digital imaging and electronic calculators) are historical studies, it was possible to identify people who had experienced the entire process of emergence and eventual dominance of the new technology. The shift to IP-based surveillance is currently taking place and hence, the same historical perspective could not be adopted. However, as the technology has been adopted by about 20% of the market and it has been around for more than ten years, it is still possible to study how and why it has emerged in the mainstream of the market. A large majority of the interviewees can be said to have had direct insight into commercial, technological and strategic issues related to the technological transitions. The information retrieved from the other respondents should rather be regarded as important background knowledge.

The questions concerned how the technology prospered and how it performed compared to the established technology along both the traditional dimension and the new attributes that were brought to the market. Additionally, questions were asked regarding how these innovations created value for customers and why they adopted it, despite the lower traditional performance. The respondents also described the challenges that were encountered when trying to develop and launch a technology with the properties mentioned above and how those were handled. While all of the collected secondary data did not directly concern the disruptive technology, additional information should still be regarded as vital since it provides important contextual information. The interviews and the collection of data were conducted from mid-2007 until late spring 2009.

Collecting data by performing interviews may imply a biased interpretation (Yin, 1994). This potential drawback was taken care of by approaching many respondents. Several follow-up interviews were conducted and compared with the written sources that have been accessed. In those cases when the sources contradicted each other, further interviews were performed. By doing so, the collected data has been triangulated. Moreover, the Hasselblad case description has been read by many of the interviewees and hence been further validated.

4 Results and analysis

This section contains a presentation of the results and an analysis of how and why disruptive technologies may prosper in high-end or mainstream markets. Table 2 provides an overall description of the studied companies and the disruptive technologies, their respective properties and how they created value for customers.

4.1 How high-end and mainstream disruptive technologies prosper

The case studies presented in this article offer some interesting evidence regarding how disruptive technologies create value for high-end or mainstream customers, despite their lower traditional performance. Generally speaking, it seems that they emerge in market segments where the ancillary performance compensates the lower traditional value to such an extent that customers are willing to buy it anyway. In two of the three cases, the

main reason for this was that the disruptive technology could remove work in the customer's process and thereby lower their total cost. Hence, the technology created value on a more systemic level rather than on the level of each individual product. This is illustrated by the cases of digital imaging and IP video below.

4.1.1 Hasselblad and digital imaging

Over the last 15 years, the camera industry has undergone a shift from film-based photography to digital imaging. The sales of digital cameras grew rapidly from the late 1990s and on when cheaper and better cameras were launched at a high pace. Prior to this remarkable growth and the eventual displacement of film, digital imaging prospered in Hasselblad's medium format segment of professional photography where a digital back could be attached to medium format cameras. These digital backs were primarily manufactured by entrant firms such as Leaf Systems, Phase One, Imacon and Jenoptik and were expensive complements to the dominant analogue technology. The main customer segment for these backs was studio photographers. Digital technology enabled these customers to view images instantly and removed the costly and time-consuming process related to using film. Additionally, those images were often scanned and digitised later on anyway and hence, digital imaging made the production of images much cheaper and simpler. Studio photographers were willing to trade-off some image quality and pay a higher price since it could save days of downtime waiting for the transparencies to be finished.

With these attributes in mind, Hasselblad sought to develop a new camera system in the mid 1990s, which was based upon a 6 megapixel sensor that had been co-developed with Philips. The camera was intended for studio photography, a high-end niche which would hopefully be willing to pay a high price and trade-off some image quality in order to remove film. Hasselblad was not used to offering this kind of value proposition and thus, the project met a lot of resistance inside the firm. The person in charge of the project, Lennart Stålfors, recalls that he "had to spend an un-proportional amount of time defending the project instead of working with development activities."

The project was eventually stopped in 1996 when a new owner changed strategy and decided to develop a new camera system that was compatible with both film and digital backs. When the shift to digital imaging came into full motion from 1999 and on, Hasselblad's semi-digital medium format cameras were displaced primarily by Canon and Nikon who introduced advanced digital SLR cameras which were simpler, lighter, cheaper and offered an image quality that was sufficient for most applications.

