ARTICLE IN PRESS

Technological Forecasting & Social Change xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

journal homepage: www.elsevier.com/locate/techfore

Disruption: Technology, innovation and society

Over the past few years, the concept of 'disruption' has become more and more popular. This special issue focuses on

1. the concept and terminology of disruption in relation to technology and innovation, including how to understand the level of disruption in specific instances
2. how disruptive technology diffuses from early leading-edge innovation through to widespread diffusion
3. the social impact and challenges of disruption, including the role of traditional and new media as well as the regulatory implications.

1. Disruption, innovation and technology

In this paper, disruption in the context of technology and innovation is defined as 'change that makes previous products, services and/or processes ineffective'. The implication is therefore one of discontinuity – previous technologies and/or ways of working are no longer viable. As discussed below, this is a wider view than that of Christensen (1997) who wishes to limit the use of the term 'disruption' to a specific mechanism and evolution path of innovation. It reflects wider definitions such as those in Tushman and Anderson (1986) on technological discontinuities and Danneels (2004) on disruptive technologies. The view taken here is that disruption is an outcome that can be measured not just by its process but by both its results and its process. Hence a major area of inquiry – represented by many of the papers below – is the nature of such disruptive outcomes and the processes by which they occur.

Disruption may be driven by a number of factors, of which five specific dimensions can be identified:

- *cost* – new technologies and/or processes make old ones uncompetitive in terms of production cost, as the new ones are so cheap that old ones become unprofitable
- *quality* – new technologies and/or processes raise the quality of products or services to a level that makes the old ones uncompetitive
- *customers* – significant changes in consumer or business customer preferences make previous products or services unattractive relative to new ones
- *regulation* – new laws or regulations no longer permit old ways of working, for example environmental or labour protection regulations designed to improve social conditions
- *resources* – previously important resources are no longer readily available for a variety of reasons ranging from exhaustion of natural resources to trade blockades.

In practice, these factors overlap. For example, the combination of changes in cost and quality may significantly change the *value for money* of existing products or services relative to new ones, for example much higher quality at little extra cost or much lower cost with little perceived reduction in quality.

This can be seen in the changing technologies in the recorded music industry. Initially digital recording technologies enabled higher *quality* through CDs relative to vinyl records and audio cassettes. Quality increased through greater durability relative to vinyl and both sound quality and durability relative to audio cassette. Then the *cost* of equipment able to provide high quality playback reduced as CD technology rapidly reduced in price. Industry leadership in terms of technology moved from Sony to Philips, as 'Walkman' technology was replaced by 'Compact CD'. Subsequent development of compression technologies, especially MP3, enabled further change. Other developments in digital technology and the internet allowed further miniaturisation of standalone playback devices and close to zero marginal cost distribution of digital music – further *quality* and *cost* changes. In practice *consumers* chose lower quality MP3 technology over higher quality CD because of its convenience and, for most consumers, the lack of perceived difference between the two. These changes in turn led to further disruption in the recorded music industry.

Disruptive innovation and disruptive technology also need to be differentiated. In line with widely accepted definitions of innovation, disruptive innovation is defined here as the commercial introduction of product, service, process and/or organisational change that disrupts the activities of existing players in an industry or similar organisational system (e.g. a part of government). This disruptive innovation can be at a variety of levels:

1. *Industry segment*, for example in recorded music playback devices, disruption to the industry segment of cassette tape head production
2. *Industry structure*, for example record companies owning musical content (with core activities such as 'A&R', the finding and contracting of 'artists

https://doi.org/10.1016/j.techfore.2017.10.020

and repertoire') no longer controlling distribution as it moved from physical CD to digital download
3. *Social system*, for example the ability of new artists to make their own commercial quality recordings at lower cost and distribute them through new digital channels and social media, thereby changing social relationships in the music industry.

Disruptive technology can be defined as technology with the *potential* to create disruptive innovation at any of these levels. As a result, a key question that several of the papers in this special issue address is whether it is possible to identify *in advance* whether a technology is disruptive in the sense that it will in practice be the foundation of disruptive innovation. In our view, this correctly places the focus on the challenge of predicting with a high degree of certainty the emergence, level and timing of disruption, seeing the problem of identifying potentially disruptive technologies as less important. This is for several reasons:

