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## Title page

### **Streams of Digital Data and Competitive Advantage: The Mediation Effects of Process Efficiency and Product Effectiveness**

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#### **Abstract**

Firms can achieve a competitive advantage by leveraging real-time Digital Data Streams (DDSs). The ability to profit from DDSs is emerging as a critical competency for firms and a novel area for Information Technology (IT) investments. We examine the relationship between DDS readiness and competitive advantage by studying the mediation effect of product effectiveness and process efficiency. The research model is tested with data obtained from 302 companies, and the results confirm the existence of the mediation effects. Interestingly, we confirm that competitive advantage is more significantly impacted by IT investments affecting product effectiveness than those affecting process efficiency.

**Keywords:** Streams of big data; process efficiency; product effectiveness; competitive advantage.

#### **1 Acknowledge**

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#### **2 Data availability statement**

Data cannot be shared since related to an FP7 European project whose data cannot be publicly available.

# Streams of Digital Data and Competitive Advantage: The Mediation Effects of Process Efficiency and Product Effectiveness

## Abstract

Firms can achieve a competitive advantage by leveraging real-time Digital Data Streams (DDSs). The ability to profit from DDSs is emerging as a critical competency for firms and a novel area for Information Technology (IT) investments. We examine the relationship between DDS readiness and competitive advantage by studying the mediation effect of product effectiveness and process efficiency. The research model is tested with data obtained from 302 companies, and the results confirm the existence of the mediation effects. Interestingly, we confirm that competitive advantage is more significantly impacted by IT investments affecting product effectiveness than those affecting process efficiency.

**Keywords:** Streams of big data; process efficiency; product effectiveness; competitive advantage.

## 3 Introduction

The study of the impacts of big data on organizational outcomes has emerged as a central topic for both practitioners and academics [1–5]. The relevance of digital transformation, analytics, and big data projects is reflected in the agendas of chief information officers (CIOs), and other senior executives, for whom big data strategic initiatives remain a priority. Indeed, CIOs expect to deliver tangible business outcomes and produce revenue and market growth [6]. While early evidence supports the positive link between big data investments and organizational performance [7,8], firms benefit to various degrees from big data investments, and the organizational conditions affecting their performance are underexplored [4].

As we summarize in the theoretical background and in the Appendix—Table A1, while the study of big data has received tremendous attention in recent years in all major Information Systems (IS) journals, the research has focused mostly on the investigation of big data adoption and use [9,10] or has remained oriented more toward the study of organizational transformational outcomes than the assessment of its business value [5]. Moreover, even the studies that have established the link between big data and business value have investigated the relationship mainly through the lens of the resource-based view and its declinations, such as dynamic capabilities, resource orchestration, or absorptive capacity [4,5,8,11–15]. Only a limited number of studies have proposed an assessment of business value in terms of financial performance [16–18] or competitive advantage [4,5]. In addition, these studies have analyzed big data in a broad sense, and instanced big data in terms of business intelligence and analytics [18], big data analytics infrastructure [11], and big data analytics capability [4], limiting the possibility of deciphering the operational aspects of the phenomenon.

This lack of specificity in the analysis of big data is probably imputable to the polysemy of the term big data itself, which is used to represent a profusion of technologies, techniques, phenomena, and initiatives. For example, we observe that most definitions of big data [8,19] emphasize the dimension of the volume of the managed datasets and the capabilities to extract business insights from large datasets. When such a definition is applied to a company context, it may simultaneously refer to initiatives related to data management, data processing, data analysis, and data visualization, with very different operational aspects and consequences. Hence, we decided to concentrate our study on the organizational impact of one specific manifestation of big data, namely, Digital Data Streams (DDSs), following the path traced by previous studies [20–23]. A DDS is defined as the “continuous digital encoding and transmission of data describing a related class of events” [21]. Therefore, DDSs result from human behavior (e.g., a tweet) or from activity by machines (e.g., a temperature reading from a connected thermostat). The DDS channels the digital representation of these events at their inception and makes them available for harvesting and later exploitation by organizations [24]. DDSs thus represent the natural unfolding of computing, which has progressed from batch processing to online transaction processing and has now reached the continuous processing of streaming data [25–27]. DDSs represent a promising level of analysis for understanding the organizational impacts of strategic big data-enabled initiatives [21], representing a key organizational resource that firms may leverage for creating

competitive advantage [25]. By directly investigating the strategic initiatives stemming from DDSs, we may gain a more precise view of how a big data investment contributes to competitive advantage.