4.1.2 IP-based video surveillance

IP video surveillance was introduced by the studied firm in the 1990s. CCTV had for a long time been analogue, while IP video is instead based upon digital technology using sensors, so the material is stored as digital files.

Another difference is that digital cameras have an IP-number and are connected over the internet, instead of via cables. While the analogue technology is still dominating the market, digital video surveillance is growing rapidly and the studied firm is an entrant and one of the actors driving the shift from analogue to digital technology. About 20% of the market is now based upon IP video solutions and this figure continues to grow.

Over the last decade, IP video has improved significantly in terms of image quality and with the rise of megapixel cameras it has now outperformed analogue CCTV along this dimension. However, the technology was growing rapidly before reaching these performance levels. One of the main reasons for this is that they are much easier and cheaper to install since the cameras are connected over the internet. This implies a lower total cost for owning and maintaining a system. The studied firm seeks to communicate the benefits of IP-based surveillance by focusing on the total cost of ownership rather than the price of one single camera.

Additionally, IP video has implied that surveillance has become both an IT and a security issue. One person in charge of technology development at the studied company states that installations of IP cameras are often performed together with the IT integrators and departments instead of with security departments. Thus, a shift has occurred inside the customer's organisation and the value proposition has changed with the new technology. It has also turned out that IT departments are more easily convinced by the total cost of ownership argument and that they are more willing to use IP cameras since they understand the technology in a better way.

So far, the incumbent firms have failed to dominate the new technology in the same way as they did with CCTV. Whether the established firms will survive this disruptive technological change or not remains to be seen. According to respondents at the studied firm, one reason why the incumbents have so far lagged behind in IP video appears to be that they do not know how to approach customers with it. The logic of selling to IT departments is new to the industry and the analogue players are not used to doing so.

4.1.3 The creation of new value inside the customer's organisation

The cases of digital photography and IP video have in common that they created value in a new way inside the customer's organisation, primarily by simplifying the work process and removing labour. Hence, it seems that the net utility threshold for a disruptive technology (Adner, 2002) can be lower in high-end or mainstream segments since these customers can use the technology in order to lower their overall expenses. While the price was higher and the technology was inferior in many ways, its ancillary performance attributes created a higher consumer surplus that could motivate the investment. The case of IP video also suggests that this threshold is different depending upon which actor is targeted inside the customer's organisation. IT departments perceive the value in a different way since they understand the technology.

This explanation of why a disruptive technology prospers in high-end or mainstream markets suggests that previous literature on this topic has maintained an over-simplified view of the customer and value creation. The framework developed by Christensen (1997) draws upon diffusion models such as the one stipulated by Rogers (1995). Those models assume a normal distribution of customers and an epidemic diffusion of innovations. The case studies in this paper indicate that while such models highlight many important aspects of innovation diffusion, they may hamper the understanding of how and why some disruptive technologies succeed since they do not assume any heterogeneity inside the customer's organisation. The IP video case illustrates that the forces of resource dependency can be imposed by different actors within the client organisation. The dominant analogue players in the CCTV industry are used to targeting security departments with another value proposition and they may therefore be 'held captive' by one actor inside the customer's organisation since security departments do not

appreciate or understand IP video in the same way. This finding suggests that previous literature on disruptive technologies has not yet addressed the subjectivity of value (Menger, 1950) to a sufficient extent. While the use value differs between different customers, it can also differ *inside* the customer's organisation and this creates a problem for incumbent firms. The consumer surplus is higher for clients if IT departments are involved in the installation of IP video systems and this is one of the main reasons why the technology could prosper in mainstream segments despite its higher price and initially inferior traditional performance. Therefore, it seems to be suitable to apply more of an adopter perspective and look further into how disruptive technologies actually create value inside the customer's organisation. Consequently, the concept of value networks needs to be nuanced within the field of disruptive innovation.

4.2 Why technologies with lower performance emerge in high-end segments

The case studies presented above suggest there are several reasons why a disruptive technology does not prosper in low-end segments or in new markets, but rather in mainstream and high-end segments. As was described earlier, it seems that those technologies may simplify and remove a lot of labour for the customer and that this can compensate the lower traditional performance and the higher price. Customer segments which have a more labour intensive business such as studio photographers or installers of video surveillance benefited extensively from this. Another important reason seems to be the high price that was associated with the technologies initially which made it impossible for low-end customers to afford them. The price parameter seemed to be the most important determinant of why electronic calculators initially emerged in high-end segments and later on entered lower segments as well as created new markets.

Electronic calculators that are based upon transistors were first introduced in the early 1960s. Those were mainly used in order to perform advanced calculations in very specific military and scientific applications. As the technology became cheaper and smaller over time, it entered Facit's office machine segment in 1964–65. Since Facit's competence base was related to mechanics, the company decided to collaborate with Sharp and thus bought their calculators and gave them a Facit design. The electronic desktop calculators that Facit sold from 1966 and on had similar computing capacity as the mechanical calculators. Therefore, they could simply replace the mechanical calculators at this point since the product offered similar performance and consequently also prospered in the same value network as the former technology. This strategy prevented Facit from losing market share initially. However, when integrated circuits were introduced in calculators from 1968, the pace of development was increased to such an extent that it was not possible any longer to rebadge calculators from another company. Moreover, the rapid development of integrated circuits implied a sharp decline in prices and a miniaturisation of the products that later on made them appealing to consumers. At this point, Facit's business to business sales model was rendered obsolete since calculators could be bought anywhere. Göran Arvidsson, who was a member of the top management group by that time, said that the entire office machine industry suffered due to these changes. The established firms had built strong relations with their customers and had their own sales offices. With the shift to electronics, both the technological competence and the sales model were rendered obsolete. Consequently, Facit suffered from severe losses in 1971–72 and was eventually acquired by another company in late 1972.

This case provides a compelling description of how important the price parameter is and it suggests that the literature on disruptive technologies ought to treat this dimension more carefully than just stating that a disruptive technology is 'typically cheaper' (Christensen, 1997). While the diffusion approach to disruptive technologies failed to explain how and why digital imaging and IP video prospered in high-end applications, it seems to be valid in the case of electronic calculators. Electronic calculators followed a more linear diffusion pattern since it did not create any new value inside the customer's organisation initially and did so in a top-down way due to the rapid decline of prices and increased performance over time.

The case studies above give a further confirmation that disruptive technologies may initially prosper in high-end or mainstream segments. These observations also suggest that the extended definition provided by Govindarajan and Kopalle (2006) is therefore more suitable since it includes events that would have been disregarded when using Christensen's (1997) original definition.

5 Discussion and managerial implications

While Christensen (1997) illustrated how difficult it is for incumbent firms to enter lower segments and commercialise an initially inferior technology, it seems to be equally tricky to approach existing customers, even though they would benefit from adopting such a technology. The case study about Hasselblad provides evidence on how firms struggle when bringing a new value proposition to existing customers. It indicates that companies need to experiment with new business models in order to succeed with disruptive technologies since they bring a new value proposition to the market. Lennart Stålfors, the R&D manager in charge of digital imaging at Hasselblad recalls how the issue of digital imaging tended to create tension and conflicts inside the company. The market organisation was reluctant to bring an initially inferior image quality to their customers since it could harm the brand of the company. Given that there was in fact a demand for this product, the challenges were not primarily related to resource dependency as stated by Christensen (1997). Rather, the disruptive technology was problematic since it was not compatible with the value proposition Hasselblad had previously offered. Hence, firms seem to struggle when developing disruptive initiatives because they break the existing linkages between the technology and the business model.

Trying to renew an established business model is therefore not only a matter of finding a customer, which demands the technology. It is also an issue related to political power both inside the firm and inside the customer's organisation. If value is created on a different level and the disruptive technology prospers in another part of the organisation, some actors may lose influence at the expense of others. For instance, when IP video is sold to IT departments, this reduces the status of security departments and a political barrier to adoption may occur. The disruptive innovation theory could therefore benefit from maintaining a more nuanced conceptualisation of value networks. The case of IP video indicates that there are several different actors inside the customer's organisation who may block the adoption of a disruptive technology. Given the subjectivity of value (Menger, 1950), these actors need to be mapped and understood in terms of their incentives and activities. Finding a business model that aligns different incentives within the customer's organisation therefore seems to be a key success factor.

One of Christensen's (1997) most influential recommendations is that in order to succeed with a disruptive technology it is necessary to launch an independent organisation which can prosper in a different value network. However, it is far from obvious that this can be done when addressing existing customers like Hasselblad had to do. Since the technology emerged in the same segment as analogue photography the company became reliant upon the established market organisation and it turned out that they were reluctant to bring a technology to the market which did not offer the superior image quality that was associated with Hasselblad's brand.

The case studies about Hasselblad and Facit also illustrate how the value proposition changed over time and how this augmented the difficulties related to surviving the technological shift. The early versions of digital imaging prospered in a high-end, niche segment by removing work as has been described above. However, from 1999 and on, digital single lens reflex cameras started to disrupt Hasselblad's semi-digital medium format cameras for professional photographers. These cameras were simpler, cheaper and offered sufficient image quality. Hence, they attacked from below and disrupted Hasselblad in exactly the way described by Christensen (1997). The same thing happened when the simpler, cheaper and portable pocket calculators disrupted Facit's mechanical and electronic calculators for office use. Thus, the classical low-end disruption occurred after the technology had initially prospered in higher segments. This development over a short period of time increased the difficulties related to surviving the technological shift since the initial value proposition was different from the one that later on came to dominate the market. Working with lead-users (von Hippel, 1988) in the early phases like Hasselblad did with studio photographers is therefore problematic since these customers had preferences that differed largely from the ones in the mainstream market when the technology had matured later on.

5.1 Conclusions and future research

While previous work on disruptive technologies has contributed to an increased understanding of how and why established firms may decline when new technologies are introduced, this stream of literature has so far not succeeded in explaining how and why such initiatives may prosper in high-end or mainstream markets segments.

The abovementioned issue has been addressed in this article both by providing empirical evidence on this issue and by drawing upon literature about value and business models. The cases in the paper suggest that disruptive technologies may prosper in high-end or mainstream segments by introducing ancillary performance attributes that create economic value on a more systemic level inside the customer's organisation, for instance by simplifying and removing time consuming work. This value creation seems to compensate the lower traditional performance that was associated with the disruptive technology. This finding implies that the literature on disruptive technologies has so far suffered from an over-simplified view of customers and that the subjectivity of value inside the customer's organisation has not been sufficiently captured. Moreover, it has been argued that it is more relevant to look at how value is created, rather than addressing different performance dimensions.

Additionally, the initially higher price that was associated with the studied technologies implied that they could only prosper in such segments and therefore it can be concluded that the literature on disruptive technologies needs to treat the price parameter more carefully than has been done previously.

The findings in this paper seem to suggest that the challenges related to disruptive innovations which prosper in a firm's existing customer segment are different from those described by Christensen (1997). Previous theory on disruptive innovation has stated that the main challenge is related to managing the internal resource allocation process. When a disruptive technology prospers in a mainstream or high-end segment, firms seem to struggle for other reasons, which are primarily related to the new value proposition and its compatibility with the existing network structure in terms of value distribution and systemic changes inside the customer's organisation. Therefore, a more nuanced conceptualisation of the term value network seems to be needed.

These conclusions indicate that more detailed studies of what effects disruptive technologies have inside the customer's organisation may be one way forward for future research into why technological shifts tend to create such problems for incumbent firms. Furthermore, the findings above suggest that many of the managerial solutions related to disruptive innovation are not necessarily valid when a technology prospers in high-end or mainstream market segments. Little is known about how firms can actually work proactively in order to renew their business models. This article has offered some tentative guidelines for doing so, which are related to mapping, understanding and aligning incentives throughout the value network. More research is needed regarding how firms can actually succeed in changing their business models to match the new value proposition that disruptive technologies tend to create.

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