2 Theoretical Background

2.1 Discontinuous Technological Change

2.1.1 Definition and Characteristics

Despite the ubiquity of the phenomenon of discontinuous technological change in the academic literature of the last decades, there is still a lack of definition for this term (Chesbrough, 2001). Even more importantly, scholars refer to similar yet somewhat different terms such as ‘disruptive,’ ‘radical,’ ‘non-paradigmatic,’ or ‘breakthrough’ when discussing related phenomena without clarifying the similarities and differences of the concepts they are building on (Suarez & Rogelio, 2005). Table 1 provides an overview of the definitions used in some articles that have been frequently cited by academics and that are particularly relevant for this thesis.

Table 1: Overview of Definitions Used in Prior Research

Authors	Year	Term	Definition	Antonym
Miller & Friesen	1980	Major change *synonymous for:* serious change, dramatic change	A change, for instance “in the external environment caused by competitor strategies, technological obsolescence, economic booms or recessions, etc.” (p. 596)	Small, piecemeal change
Abernathy & Clark	1985	Revolutionary innovation	An “innovation that disrupts and renders established technical and production competence obsolete, yet is applied to existing markets and customers” (p.12)	Regular and niche innovation
Foster	1985	Technological discontinuity	Technological opportunities with “superior performance improvement potential” (p. 132), i.e. more remote “technical limits” (p.128), lying on a different “S-curve” as compared to the old technology	Evolutionary progress (along established S-curve)

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Authors	Year	Term	Definition	Antonym
Tushman & Anderson	1986	Product/process discontinuities/major technological shifts	"Technical advance so significant that no increase in scale, efficiency, or design can make older technologies competitive with the new technology" (p. 441)	Incremental improvement
Anderson & Tushman	1990	Technological breakthrough, *synonymous for:* technological discontinuity, breakthrough innovation	"innovations that dramatically advance an industry's price vs. performance frontier" (p. 604); innovations that "command a decisive cost or quality advantage and […] strike not at the margins of the profits and the outputs of the existing firms, but at their foundations, their very lives" (Schumpeter, 1942:84) (p. 606)	(Continuous) incremental innovation
Henderson & Clark	1990	Architectural innovation	"reconfiguration of an established system to link together existing components in a new way" (p. 12)	Radical, incremental or modular innovation
Christensen	1997	Disruptive technology	Disruptive technologies' are characterized by "worse product performance, at least in the near-term," offering "very different value proposition," often "cheaper, simpler, smaller […] more conveniently to use," thus being attractive for "few fringe (and generally new) customers." (p. xviii)	Sustaining technology
Chesbrough	2001	Technological change	None (highlights a classification along 3 dimensions: technical complexity, external linkages, institutional environment)	None

Authors	Year	Term	Definition	Antonym
Hill & Rothaermel	2003	Radical technological innovation	"involves methods and materials that are novel to incumbents [in order to achieve a commercial or industrial objective]" and can be based either on an "entirely different knowledge base or [stem] from the recombination of parts of the incumbents' established knowledge." (p. 258)	Incremental technological innovation
Gilbert	2005	Discontinuous change	"external changes that require internal adaptation along a path that is nonlinear relative to a firm's traditional innovation trajectory" (p.742)	None
Benner	2007	Radical technological change	A change that "shifts the underlying base of technological knowledge in an industry's products and promises dramatic improvement in price and performance, possibly resulting in product substitution" (p. 704)	None
Kaplan & Tripsas	2008	Discontinuous change/technological discontinuity	None (referring to Anderson & Tushman's models of evolutionary cycles)	None
Tripsas	2009	Identity-challenging technology	"technologies that deviate from the expectations associated with an organization's identity" (p. 442)	None
König, Schulte, & Enders	Forth-coming	Non-paradigmatic change	"a distinctively novel model or pattern for resolving selected problems in a collectively shared cognitive domain" (p. 5)	Paradigmatic change

It seems important to begin the definitional discussion by emphasizing the difference between 'inventions' and 'innovations' as first described by Schumpeter (1934). 'Inventions' refer to "the discovery of new knowledge" (Hill & Rothaermel, 2003: 258) and as such are mainly relevant for the R&D departments of organizations. 'Innovations,' however, go one step beyond and constitute "attempts to commercialize an invention" (Hill & Rothaermel, 2003: 258). As such, their importance and impact is not constrained to organizations' R&D departments but they also substantially affect, for instance, production, sales and marketing as well as the purchasing departments. Put differently, innovation refers to a change in technology, whereby 'technology' depicts the "process by which an organization transforms labor, capital, materials, and information into products and services of greater value" (Christensen, 1997: xvi). Thus, I will henceforth use the terms 'innovation' and 'technological change' synonymously.