- First, the future development path of a technology is uncertain, especially in its early stages or if it hits significant problems in its technological development. A classic example is commercial nuclear fusion, which has been seen for decades (since the 1950s) as a disruptive technology in electricity generation with the potential to produce electricity at low *cost* and to remove the *resource* constraints of fossil fuels as well as the waste associated with nuclear fission power generation. According to *Encyclopaedia Britannica* (2017), "Commercial fusion reactors promise an inexhaustible source of electricity for countries worldwide". Yet while nuclear fusion has been a disruptive technology in the military sphere through nuclear weapons, commercial nuclear fusion has proved hard to develop and hence not yet led to disruptive innovation.
- Second, beyond the impact on an industry segment, disruptive innovation typically involves many disruptive technologies which together enable disruption of industry structure, perhaps accompanied by substantial product, service process and/or organisational innovation. Impact at the level of the social system requires both these and social, political and/or cultural factors. In the recorded music example, it was a combination of disruptive technologies in recording, distribution and playback that created disruption in industry structure. Further, social factors such as relaxed public attitudes towards copyright and intellectual property enabled free music sharing sites such as Napster to force much more rapid change on the music industry than was desired by most industry players.
- Third, as discussed in the papers by Zhukov, Khvatova, Lesko & Zaltcman and Nieuwenhuis, Ehrenhard & Prause, the diffusion of disruptive innovation is more complex than is often assumed, especially in retrospect. Early versions of disruptive technology often have significant flaws that limit their adoption. On the one hand, there may be regulatory uncertainty or prohibition of disruptive technologies in some cases, whereas in other cases there are regulatory gaps that enable accelerated diffusion despite creating social issues which most would see as requiring regulation. An example is the rapid spread of bike sharing services in China, such as Mobike and Ofo, enabled by smartphone apps linked to digital cycle locks, which meant that shared bikes were no longer stored only at fixed docking stations, but could be reserved, collected and left anywhere in a target city. The growth of these services was very rapid from 2016 – for example just one leading operator Ofo is reported to have "6.5 million bikes in 150 cities" (Bloomberg, 2017) while Shanghai alone has an estimated 450,000 bikes in total. The first government regulations were introduced in December 2017 in Shenzhen which by then had 120,000 such bikes on the streets under a year after its launch (Chai, 2016). After many years of declining bike use, the disruptive innovation of new bike rental services reversed this trend, meeting consumer demand for low cost personal urban transport. But at the same time, it created issues including uncontrolled bike parking and consumer protection for the cash deposits taken by the bike sharing companies.

This last example is also an example of how rapid the rate the diffusion of disruptive innovation can be. It has been estimated that these bike-sharing services have doubled the proportion of urban transport undertaken by bike in under two years (Mobike, 2017). Social and environmental change includes the following: halving the use of personal and hired cars by shared bike users; 70% of unlicensed drivers seeking other jobs in an affected neighbourhood; and a (hypothetical) reduction of carbon emissions by 540,000 tonnes (Mobike, 2017). Such rapid diffusion is part of a general trend of acceleration in the rate of new product diffusion (see for example McGrath, 2013; Van Den Bulte, 2000). This poses the question of how disruptive innovations are diffused.

2. Mechanisms of disruption

The dominant model of diffusion of innovation assumes a normal curve (Meade and Islam, 2001, 2006) with the rate of adoption following a normal distribution: slow at first, then accelerating, peaking and declining as the innovation is universally adopted. Typically, it identifies five groups,

1. innovators
2. early adopters
3. early majority
4. late majority
5. laggards

Rogers (1962a) summarises the origin of the approach which by that date had led to 262 research publications on diffusion of innovation within rural sociology. First, they found that innovators moved from awareness to interest followed by evaluation, small scale trial and then full adoption. Second, the rate of adoption was seen to follow a normal distribution giving remarkably precise, mathematically derived figures; innovators comprising 2.5% of the relevant population, 13.5% early adopters, 34% each for early and late majority, and 16% for laggards. The approach was popularized in the area of technology-based innovation starting with Rogers (1962b).

While the overall viewpoint of diffusion theory is widely accepted for innovations which become dominant, its predictive value can be challenged, especially for disruptive technology. For example, Moore (1991) identified a 'chasm' between the first two groups and the majority (both early and late) that led to the stalling of innovation adoption. As argued in the paper by Laurell & Sandström the role of the media is important as well as the underlying progress of a disruptive technology and associated innovations. A perspective linked to media coverage that seeks to explain why apparently disruptive technologies do not have the impact initially foreseen has been termed the 'hype cycle' by research company Gartner (Fenn and Raskino, 2008). This identifies stages in perceptions of technologies that have the potential to enable disruptive innovation: