Disruption Versus Discontinuity: Definition and Research Perspective From Behavioral Economics

Esteban Fernández, Sandra Valle, and Guillermo Pérez-Bustamante

Abstract—**This paper promotes a new academic research perspective for the analysis of industrial innovation and technological development. Specifically, it aims to apply the prescriptions of behavioral economics to conjecture, which can be the result of the battle between the firms established in a mainstream market and their disruptive or discontinuous attackers. Sometimes, differentiating between disruption and discontinuity can be misleading. Therefore, the paper proposes a definition of disruptive technology that clearly sets its necessary and sufficient conditions. This definition expands Christensen's—the pioneer and the driver behind the concept of disruptive technology—opening it to include additional casuistry. It also causes the elaboration of an additional graphic representation. This paper contributes to the academic field in several ways. First, it facilitates the understanding of a very confusing concept that results from an inconsistent use of the term in the literature. Second, it proposes a new research perspective that, in addition to explain the existing and sometimes surprising empirical evidence, also opens novel and numerous future research avenues. The contributions for business practice are the recommendations that managers can derive to improve their decision making processes related to the potential attacks of emerging technologies, differentiating between disruptive and discontinuous technologies.**

Index Terms—**Engineering management, business management, research and development management, technology management.**

I. Introduction

In the past two decades, the study of discontinuous and disruptive technologies has occupied a privileged space in the literature [1], [2], [3], [4]. Both technologies are radical product innovations that attack the dominant technologies in their mainstream markets. The difference lies in the fact that discontinuous technologies get started in the mainstream market, while disruptive technologies get started in an emerging or insignificant market. In both cases, there is a breach in the trajectory of the dominant technology. This occurs because both the dominant technology and the emergent one (either disruptive or discontinuous) are leveraged by different knowledge bases [5].

There is a large unanimous agreement about what discontinuous technologies are [6], [7], while disruptive technologies are characterized by a lack of understanding that leads to multiple interpretations, thus creating difficulties to define them [1], [2], [8]–[15]. Therefore, one of the objectives of this paper is to clarify what is meant by disruptive technology. Toward that end, we propose a definition that clearly delimits the necessary and sufficient conditions to consider a technology as disruptive. This definition should be seen as an extension of Christensen's approach, who initially coined the term disruptive technology in his seminal works [16]–[18], and of other scholars' proposals [11], [13], [19]. Besides enlarging the casuistry of prior research on disruption, our perspective conduces to a novel and additional graphic representation of disruptiveness that complements Christensen's and becomes another contribution of the paper.

Additionally, extensive evidence shows that established companies do not respond the same way to the attacks of disruptive and discontinuous technologies. While they are successful in their response to the attacks of discontinuous pioneers, they are usually incapable to react successfully to the attack of disruptive pioneers [16]–[18]. The reason for this evidence is still an unresolved matter, which this paper also attempts to settle. To do so, the tenets of behavioral economics are taken into consideration [20], [21], developing a novel research approach in the fields of industrial innovation and technology development. Therefore, another contribution of the paper is the new research approach built applying the rules of behavioral economics to the study of technology.

To fulfill the proposed objectives, the paper is structured as follows. First, we present the theoretical background on disruption and discontinuity, delimitating them. Second, we propose a definition of disruption that clearly specifies its necessary and sufficient conditions and its casuistry. Third, our proposed conjecture to explain the success of disruptive pioneers and the failure of discontinuous pioneers is supported. Fourth, the contributions and implications of the paper are presented, ending up with the limitations and future research proposals.

II. Discontinuity Versus Disruption: General Overview

Although it is part of the general appreciation of technology to be the application of scientific—or other organized—knowledge to practical tasks, in this paper, we assume a more restricted approach identifying technology only as a Schumpeterian combination (a platform or an architecture); that is, as a new assembled product made up of several components. Therefore, independently of the functional area where they are developed, we do not consider nonassembled product innovations, such as chemicals or pharmaceuticals, productive processes, or other

Manuscript received September 11, 2018; revised November 23, 2018; accepted December 9, 2018. Date of publication January 10, 2019; date of current version July 16, 2020. Review of this manuscript as arranged by Deparment Editor T. Daim. *(Corresponding author: Sandra Valle.)*

The authors are with the Facultad de Economía y Empresa, Universidad de Oviedo, 33071 Oviedo, Spain (e-mail: esfernan@uniovi.es; svalle@uniovi.es; gperez@uniovi.es).

Color versions of one or more of the figures in this paper are available online at http://ieeexplore.ieee.org.

Digital Object Identifier 10.1109/TEM.2018.2889160

radical innovations [22]. Business model innovations are not considered at all. We use the term "emerging technology" to describe a new combination regardless of whether it is being introduced in a niche or directly into the mainstream market. If the technology has triumphed in the market, we refer to it as "dominant technology." Should the core product need a complementary product in order to be used, we will also include it in our concept of technology. Finally, we also consider that, in order to meet the needs of the market, a technology might have to provide several dimensions of performance (or performance metrics). To simplify matters, in this paper, we summarize these dimensions in just two dimensions: a primary and a secondary (or ancillary) technological dimension. The primary dimension represents the technological provision that main customers care about and which incites them to buy a certain product. The secondary dimensions refer to other technological features of the product also expected by the customers. They do not contribute to improve the competitiveness of the company; though, if these basic technological requirements are not present in the product or are present at unsatisfactory levels, they lead to a competitive disadvantage. From now on, in order to simplify the arguments, we will mention just one secondary dimension (which would encompass all of them).

A mainstream market is a very profitable market. It is characterized by the existence of a dominant technology that supports assembled products with clearly defined dimensions of performance, so the differences between competing brands are less relevant than their similarities. However, in order to not be overtaken and lose market share, established firms strive to continue improving the performance dimensions and the effectiveness of the dominant technology. The requirements of the mainstream market in the primary dimension of performance increase over time. Therefore, established companies must improve the performance of the product in that dimension. Competition among companies is fierce because there is a fear that if a competitor manages to offer a higher value in this primary dimension, it will attract the customers from those established companies that have not improved it [23].

The mainstream market can be attacked by a discontinuous technology (or radical sustaining technology as termed by Christensen [18]). When an emerging technology consists in radical improvements in the primary technological dimension and the emerging technology attacks directly the mainstream market, a discontinuity occurs. If a technological trajectory is represented by an S curve [24], [25] that relates in the x-axis (abscissa), the time elapsed (rather the investments or effort made over time to improve the product), and in the y-axis (ordinate), the technological development (or dimension of performance), a discontinuous technology would be represented by a pair of intersecting S curves in the first quadrant of a Cartesian coordinate system. In fact, the gap between both curves represents the technological discontinuity: a nonevolutionary change [6]. When the discontinuous technology is introduced to the mainstream market, the dominant technology shows better performance metrics in the primary dimension, though it has a minor potential for future improvements. The discontinuous technology also has an intrinsic superior technical limit [26]. At some point in time, the performance of the discontinuous technology in the primary technological dimension will exceed that of the dominant technology making the customers shift to the discontinuous technology [6], [27], [28].