Common to most of the definitions given in this context is the comparison of disruptive/discontinuous/radical as opposed to sustaining/continuous/incremental/ evolutionary technological change. Any input or output functions, such as knowledge accumulation, resource requirements, or product performance of the latter type typically shows what mathematicians call 'continuously differentiable behavior'[6]. On the contrary, the characteristic curves of discontinuous technological changes exhibit sharp bends and steps: Knowledge, resources, or product features that are crucial for the old technology become irrelevant whilst new knowledge, resources, or product features become necessary. Whereas some authors, for instance Christensen, become very specific about detailed characteristics of these changes such as the development of product performance criteria over time, others such as Kaplan remain rather vague when defining the nature and characteristics of their focal construct.

In this thesis, I build on a combination of Gilbert's (2005) and Hill and Rothaermel's (2003) view envisaging discontinuous technological changes as:

Definition 1: Discontinuous Technological Changes

'Innovations triggered by external players, that involve methods and/or materials that are novel to incumbents and that require internal adaptation along a path nonlinear to the firm's traditional trajectory.'

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[6] Given an appropriate level of granularity.

By drawing on this definition, I aim to highlight three aspects:

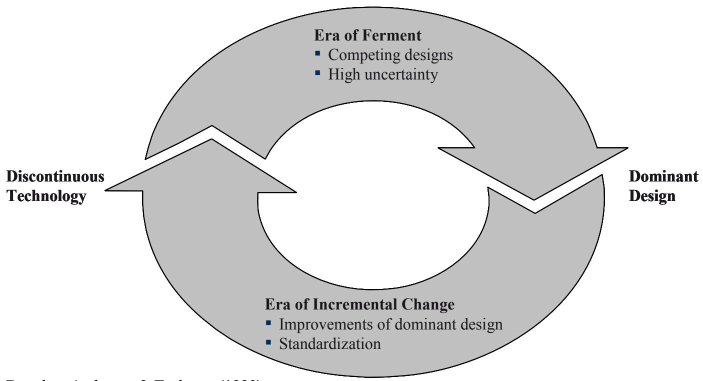
1) The phenomenon I am investigating is triggered *externally* (as opposed to internally)
2) via a new *technology* (as opposed to political turmoil, general economic crises,…); and
3) adoption of such a new technology requires *non-paradigmatic changes* of internal resource commitments and routines.

This definition allows me to sufficiently focus the core construct in order to build reliable and specific theory, whilst at the same time being broad enough to allow for generalization and empirical evidence within multiple settings.

More specifically, the definition used here includes product and process innovations (Anderson & Tushman, 1990) as well as innovations referring to business models, i.e. the way of capturing value, and any combinationary cases (König, 2009). The same holds true for Henderson and Clark's (1990) differentiation between architectural innovations (referring to reconfiguring existing components in a novel way) as opposed to radical innovations (referring to innovations based on substantially new components requiring a new architecture), both of which are discontinuous technological changes as defined here. Furthermore this definition comprises, but is not restricted to, 'identity-challenging' innovations that contravene the organizational members' shared beliefs about the nature of the central, distinctive, and enduring elements of the organization (Tripsas, 2009). This thesis focuses on competence-destroying rather than competence-enhancing innovations (Anderson & Tushman, 1990).

A static analysis of adaptation to discontinuous change holds little promise; yet, any study of adaptation to discontinuous change needs to consider the temporal evolution of such changes. In their ground-breaking articles (1990; 1986), Anderson and Tushman propose a cyclical model of continuous and discontinuous technological changes as depicted in Figure 3. At a given point in time, a technological discontinuity emerges entailing an 'era of ferment'. In this phase, characterized by high uncertainty, many potential designs co-exist while the residual fit with the established technology steadily decreases. This phase ends with the emergence of a 'dominant design' that heralds the 'era of incremental change,' a phase that is dominated by incremental innovations and standardization. To come full circle, a new technological discontinuity triggers the next evolutionary cycle[7].

Figure 3: Evolutionary Cycle of Technological Changes



Based on Anderson & Tushman (1990)

In their intriguing study on the hard disk industry, Christensen and Bower (1996) investigated how technological discontinuities come to maturity, i.e., in terms of Anderson and Tushman (1990), how a dominant design emerges. Disruptive innovations—as they are labeled by Christensen and Bower (1996)—are often cheaper, easier, or more convenient to use. Christensen and Bower (1996) describe the nature and evolution of disruptive innovations as follows: The technologies are first commercialized by new entrants, in many cases spin-offs of established incumbents, and initially only attract fringe customer groups due to their lower performance regarding traditional performance criteria (such as areal recording density in the case of hard disks). It is, however, important to note, that product performance and customer requirements on product performance often deviate for mature technologies. In other words,