As it has been pointed out, discontinuous technologies attack the mainstream market directly. They do so by using a new technology on a small scale, which occurred when the manufacturers of artificial ice attacked the natural ice collectors, who had hoarded until then the entire ice market [28]. They can also attack the market on a large scale and abruptly, such as when IBM attacked the manual typewriter market with the electric machine [29]. In both cases, the attacking technology had no previous application in a niche or in a related market and represented a technological discontinuity: a great leap forward, and not an evolution of the technology in use [7].

The mainstream market can also be attacked by a disruptive technology, which is a widely confusing term. Among other reasons, this confusion is due to the fact that many authors currently apply the qualifier "disruptive" to a product technology—as it was in its origins, but also use it as a synonym of radicalness [30] for different business functions and fields of application [31], including business models [12], [32]. In fact, as Thiel and Masters pointed out, the disruption has recently transmogrified into a self-congratulatory buzzword for anything posing as trendy and new [33]. As a result, some scholars consider Uber's technology as disruptive [34] and others as nondisruptive [35].

Disruptive technology was a concept initially conceived to refer to any new technology that, relatively to the dominant one, is more performant in the secondary dimension and less performant in the primary one. Since its primary dimension does not satisfy the needs of the mainstream market, the established firms reject their use. However, the set of performance attributes provided can fully satisfy the needs of another segment, the one at the low end of the market (low-end disruption) [16], [18] or of a new market segment (new market disruption) [32]. Over time, the emerging technology (also conceptualized here potentially disruptive technology as Sood and Tellis named it [13]) will improve in this segment all its dimensions of performance, including the primary one. Once the technological advances drive improvements in the primary technological dimension beyond the baseline satisfactory levels required by the mainstream customers, the potentially disruptive technology will invade the mainstream market (becoming at that moment a disruptive technology). In other words, to be viable in the mainstream market, the emerging technology must surpass the functionality threshold that the existing customers in this market require for the primary technological dimension. When that occurs, the potentially disruptive technology becomes a disruptive technology.

Christensen's approach to the disruptive concept can be summarized in three determining characteristics [11], [19], [35]. The first characteristic refers to the technological development itself. In its initial stage, the emerging technology (potentially disruptive) is inferior to the dominant technology on accepted performance dimensions; therefore, it is simpler and cheaper than the dominant one. This technology also shows an uncertain future and lower profitability. The mainstream market rejects it because this technology does not provide a satisfactory performance in the primary technological dimension. The established companies consider this technology to be adequate only for limited applications that their current customers do not require, appreciate or value. Additionally, its potential for future improvement is unclear. Thus, the technology may disappear in the medium-term before any significant achievements can occur and without having had the chance to be implemented in the mainstream market. Sometimes, the emerging technology does not transcend beyond the niche it supplies, remaining disconnected and isolated from the other products in the mainstream market (in an island of application) [36].

The second characteristic refers to the fact that those firms that challenge established large companies are small and migrate to the mainstream market from low-end or new market footholds [35].

The third and most distinctive characteristic refers to the variations on the basis of competition by changing the performance metrics along which firms compete [9]. When the disruptive technology emerges, the users start to value the provision of the secondary technological dimension in the products already being offered in the mainstream market. Relative to a disruptive technology, the dominant technology can provide, neither at that moment nor in the near future, the same performance level for the secondary dimension. As a result, the secondary dimension becomes an insurmountable competitive disadvantage. Consequently, the secondary technological dimension becomes a competitive advantage for the new entrants into the mainstream market and a competitive disadvantage for the established companies. Competition displaces to the secondary dimension of performance.

Therefore, relative to a disruptive technology, the dominant technology maintains a superior performance in the primary technological dimension, sometimes leading to a performance oversupply for which customers are not willing to pay [18]. In this dimension, the disruptive technology improves at a parallel pace, though below the dominant technology, so that their technological trajectories do not intercept. Therefore, it is not necessary to wait for the intersection of the primary dimension of the two technologies, but to determine and foresee if the technological needs of the market are going to change, resulting in the primary dimension being displaced by the secondary dimension as the main technological priority. This change will occur when the primary dimension of the potentially disruptive technology advances along a trajectory that drives improvements above and beyond the needs of the mainstream market. The graphic representation of Christensen's model in a Cartesian coordinate system (see Fig. 1) implies the existence of 1) two curves of technological development. In order to simplify the graph, Christensen depicts them as two positive sloped and parallel straight lines representing in the x-axis (abscissa) the time elapsed, T, and in the y-axis (ordinate) the primary technological dimension, P–. 2) One straight line that represents the evolution of the technological demand of the mainstream market, M.

As seen in Fig. 1, the line representing the evolution of the technological demand of the market, M, initially has a lower slope than the line representing the disruptive technology, A, so it evolves always below the line representing the evolution of the dominant technology, D, and above the line representing the potentially disruptive technology. In its origins, the disruptive technology is introduced in a niche market, N, and evolves in it until a matching point, 0, when the potentially disruptive technological curve reaches performance metrics above and beyond those required by the technological demand of the mainstream market. Thus, it becomes a disruptive technology.

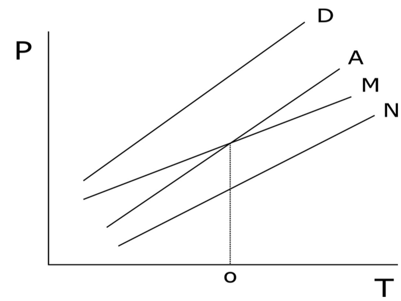

Fig. 1. Technological disruption originating in the low end of the market or in a new market [18].

In short, the discontinuous technology attacks the dominant technology, significantly improving the performance of the primary technological dimension by a 10 X factor as proposed by Grove [37]; that is to say, multiplying by 10 the actual performance level of the dominant technology. The disruptive technology attacks the dominant technology being less performant in the primary dimension, though exceeding the needs of the mainstream market. Once the mainstream market customers have satisfied their needs in relation to the primary dimension, they will start valuing the performance provided by the secondary dimension. The secondary dimension becomes the new technological priority while the primary dimension becomes a constraint to compete. The preferences for the technological dimensions are displaced. Then, a technological disruption occurs.

III. Proposal of a Definition of Disruptive Technology and Casuistry

According to the original concept of disruptive technology, as pointed out by Danneels [9], it seems clear that a disruptive technology is a technology that changes the bases of competition by modifying the performance metrics along which firms compete. The displacement in the performance metrics is a necessary condition for a disruptive technology to emerge, but it is not an entirely sufficient predictor because a technology could displace the metrics without being disruptive. An example was IBM's introduction of the electric typewriter (which we consider a discontinuous technology) in the mechanical machines market (the dominant technology at the time).

As the sufficient condition, we propose that before attacking the mainstream market, the potentially disruptive technology must have already been commercialized in another segment. This delimitation allows for broadening the field of application of the original concept of disruptive technology. On one hand, relative to the dominant technology, the disruptive technology at its beginning as a potentially disruptive technology may provide a low end or high end value and, therefore, might lead to lower or higher prices. On the other hand, there are no restrictions to the fact that the disruptive technology may be introduced by any kind of company: small or large, national or foreign, new or established in the main market. In fact, alternative works to Christensen's have extended the origin of the disruptive technology to the high end of the market (with higher performance features and prices) [11], [13], [19], thus considering that the large firms established in the mainstream market could introduce a disruptive technology as well as the small companies. Likewise, other studies consider that reverse technologies, which originate in the subsidiaries of multinational companies, can also be the origin of a disruptive technology [38].

Consequently, in this paper, we consider, and thus propose it as a definition, that a disruptive technology is a technology that attacks the mainstream market from a niche or market (national or international) where it has been developed, with the results of displacing the technological performance metrics along which established firms compete.

Our consideration of a disruptive technology does not contradict Christensen's original proposal. Instead, it broadens it, clarifying which are the necessary and sufficient conditions to consider a technology as disruptive. The definition provided helps to differentiate disruptive technologies from discontinuous technologies. In addition, it enlarges its application from small firms in a niche to cover all the casuistry of a disruptive attack, large or small firms and attacks originating in the high or low end of the market, or even in the mainstream market itself. The sufficient condition proposed also constitutes an ideal starting point to conjecture on Christensen's finding of why established companies are incapable to react successfully to the attack of a disruptive technology while they are successful in their response to the attacks of discontinuous technologies.

Before building this conjecture in the following section, we will conclude this section presenting evidence of disruptive technologies that evince some of the mentioned casuistry, especially that uncovered by Christensen´s approach. So, as an example, the evolution of insulin in the emergence of modern recombinant DNA biotechnology provides us with a salient example to describe a disruptive technology introduced in the mainstream market by an established company that was losing the battle. Historically, insulin was obtained from animal sources: the pancreas of cows and pigs. Most innovations during the 20th century were intended to increase the purity of insulin (primary technological dimension). Eli Lilly, the leading manufacturer of insulin in the world, was the main contributor to reduce the impurity levels from 50.000 parts per million (ppm) in 1925 to only 10 ppm in 1980 [39].

Despite the purity levels, which Eli Lilly had been able to achieve, animal insulin still differed somewhat in effectiveness from human insulin due to insulin structure varying slightly between species. Therefore, Eli Lilly cooperated with Genentech to produce human insulin in large quantities by recombinant DNA techniques. After investing almost $1 billion in the effort, Eli Lilly obtained a product, which was superior to other insulin products in the mainstream market. It marketed its innovation under the Humulin trademark. However, sales growth was disappointingly slow. Most insulin patients were not willing to pay more for insulin that, despite being technically superior, did not have a major impact on the conditions of their treatment.

Meanwhile, a small Danish insulin manufacturer, Novo Nordisk, identified a new dimension of performance for the mainstream market: comfort (secondary technology dimension). The company created a dispenser or insulin injection pen, which simplified the application of insulin for diabetic patients. Traditionally, diabetic patients had to carry a syringe with them, load the precise amount of insulin from a small blister, hold the needle, and squeeze the syringe several times to remove any remaining air bubbles. They usually had to repeat this process to load a second type of insulin from a different blister.

Novo Nordisk's injection pen greatly simplified the process. It had a cartridge that contained a mixture of two types of insulin and the users only had to turn a small dial to determine the amount of insulin they needed to inject, place the injection pen on the skin, and press a button. Diabetic patients, who used insulin every day or even several times a day, considered this improvement in efficiency an important advance. Novo Nordisk was able to increase its selling price per unit of insulin by 30%. The success of the insulin injection pen and the prefilled cartridges helped the company increase its global market share substantially and profitably. Both Eli Lilly and Novo Nordisk had met the needs of the main market in terms of insulin purity (primary technological dimension). The regulators had ensured the reliability of their products. Once the consumer's need for purity had been satisfied, the key competitive aspect shifted to comfort (secondary technological dimension), and the company that had provided a more practical product, easier to use while still being safe, benefited.

Contrasting with the minority disruptive attacker, there are the disruptive majority attackers. These companies are established in a consolidated, adjacent, and related market and they exploit the transversal properties of the technologies they operate with in order to invade the mainstream market of a dominant technology. A clear example is that of Wilkinson. In 1962, Wilkinson applied its knowledge of stainless steel technologies, which was currently being used to manufacture swords and household appliances, to start producing razor blades. Wilkinson overtook Gillette, which, although it knew about this novel technology, it did not want to cannibalize its very profitable carbon steel blades market. In this case, the established company was not defeated, but Gillette suffered a significant fall in its market share from 72 to 50% [40]. Furthermore, Wilkinson entered the razor market and remained there. This disruptive majority attacker developed and successfully applied its technology into a related market. When Wilkinson observed that an already tested and experienced technology could easily be applied to the mainstream market, it quickly moved into it with the aim of conquering it.

Another interesting situation arises when the disruptive majority attacker is already operating in an emerging country. There it develops the technology for an unserved market segment and finally attacks the main market. For example, at the end of the 1950's, Honda entered the United States with one of its great Japanese sales successes, the 50cc Super Cub motorcycle. Unexpectedly, Honda could only serve a market niche, which had not aimed for: those Americans who had never owned a motorcycle and wanted one for short journeys within the city. This was considered an unprofitable segment and had remained unserved by the large firms in the sector, which were focused on the very competitive and profitable market of motorbikes for young gang members who used them for very long journeys [41].

On other occasions, a multinational develops a reverse technology for an emerging country and, once it is successful, it is commercialized back into its country of origin, even finding new applications. This would be the case of General Electric, which designed low cost and portable electrocardiogram and ultrasound machines for the rural Asian market. The priorities were price and portability. Subsequently, General Electric ended up selling these items in the United States for those market segments for which portability is important, such as emergency teams that provide assistance in traffic accidents [42]. Little by little, they have been taking over the mainstream market.

A disruptive technology can also be introduced from the high end of the market by a company already established in the mainstream market, though in the future, it may cannibalize the dominant technology. Initially, Nespresso commercialized espresso coffee as a gourmet product, targeting 35–45 years old, high-income professionals. Finally, it entered the main market of consumer households [43]. Handheld electronic scientific calculators are also a good example of a disruptive technology initially characterized by high technological features though very expensive to buy. However, in a very short period of time, price reductions made slide rules obsolete, relegating this most common used calculation method tool to pieces of collection in museums [11], [28]. The latter examples refer to technologies that are more expensive and complex than the dominant one, and thus, have higher selling prices.

When the attack originates in the high end of the market, as it occurred in the above-mentioned examples, relative to the dominant technology, the disruptive technology provides competitive parity for the primary technological dimension and excelling superiority for the secondary one. However, the cost/price ratio is very high for the mainstream market, which rejects it. At some point in time, the improvements in the potentially disruptive technology (which tend to affect the process) reduce the cost/price ratio to acceptable levels for the main market. Then, the disruptive technology can successfully invade the mainstream market, thus displacing the technological performance metrics. Relative to the dominant technology, the offer of the disruptive technology for the mainstream market is not only superior and distinctive for the secondary technological dimension, but also reasonably priced and at acceptable levels for the mainstream market.

If, analogically to Christensen's graphic for disruptions originating in the low end of the market (presented in Fig. 1), we represent graphically this situation for disruptions originating in the high end of the market, we get Fig. 2.

Relative to the dominant technology, the graph in Fig. 2 shows that the disruptive technology presents a higher cost/price ratio until moment of time 0, (in this case, P, measures the cost/price ratio of the secondary technological dimension). From

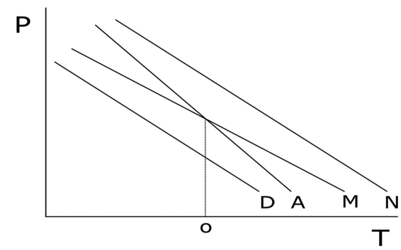

Fig. 2. Technological disruption originating in the high end of the market.

the moment of time 0 onwards, the cost/price ratio becomes at reasonable levels for the mainstream market, though it is still superior to the cost/price ratio of the dominant technology. However, at this point of time, the market starts valuing the performance of the disruptive technology, which will finally displace the dominant technology.

Figs. 1 and 2 complement each other to explain the evolution of disruptive technologies.

IV. Success of Disruptive Pioneers Versus Failure of Discontinuous Pioneers: A Conjecture Based on Behavioral Economics

There is empirical evidence that sustains that most established firms are pushed out of their market when a disruptive technology is introduced by new companies [18] although established firms continue to outperform the new entrants when it comes to discontinuous technologies [18], [44]. This surprising evidence can be explained through the lens and prescriptions of behavioral economics.

According to Gilbert [45], assigning resources to develop a technology is dependent on it being perceived as a threat or an opportunity. The conjecture that we propose is that established companies perceive discontinuous technologies as threats of losses (a reduction in the revenues due to some customers of the dominant technology adopting the discontinuous one) while the same companies perceive potentially disruptive technologies as opportunities for gains (an increase in the revenues due to getting new clients in underserved segments). Following Thaler [46], we consider that, despite the fungible nature of money, firms perceive independently the reduction in revenues of the dominant technology and the increase in revenues of the potentially disruptive technology. Additionally, taking into account Kahneman and Tversky's works [47], in absolute terms, psychologically losses are twice as powerful as gains, [48]. Therefore, people pay more attention to what can be lost than to what can be won [49]. This behavior is related to the endowment effect [50], which refers to the greater suffering experienced by people when they lose something they already possess, as opposed to the pleasure felt when they receive or win that thing. That is to say, people value more what they already possess than what they do not yet possess. This is valid even in the case of the expected outcomes being the perception of a reduction in revenues from those clients moving to the discontinuous technology, relative to the perception of an increase in revenues from those new clients adopting the potentially disruptive technology. This overvalued perception of a potential loss encourages established companies to react as quickly as possible to face the attacks of a discontinuous technology. Meanwhile, in the case of a potential disruptive technology, the lower perception of the value of additional gains leads them to remain stuck with their *status quo*.

In short, the loss of some of their clients makes managers perceive the discontinuous technology as a menace, so they concentrate their efforts and resources on the defense of their mainstream market customers [32]. Therefore, they react quickly to discontinuous technologies and, since they usually have abundant technological capabilities and possess complementary assets, they can easily outperform new entrants. Although the established companies have not been the pioneers in the market with the discontinuous technology, they usually win the battle [18], [44].

The opposite occurs with the potentially disruptive technologies. While they are being developed, the established companies perceive them as an uninteresting opportunity outside their mainstream market [51]. With their prospects for potential revenues being unclear and, in any case, less attractive than those of the dominant technology, it is difficult to justify any additional investments in the disruptive technology under the criterion of return on investment [28]. The Weber–Fechner psychophysical law can also explain this behavior as it states that the minimum perceptible difference is proportional to the original intensity of the stimulus. Therefore, the more intense the stimulus, the larger the difference in absolute terms should be to be capable to perceive something [20]. Any additional revenues of the disruptive technology are thus perceived as insignificant. On the other hand, the "certainty effect" also plays a major role because it prescribes that the relatively safe returns derived from investing in sustained improvements in a dominant technology in the mainstream market are more highly valued than the risky investments in a potentially disruptive technology [52]. Therefore, established companies prefer to prioritize their existing customers by concentrating on the dominant technology, which continues to provide great revenues [51].

Until the potentially disruptive technology enters the mainstream market and becomes a disruptive technology, the established companies do not consider it a menace. What happens then? Supposedly, when the disruptive technology attacks the mainstream market, it is in the initial stage of the "specific phase" of Abernathy and Utterback's innovation model [53]. In this phase, there are important economies of scale and a powerful experience effect. That is to say, in its original market, the disruptive attacker has developed first a radical innovation in the product and then the subsequent radical innovation in the process. As a result, when it attacks the mainstream market, its product and process technologies are co-specialized [54], which favors greater productivity [55] and represents a devastating competitive force.

The dominant technology is in the final stages of the "specific phase" with a co-specialized product and process technology as well. However, the disruptive technology is supported by a different and incompatible technological trajectory than the existing dominant one [44]. Being co-specialized, the product and process technologies are so integrated that any minor change in the architecture of the product implies undertaking significant and expensive changes in various elements of the process [53]. The same occurs with any improvements in the process and its effects on the product. There might also be previous commitments with suppliers or clients, as well as a high dependence on the technological trajectory [56], [57]. These circumstances reduce the flexibility of established companies to react to the attack of a disruptive technology.

In addition, the attack of a disruptive technology is very fast [58] and the technological priority is abruptly displaced. Established companies are also affected by time compression diseconomies [59]. These make it difficult to efficiently imitate a technology in a short period in spite of the resources and investments devoted to its development. Although product innovations can be easily replicated in a short period through reverse engineering [60], this is not the case for radical process innovations. Processes are characterized for being more complex, for being invisible in the market, and for relying partially on tacit knowledge. The combination of these characteristics makes it more difficult to imitate a radical process than a product [28].

The disruptive attacker interconnectedness of technological and social, tangible and intangible assets also plays against the established companies [59]. The disruptive attacker enters the mainstream market with a technology already tested in a market, therefore knowing the appropriate qualities and costs. During its development process, it might have relied on external manufacturers and suppliers of complementary products and assets and thus might have been able to establish alliances, joint ventures or sign exclusive cooperation agreements with the innovation complementors [54], [61]. When the established companies try to react to the attack, they may not find any allies or suppliers for the necessary inputs, products, and complementary assets. Developing them internally is not an option because it would require large investments and, above all, a lot of time and a specialized knowledge base that these companies might not possess. It must also be borne in mind that customers tend to be loyal to their first brand and that the pioneer has been able to build a good reputation that contributes to better lever, establish and defend its position in the main market [62].

It is worth mentioning that the disruptive attacker assumes twice the role of a pioneer: initially, when it commercializes for the first time the potentially disruptive technology and then, when it introduces the disruptive technology in the main market. In the second case, the previous experience of being a first mover in another market contributes to avoid repeating the same mistakes again. The chasm has been crossed [25] and satisfying early adopters' needs is no longer the objective, with the new focus being the early majority's needs. This requires adopting changes in both the organizational structure and the competitive strategy and, consequently, in the functional strategies [45]. The time interval between both pioneering roles of the disruptive attacker is a blind spot for established firms that reject the potentially disruptive technology due to its marginal revenue stream and, above all, because their mainstream customers also reject it.

All the above-mentioned circumstances are a direct consequence of how pioneers and incumbents make use of the time elapsed while the potential disruptive technology was developed: "lost" time to adjust by the incumbent firms and "won" time to experiment by the pioneers. These circumstances create difficulties for established companies to imitate the potentially disruptive technology soon, in spite of their large resources. That is to say, the sufficient condition for a technology to be considered as disruptive (be previously commercialized in an alternative market) also favors its success and vanquish the established firms, expelling them out of the main market.

V. Contributions and Implications

This paper presents two main contributions. First, it improves our understanding of the concept of disruptive technology. It contributes to clearly delimitate the sufficient and necessary conditions for an innovation to be considered a disruption. This conceptual delineation extends Christensen's traditional and seminal definition, enlarging the origins of a disruptive technology to other market segments not considered by him, such as high end of the market customers or reverse technologies. The proposed definition also allows for inferring that any type of company, large or small, new or established, national or foreign, can introduce disruptive technologies. Likewise, it makes it possible to clearly differentiate a disruptive technology from a discontinuous one. The paper also provides a novel graphic representation for the proposed definition, which complements Christensen's classical and largely accepted representation.

Second, on the grounds of behavioral economics, this paper explains how established firms in a mainstream market react to the frequent attacks of emerging technologies (either discontinuous or disruptive). Thus, the second contribution of the paper is the enlargement of the traditional research perspectives in the literature on industrial innovation and technological development with a novel research focus, incorporating the contributions of behavioral economics.

This perspective leads us to build a conjecture to explain why established firms in the mainstream market cannot successfully confront the attacks of disruptive pioneers, while they are successful to confront the attacks of discontinuous pioneers. Applying the principles of behavioral economics leads to the reflection that established companies underestimate a potentially disruptive technology when they discover it, while, on the contrary, they react quickly to a discontinuous technology. By not perceiving the potential disruptive technology as a relevant menace, but as a marginal opportunity, these firms do not react to the pioneer's introduction in a market segment or niche away from the mainstream market. This initial absence of reaction gives the pioneer time to successfully develop and test its technology. When this technology finally enters the main market, it does so with a productive process co-specialized to the disruptive product, which gives it a competitive advantage that is difficult for established companies to match. In addition, the pioneer can exploit the experience and advantages acquired as a *first-mover* [62] in another market or niche with the potential disruptive technology.

This novel perspective of research is not only relevant for the academic field, but it might be extremely useful for decision-making processes. Thus, a relevant practical recommendation is that managers of established companies should search for any potential disruptor in different markets and avoid falling into the sunk-cost trap. That is to say, managers should focus their efforts on discovering those technologies with a secondary dimension of performance that eventually may become attractive for their existing customers in their mainstream market; despite they might cannibalize in the future any actual investments [63]. This implies knowing well their customers' technological needs. This approach is especially relevant for complex products, which are characterized for having several performance metrics.

In other words, managers should avoid a technological oversupply in the primary dimension of the dominant technology so as not to squander investments in technology [10]. And above all, they should explore which are the ignored and unmet needs that the mainstream market could prioritize in the near future. This implies monitoring those segments or related markets in which potentially disruptive technologies are being developed. As for example, established steel companies should not lose sight of the evolution of stainless steel technologies. At present, due to the high costs of production of stainless steel, they might not be a real menace for common steel companies but it is still possible that in the near future stainless steel companies will find a way to manufacture it at a lower cost. In fact, in China and Indonesia serious attempts have occurred [64], though so far have been unsuccessful. If they become successful, the stainless steel companies will enter some segment of the common steel market, thus leading to a disruption. Established firms should be prepared.

According to our definition, a disruptive technology is already being commercialized as a potentially disruptive technology in any market. Therefore, as predicted by Porter's five competitive forces model [65], the discontinuous pioneer is a competitive rival, whereas the potentially disruptive pioneer is a threat of new entrant. According to the nature of the competitive force in practice, the established firms will implement different strategic approaches.

In relation to the disruptive technology, the managers of established firms, rather than being visionary leaders aiming to create new markets, should monitor their potential competitors and focus on the evolution of the needs of the mainstream market. As pointed by Gans, the disruption comes from the demand, or customer, side [15].

VI. Limitations and Further Research

The conjecture outlined in this paper could be a founding block for the analysis of the different contradictions in the battle pioneer–follower depicted by the empirical evidence. Some research signals that established firms win the battle against pioneers [44], [54], while other research verifies that they are indefectibly defeated by pioneers [66], [67], [68]. Thus, additional research is required to verify if these opposed results are related to the concerned technology. We assume that established firms react late when they are confronted to a potential disruptive technology as compared to their faster reaction when confronted to a discontinuous one. Thus, it would be necessary to review the different casuistry presented in order to verify if the pioneer is successful when the mainstream market is attacked with a disruptive technology, and losses the battle against the follower when the mainstream market is attacked with a discontinuous technology. These realities lead to a reflection that could explain the outcome of the battle on the fact that the discontinuous pioneer has similar characteristics as the potential disruptive pioneer and different to those of the disruptive pioneer.

Other empirical evidence shows that, sometimes, technological disruptive newcomers do not oust the established firms [69]. Applying the principles of behavioral economics, the reasoning would be that, in this case, managers are not settled for their actual *status quo;* they can perceive sooner the threat posed by a potential disruptive technology and, therefore, they can react faster. However, additional research is needed to confirm this hypothesis.

For established firms, there are two important aspects of disruptive threats: detecting the threats and building an organization that can efficiently manage disruptive innovation. In this sense, it is worth mentioning that an ideal complement to this paper would be the analysis of the different tools established firms could use to defend themselves from disruptive and discontinuous attacks. Are they the same? The academic literature has already signaled the most important ones, such as entrepreneurship, sunk works, ambidextrous organizations, corporate venture capital, strategic partners' complementary assets, joint ventures or acquisitions [10], [15], [18], [69], [70], [71], [72], [73]. A future research objective would be to analyze if the effectiveness of those tools is dependent on the technology being discontinuous or disruptive.

Finally, other aspects that could be the object of additional empirical research are related to the managers involved in the decision-making process to invest in a new technology and their competences. Are there differences if the corporate board or the R&D managers make the decision? Do they have an analogous perspective of the disruptive technology? Are the managerial competences needed to develop a potentially disruptive technology similar to those needed to face up a disruptive technology?

Despite its potential to become the grounds of future works, this paper is not exempt of limitations. It is a theoretical study, and the conjecture developed is conducted through a literature analysis. Thus, the main limitation is the need for its empirical validation. More casuistry is needed from disruptions arising in non developed countries or to support reverse technology as a disruptive technology. Other limitations of this paper are that products with network externalities are not explicitly considered, nor the different ways disruptive technologies can attack the main market. Addressing both aspects would not only enrich the theoretical analysis, but could also lead to future potential research. Finally, we have assumed a very restrictive perspective for the conceptual analysis of a disruption, limiting it to a product technology. It would be necessary to include process technologies as well. Many firms (such as Zara) become global leaders incorporating a disruptive technology to their productive process.

References

[1] C. M. Christensen, R. McDonald, E. J. Altman, and J. Palmer, "Disruptive innovation: Intellectual history and directions for future research," *J. Manage. Stud.*, vol. 55, no. 7, pp. 1043–1078, 2018. [Online]. Available: https://doi.org/10.1111/joms.12349.

[2] D. Nagy, J. Schuessler, and A. Dubinsky, "Defining and identifying disruptive innovations," *Ind. Marketing Manage.*, vol. 57, pp. 119–126, 2016. [Online]. Available: https://doi.org/10.1016/j.indmarman.2015.11.017

[3] C. Hopp, D. Antons, J. Kaminski, and T. O. Salge, "Disruptive innovation: Conceptual foundations, empirical evidence, and research opportunities in the digital age," *J. Product Innov. Manage.*, vol. 35, no. 3, pp. 446–457, 2018. [Online]. Available: https://doi.org/10.1111/jpim.12448

[4] K. Kilkki, M. Mäntylä, K. Karhu, H. Hämmäinen, and H. Ailisto, "A disruption framework," *Technol. Forecasting Social Change*, vol. 129, pp. 275–284, 2018. [Online]. Available: https://doi.org/10.1016/j.techfore.2017.09.034

[5] G. Dosi, "Technological paradigms and technological trajectories," *Res. Policy*, vol. 11, pp. 147–162, 1982. [Online]. Available: http://dx.doi.org/10.1016/0048-7333(82)90016-6

[6] R. Foster, *Innovation: The Attacker's Advantage*. New York, NY, USA: Summit Books, 1986.

[7] R. W. Veryzer, "Discontinuous innovation and the new product development process," *J. Product Innov. Manage.*, vol. 15, no. 4, pp. 304–321, 1998. [Online]. Available: http://dx.doi.org/10.1016/s0737-6782(97)00105-7

[8] R. Adner, "When are technologies disruptive? A demand-based view of the emergence of competition," *Strategic Manage. J.*, vol. 23, no. 8, pp. 667–688, 2002. [Online]. Available: https://doi.org/10.1002/smj.246

[9] E. Danneels, "Disruptive technology reconsidered: A critique and research agenda," *J. Product Innov. Manage.*, vol. 21, pp. 246–258, 2004. [Online]. Available: http://dx.doi.org/10.1111/j.0737-6782.2004.00076.x

[10] J. Paap and R. Katz, "Anticipating disruptive innovation," *Res. Technol. Manage.*, vol. 47, no. 5, pp. 13–22, 2004. [Online]. Available: https://doi.org/10.1080/08956308.2004.11671647

[11] J. M. Utterback and H. J. Acee, "Disruptive technologies: An expanded view," *Int. J. Innov. Manage.*, vol. 9, no. 1, pp. 1–17, 2005. [Online]. Available: http://dx.doi.org/10.1142/s1363919605001162

[12] C. Markides, "Disruptive innovation: In need of better theory?" *J. Product Innov. Manage.*, vol. 23, pp. 19–25, 2006. [Online]. Available: http://dx.doi.org/10.1111/j.1540-5885.2005.00177.x

[13] A. Sood and G. J. Tellis, "Demystifying disruption: A new model for understanding and predicting disruptive technologies," *Marketing Sci.*, vol. 30, no. 2, pp. 339–354, 2011. [Online]. Available: https://doi.org/10.1287/mksc.1100.0617

[14] A. A. King and B. Baatartogtokh, "How useful is the theory of disruptive innovation?," *MIT Sloan Manage. Rev.*, vol. 57, no. 1, pp. 77–90, 2015.

[15] J. S. Gans, "Keep calm and manage disruption," *MIT Sloan Manage. Rev.*, vol. 57, no. 3, pp. 82–80, 2016.

[16] J. L. Bower and C. M. Christensen, "Disruptive technologies: Catching the wave," *Harvard Bus. Rev.*, vol. 73, no. 1, pp. 43–53, 1995.

[17] C. M. Christensen and J. L. Bower, "Customer power, strategic investment, and the failure of leading firms," *Strategic Manage. J.*, vol. 17, no. 3, pp. 197–218, 1996. [Online]. Available: https://doi.org/10.1002/(sici)1097-0266(199603)17:3%3C197::aid-smj804%3E3.3.co;2-l

[18] C. M. Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Boston, MA, USA: Harvard Bus. School Press, 1997.

[19] V. Govindarajan and P. K. Kopalle, "The usefulness of measuring disruptiveness of innovations ex post in making ex ante predictions," *J. Product Innov. Manage.*, vol. 23, pp. 12–18, 2006. [Online]. Available: https://doi.org/10.1111/j.1540-5885.2005.00176.x

[20] D. Kahneman, *Thinking, Fast and Slow*. New York, NY, USA: Farrar, Straus and Giroux, 2011.

[21] R. Thaler, *Misbehaving: The Making of Behavioral Economics*. New York, NY, USA: W. W. Norton & Company, 2015.

[22] OECD, *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, 3rd ed. Paris, France: OECD, 2005.

[23] R. N. Langlois and P. L. Robertson, *Firms, Markets and Economic Change*. London, U.K.: Routledge, 1995.

[24] E. M. Rogers, *Diffusion of Innovations*. New York, NY, USA: The Free Press, 1962.

[25] G. A. Moore, *Crossing the Chasm. Marketing and Selling Disruptive Products to Mainstream Customers*. New York, NY, USA: Harper Collins Publishers, 1991.

[26] M. L. Tushman and P. Anderson, "Technological discontinuities and organizational environments," *Adminis. Sci. Quart.*, vol. 31, no. 3, 439–465, 1986. [Online]. Available: https://doi.org/10.2307/2392832

[27] A. C. Cooper and D. Schendel, "Strategic responses to technological threats," *Bus. Horizons*, vol. 19, no. 1, pp. 61–69, 1976. [Online]. Available: https://doi.org/10.1016/0007-6813(76)90024-0

[28] J. M. Utterback, *Mastering the Dynamics of Innovation*. Boston, MA, USA: Harvard Bus. School Press, 1994.

[29] P. F. Drucker, *Innovation and Entrepreneurship*. New York, NY, USA: Harper & Row, 1985.

[30] S. K. Kassicieh, B. A. Kirchhoff, S. T. Walsh, and P. J. McWhorter, "The role of small firms in the transfer of disruptive technologies," *Technovation*, vol. 22, no. 11, pp. 667–674, 2002. [Online]. Available: https://doi.org/10.1016/s0166-4972(01)00064-5

[31] F. Wan, P. J. Williamson, and E. Yin, "Antecedents and implications of disruptive innovation: Evidence from China," *Technovation*, vols. 39/40, pp. 94–104, 2015. [Online]. Available: https://doi.org/10.1016/j.technovation.2014.05.012

[32] C. M. Christensen and M. E. Raynor, *The Innovator's Solution: Creating and Sustaining Successful Growth*. Boston, MA, USA: Harvard Bus. School Press, 2003.

[33] P. Thiel and B. Masters, *Zero to One*. New York, NY, USA: Crown Business, 2014.

[34] C. Laurell and C. Sandström, "Analysing Uber in social media—Disruptive technology or institutional disruption?" *Int. J. Innov. Manage.*, vol. 20, no. 5, pp. 1–19, 2016. [Online]. Available: https://doi.org/10.1142/s1363919616400132

[35] C. M. Christensen, M. Raynor, and R. McDonald, "What is disruptive innovation?" *Harvard Bus. Rev.*, vol. 93, no. 12, pp. 44–53, 2015.

[36] R. Adner and D. A. Levinthal, "Technology speciation and the path of emerging technologies, " in *Wharton on Managing Emerging Technologies*, G. S. Day, J. H. Schoemaker, and R. E. Gunther Eds. New York, NY, USA: Wiley, 2000, pp. 55–74.

[37] A. S. Grove, *Only the Paranoid Survive: How to Exploit the Crisis Points that Challenge Every Company and Career*. New York, NY, USA: Doubleday, 1996.

[38] S. Corsi and A. Di Minin, "Disruptive innovation ... in reverse: Adding a geographical dimension to disruptive innovation theory," *Creativity Innov. Manage.*, vol. 23, pp. 76–90, 2013. [Online]. Available: https://doi.org/10.1111/caim.12043

[39] S. D. Anthony, M. W. Johnson, J. V. Sinfield, and E. J. Altman, *The Innovator's Guide to Growth: Putting Disruptive Innovation to Work*. Boston, MA, USA: Harvard Bus. Press, 2008.

[40] G. J. Tellis and P. Golder, "First to market, first to fail? Real causes of enduring market leadership," *Sloan Manage. Rev.*, vol. 37, no. 2, 65–75, 1996.

[41] R. T. Pascale, "Perspective on strategy: The real story behind Honda's success," *California Manage. Rev.*, vol. 26, no. 3, pp. 47–72, 1984. [Online]. Available: https://doi.org/10.2307/41165080

[42] J. R. Immelt, V. Govindarajan, and C. Trimble, "How GE is disrupting itself," *Harvard Bus. Rev.*, vol. 87, no. 10, pp. 56–65, 2009.

[43] A. Brem, M. Maier, and C. Wimschneider, "Competitive advantage through innovation: The case of nespresso," *Eur. J. Innov. Manage.*, vol. 19, no. 1, pp. 133–148, 2016. [Online]. Available: https://doi.org/10.1108/ejim-05-2014-0055

[44] C. Markides and P. A. Gerosky, *Fast Second: How Smart Companies Bypass Radical Innovation to Enter and Dominate New Market*. San Francisco, CA, USA: Jossey-Bass, 2005.

[45] C. G. Gilbert, "Unbundling the structure of inertia: Resource versus routine rigidity," *Acad. Manage. J.*, vol. 48, no. 5, pp. 741–763, 2005. [Online]. Available: https://doi.org/10.5465/amj.2005.18803920

[46] R. Thaler, "Mental accounting and consumer choice," *Marketing Sci.*, vol. 4, no. 3, pp. 199–214, 1985. [Online]. Available: https://doi.org/10.1287/mksc.4.3.199

[47] D. Kahneman and A. Tversky, "Prospect theory: An analysis of decision under risk," *Econometrica*, vol. 47, no. 2, pp. 263–292, 1979. [Online]. Available: https://doi.org/10.2307/1914185

[48] N. Novemsky and D. Kahneman, "The boundaries of loss aversión," *J. Marketing Res.*, vol. 42, pp. 119–128, 2005. [Online]. Available: https://doi.org/10.1509/jmkr.42.2.119.62292

[49] D. Ariely, *Predictably Irrational: The Hidden Forces that Shape our Decisions*. New York, NY, USA: Harper Collins, 2008.

[50] D. Kahneman, J. L. Knetsch, and R. H. Thaler, "Experimental tests of the endowment effect and the coase theorem," *J. Political Econ.*, vol. 98, no. 6, pp. 1325–1348, 1990. [Online]. Available: https://doi.org/10.1086/261737

[51] S. Hüsig, C. Hipp, and M. Dowling, "Analysing disruptive potential: The case of wireless local area network and mobile communications network companies," *R&D Manage.*, vol. 35, no. 1, pp. 17–35, 2005. [Online]. Available: https://doi.org/10.1111/j.1467-9310.2005.00369.x

[52] J. E. Bercovitz, J. Figuereido, and D. J. Teece, "Firm capabilities and managerial decision making: A Theory of innovation biases," in *Technological Innovation: Oversights and Foresights*, R. Garud, P. R. Nayyar, and Z. B. Shapira, Eds. Cambridge, MA, USA: Cambridge Univ. Press, 1997, pp. 233–259. [Online]. Available: http://dx.doi.org/10.1017/cbo9780511896613.015

[53] W. J. Abernathy and J. M. Utterback, "Patterns of industrial innovation," *Technol. Rev.*, vol. 80, no. 7, pp. 41–47, 1978.

[54] D. J. Teece, "Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy," *Res. Policy*, vol. 15, pp. 285–305, 1986. [Online]. Available: http://dx.doi.org/10.1016/0048-7333(86)90027-2

[55] P. P. Milgrom and J. Roberts, *Economics, Organization and Management*. Englewood Cliffs, NJ, USA: Prentice-Hall, 1992.

[56] C. M. Christensen and R. S. Rosenbloom, "Explaining the attacker's advantage: Technological paradigms, organizational dynamics and the value network," *Res. Policy*, vol. 24, pp. 233–257, 1995. [Online]. Available: http://dx.doi.org/10.1016/0048-7333(93)00764-k

[57] P. David, *Technical Choice, Innovation and Economic Growth*. Cambridge, MA, USA: Cambridge Univ. Press, 1975.

[58] S. T. Walsh, B. A. Kirchhoff, and S. Newbert, "Differentiating market strategies for disruptive technologies," *IEEE Trans. Eng. Manage.*, vol. 49, no. 4, pp. 341–351, Nov. 2002. [Online]. Available: http://dx.doi.org/10.1109/tem.2002.806718

[59] I. Dierickx and K. Cool, "Asset stock accumulation and sustainability of competitive advantage," *Manage. Sci.*, vol. 35, pp. 1504–1514, 1989. [Online]. Available: http://dx.doi.org/10.1287/mnsc.35.12.1514

[60] E. Mansfield, "Patents and innovation: An empirical study," *Manage. Sci.*, vol. 32, pp. 173–181, 1986. [Online]. Available: http://dx.doi.org/10.1287/mnsc.32.2.173

[61] C. Shapiro and H. R. Varian, *Information Rules. A Strategic Guide to the Network Economy*. Boston, MA, USA: Harvard Bus. School Press, 1999.

[62] M. B. Lieberman and D. B. Montgomery, "First-mover advantages," *Strategic Manage. J.*, vol. 9, no. (S1), pp. 41–58, 1988. [Online]. Available: http://dx.doi.org/10.1002/smj.4250090706

[63] G. J. Tellis, "Disruptive technology or visionary leadership?" *J. Product Innov. Manage.*, vol. 23, no. 1, pp. 34–38, 2006. [Online]. Available: https://doi.org/10.1111/j.1540-5885.2005.00179.x

[64] A. Hidalgo, *Acerinox. Una Historia Sostenible*. Madrid, Spain: Claves de Gestión, 2017.

[65] M. E. Porter, *Competitive Strategy. Techniques for Analysing Industries and Competitors*. New York, NY, USA: Free Press, 1980.

[66] W. T. Robinson and C. Fornell, "Sources of market pioneer advantages in consumer goods industries," *J. Marketing Res.*, vol. 22, no. 3, pp. 305–317, 1985. [Online]. Available: http://dx.doi.org/10.2307/3151427

[67] W. C. Kim and R. Mauborgne, "Blue ocean strategy," *Harvard Bus. Rev.*, vol. 82, no. 10, pp. 76–85, 2004.

[68] M. Lambkin, "Order of entry and performance in new markets," *Strategic Manage. J.*, vol. 9, no. S1, pp. 127–140, 1988. [Online]. Available: http://dx.doi.org/10.1002/smj.4250090713

[69] D. Yu and C. Hang, "A reflective review of disruptive innovation theory," *Int. J. Manage. Rev.*, vol. 12, no. 4, pp. 435–452, 2010. [Online]. Available: http://dx.doi.org/10.1111/j.1468-2370.2009.00272.x

[70] J. Herber, J. V. Singh, and M. Useen, "The desing of new organizational forms," in *Wharton on Managing Emerging Technologies*, G. S. Day, J. H. Schoemaker, and R. E. Gunther, Eds. New York, NY, USA: Wiley, 2000, pp. 376–392.

[71] J. T. Macher and B. D. Richman, "Organizational responses to discontinuous innovation: A case study approach," *Int. J. Innov. Manage.*, vol. 8, no. 1, pp. 87–114, 2004. [Online]. Available: https://doi.org/10.1142/s1363919604000939

[72] D. Wu, R. Ma, and Y. Shi, "How do latecomer firms capture value from disruptive technologies? a secondary business-model innovation perspective," *IEEE Trans. Eng. Manage.*, vol. 57, no. 1, pp. 51–62, Feb. 2010. [Online]. Available: https://doi.org/10.1109/tem.2009.2033045

[73] F. T. Rothaermel, "Technological discontinuities and interfirm cooperation: What determines a startup's attractiveness as alliance partner?" *IEEE Trans. Eng. Manage.*, vol. 49, no. 4, pp. 388–397, Nov. 2002. [Online]. Available: https://doi.org/10.1109/tem.2002.806725

Esteban Fernández received the Ph.D. degree in business administration from the University of Oviedo, Oviedo, Spain, in 1982.

He is a Full Professor of Management with the Business Administration Department, University of Oviedo. His research activities have been published in books and peer-reviewed journals, including *Technovation, International Journal of Technology Management, International Journal of Production Research, OMEGA, The International Journal of Management Science, The Journal of Entrepreneurship, Small Business Review, International Journal of Production Economics, Ecological Economics,* and *International Journal of Human Resource Management*. His research interests include production management, business strategy, and technology and innovation management.

Sandra Valle received the Ph.D. degree in business administration from the University of Oviedo, Oviedo, Spain, in 2001.

She is an Associate Professor of management with the Business Administration Department, University of Oviedo. Her research revolves around innovation. She has worked on the analysis of the strategic and organizational factors involved in NPD process, mainly concurrent engineering and supplier involvement practices. She has published in relevant international journals, such as, *Journal of International Management*, *International Journal of Production Economics*, *International Journal of Manufacturing Technology and Management,* and *European Journal of Innovation Management.* Her research is also centered on the international relocation of firms' value chain activities, particularly on manufacturing offshoring and its effect on firm innovation.

Guillermo Pérez-Bustamante received the Ph.D. degree in business administration from the University of Oviedo, Oviedo, Spain, in 1998.

He is an Associate Professor of management with the Business Administration Department, University of Oviedo. He has published in *International Journal of Technology Management, Management Decision, Journal of the Operational Research Society, International Journal of Business Environment, International Journal of Business Competition and Growth,* and *Journal of Business Economics and Management*. His research is within the fields of innovation, human resource management, and business applications.