[7] The discontinuous technological changes selected for this work are situated on different phases of this evolutionary cycle: Electronic toys and games were in a phase of incremental innovation at the time of this study. In the retailing industry, a dominant design for online businesses had already been established for most segments (except perishable food), whereas the publishing industry was amidst an era of ferment. The metering industry anticipated the emergence of smart meters as a discontinuous technological change in the close future.

the ‘old’ technologies already fulfill or even over-fulfill customer demands and sustaining innovations do not contribute to better customer satisfaction. Disruptive, initially inferior, technologies, however, typically improve their performance rapidly, thus meeting the customers’ performance requirements after a certain time span. At the same time, they are superior regarding new performance criteria, e.g., size, price, or convenience. Thus, after a given period of time, established customers will also begin to switch from the old technology to the new technology, i.e. from purchasing goods or services from the incumbent players to the new entrants (compare Christensen & Bower, 1996).

The above described evolution refers to successful discontinuous technological changes. As stated, for instance by Hill and Rothaermel (2003), however, it is difficult, if not impossible to assess the future success of a technological discontinuity *ex-ante*.

2.1.2 Organizational Adaptation to Discontinuous Technological Change

Although established companies vary in the ways in which they adapt to discontinuous technologies, they typically find it difficult to change internal processes and structures radically and, in turn, tend to respond sluggishly to discontinuous technological change (Christensen & Bower, 1996; Hill & Rothaermel, 2003; Miller & Friesen, 1980). This phenomenon has often been referred to as incumbent ‘inertia’ (Gilbert, 2005; Hannan & Freeman, 1984). In this respect, researchers have observed four specific dimensions of incumbent inertia that affect whether, when, and how incumbents adapt to discontinuous technologies: speed, intensity, stamina, and routine flexibility (Christensen & Bower, 1996; Gilbert, 2005). Scholars have identified a broad range of adaptation strategies, including but not limited to adoption[8], re-investment in current technologies, or retrenchment into niches (Ford & Baucus, 1987; Zammuto & Cameron, 1985). The following discussion of adaptation dimensions is tailored to the case of ‘adoption’ as this reaction type is specifically challenging for incumbent companies and is at the core of the innovator’s dilemma (Christensen, 1997).

[8] There is a fundamental difference between the terms ‘adapt’ and ‘adopt.’ According to Oxford Dictionaries, ‘adapt’ means “become adjusted to new conditions,” whereas ‘adopt’ means to “choose to take up or follow an idea.” Hence, adoption of discontinuous technologies refers to companies actively striving to commercialize the innovation. Adaptation to discontinuous change is more broadly defined, including adoption of the innovation but also non-adoption strategies such as retrenchment into niches (Ford & Baucus, 1987). For the sake of parsimony, the conceptual model of this thesis will focus on the link between family influence and adoption. The empirical parts, however, include cases of non-adopters and consequently, I will discuss other adaptation strategies wherever required.

2.1.2.1 Dimensions of Organizational Adaptation to Discontinuous Technological Change

Table 2 summarizes the definitions of and the previous scholarly work conducted on the four above-mentioned dimensions of organizational adaptation to discontinuous change. These dimensions will be discussed in more detail in the following subchapters.

Table 2: Dimensions of Organizational Adaptation

Dimension	Definition	Relevant Literature
Speed	Inverse of time lag between emergence of technological discontinuity and adaptation of the firm. Time is the sum of a) time until awareness, b) time for interpretation, c) time for decision-making, d) time for implementation	Gatignon, Robertson, & Fein, 1997; Golder & Tellis, 1993; Szymanski, Troy, & Bharadwaj, 1995; Tripsas & Gavetti, 2000; Tushman & Anderson, 1986
Intensity	Time-averaged amount of resources (financial, manpower, operational) committed to the technological discontinuity, as opposed to re-investment in the existing technology	Christensen & Bower, 1996; Gilbert & Newbery, 1984; Gilbert, 2005; March, 1991; Reinganum, 1983
Stamina	Degree of continued investment in the technological discontinuity as opposed to abandonment of the investment after initial setback	Block & MacMillan, 1985. Implicitly: Christensen, 1997; Gilbert, 2006; Suarez & Lanzolla, 2000; Tripsas & Gavetti, 2000
Routine flexibility	Degree to which established routines within the organization, i.e. processes, systems, structures, are replaced by new, non-paradigmatic ones	Feldman & Pentland, 2003; Gilbert, 2005; March & Simon, 1958; Tripsas & Gavetti, 2000

2.1.2.1.1 Speed

'Speed of adaptation' denotes the speed at which organizations recognize and interpret technological discontinuities, decide on the respective domain creation strategies (Ford &

Baucus, 1987), and ultimately implement competitive responses based on the discontinuous technology (Bower, 1986; Burgelman, 1983; Weick, 1995a).

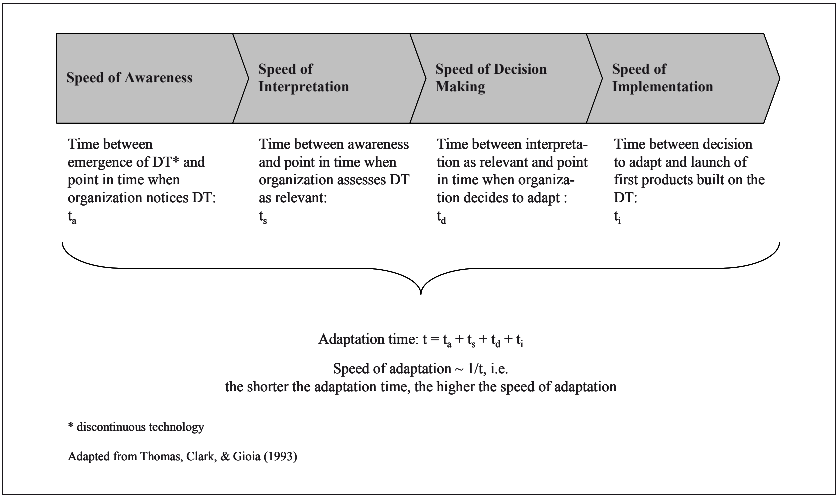
Figure 4 depicts the individual components of adaptation speed. First, organizational members need to notify the emergence of the new technology, which is frequently developed and first commercialized by new entrants outside the organizations' established networks (Rothaermel, 2002). Although scholars have emphasized the importance of early awareness as a competitive advantage (Chen, 1996), this section of the speed chain appears to be the least critical part when adapting to technological discontinuities. As Christensen and Bower (1996) highlight, not only are incumbent players frequently early aware of new discontinuous technologies; in many cases they even have prototypes ready but struggle with the further steps of adaptation such as interpretation, decision-making, and implementation. Second, organizations need to interpret these technological changes as relevant for their own business, despite potential performance disadvantages in early phases of the technological cycle (Christensen & Bower, 1996). Third, managers need to make the decision to adapt to the new technology despite potential uncertainties concerning the future market, and communicate those adaptation strategies throughout the organization. Fourth and last, the organization needs to implement, i.e., develop, produce, and sell products based on the new technology.

Researchers have found that established companies tend to react to technological discontinuities more slowly than new entrants (Gatignon, Robertson, & Fein, 1997; Golder & Tellis, 1993; Szymanski et al., 1995; Tripsas & Gavetti, 2000). Tushman and Anderson (1986) used the examples of the airline and cement industries to show how failure to timely adopt the new technology ultimately resulted in the loss of market dominance of incumbent players in those industries.

Despite this abundant empirical and theoretical evidence of late adaptation as a major impediment for successful adaptation, there is no *a priori* association between incumbents' early adoption of discontinuous technologies and adoption success (Lieberman & Montgomery, 1988; Suarez & Lanzolla, 2007). Suarez and Lanzolla (2007) theorize that the existence of a 'first mover advantage' depends on several firm- and industry-dependent factors such as the ability to keep up with steady product innovations, efficiency of patents, customer buying and switching behavior, and pace of market development. When "vintage effects" (Suarez & Lanzolla, 2007: 383) occur, late entrants might even enjoy competitive advantages as compared to first movers.

Not all incumbent players adopt a discontinuous technology. Instead, some of them—deliberately or unintentionally—retreat into niches, and engage in what Ford and Baucus (1987) describe as domain defense, domain offense, domain consolidation, or passive reactions. These organizations 'stop' at some point along the adaptation chain, mostly because they interpret the technological change as irrelevant, inferior, incommensurate with the incumbents' conceptions, or too resource or knowledge intensive. The following theorizing will focus on incumbents with positive speed (i.e. those adopting the new technology), the empirical part, however, will discuss several cases of businesses reacting passively (and thus at a 'zero' speed).

Figure 4: Speed of Adaptation



2.1.2.1.2 Intensity

'Adoption intensity' refers to the degree to which established organizations commit resources to the exploration of discontinuous technologies, as opposed to reinvesting in existing technologies and capabilities (Gilbert & Newbery, 1984). The term 'resources' thereby refers to financial investments ($R_{financial}$ in figure 5), manpower (including managerial attention; $R_{manpower}$ in Figure 5), and equipment utilization ($R_{equipment}$ in figure 5). Low resource commitment can either occur because managers decide to commit only few or no resources to the discontinuous technology during the decision-making phase or because, after an initial

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