Since organizational conditions are critical barriers to the success of big data initiatives [28] and their study is still an open question [5], to assess how these conditions affect the performance of DDSs initiatives, we base our investigation on the concept of organizational readiness [29,30]. The organizational readiness has been shown to play a relevant role in organizational change [31] and implementation success [32], being a necessary condition for firms to manifest a competitive advantage. We investigate this link by looking at the organizational readiness in DDS, the DDS readiness [33].

From there, and inspired by the literature on Information Technology (IT) implementation success [34–36] and the ongoing discourse on success’ mediating variables (e.g., [8,17,37]), we advance that the implementation of DDS initiatives improves the competitive advantage of firms through the mediating effect of two other success dimensions of IT implementations: product success, in terms of product effectiveness, and process success, in terms of process efficiency [38]. We posit that taken together, these dimensions of IT implementation success yield a more comprehensive view of DDS impacts and may shed light on the complex relationship between big data and performance, both still open research questions [5]. We answer the following research questions: “*To what extent does digital data stream readiness impact companies’ competitive advantage?*” and “*To what extent do product effectiveness and process efficiency mediate the relationship between digital data stream readiness and competitive advantage?*”.

This paper represents one of the first attempts to measure the mediating effect of product effectiveness and process efficiency on the relationship between DDS readiness and competitive advantage. We contribute leveraging empirical data from a sample of 302 companies that participated in a questionnaire-based survey. The rest of the paper is structured as follows. First, we present the theoretical background and formulate our hypotheses. We then detail our methodology and present our results. We continue with a discussion of the findings, our conclusions, and guidelines for future studies.

## **4 Theoretical background**

The study of the effects of IT investments and performance has a long tradition in the IS field, as the study of the strategic role of IT in creating and sustaining a competitive advantage [4,39–41]. Similarly, the literature investigating big data effects on performance is rapidly growing (see Appendix—Table A1). Until now, a large part of big data studies analyzed business value creation by looking at the role of analytics almost exclusively [5,8,42,43]. Therefore, the investigated mechanisms and processes affecting value creation remained limited to those concerned with the decision-making processes or the capability building necessary to make sense of the newly available data and insight to steer the firm’s strategies [4,44]. In other words, current studies on big data represent, in large part, an evolutive step building on the business intelligence research stream and provide a partial understanding of how the implementation of big data could affect a firm’s performance and competitive advantage [7].

The concept of DDS was proposed from the observation that streaming data represented a defined and different opportunity compared to what, at the time, the overall big data studies were implying [45]. They represented a different set of possibilities (both tactical and strategic), beyond decision-making [21]. We purposely adopted the DDS conceptualization as a convenient level of analysis that enables us to focus on those initiatives that, intrinsically, pertain to the overall big data phenomenon, but that fall beyond the more informed insight and the consequent effect on and of decision-making [5,12]. We aim, with this choice, at identifying different mechanisms through which investment in big data becomes a source of competitive advantage.

### **4.1 Digital data streams**

As introduced before, a DDS is the continuous digital encoding and transmission of data describing a related class of events. The DDS concept builds on the idea of Digital Data Genesis (DDG), the digital representation of a discrete event, or a continuous event at a particular point in time [46,47]. It is the transmission, or flow, of these digital representations of events that engenders the DDS [24]. For example, Uber, the world’s largest “taxi” company, bases its value proposition on optimally matching the real-time DDS of its affiliated drivers with that of transportation demand [26]. This value proposition originating from

its DDS-enabled cab marketplace initiative revealed so profitable that the company extended it to food delivery.

DDSs are becoming increasingly important, given the diffusion of connected devices that produce growing amounts of real-time digital data [2,48]. DDS can constitute the base on which firms develop their digital business strategy [49–52]. The currency of the data is a key component of the data quality [53] on which decisions are taken [14,27] and capabilities developed [54]. Hence, decisions supported by real-time data streams would increase organizational competitive advantage [51,55]. Coca-Cola's Black Book algorithm, for example, represents an early example of DDS exploitation. The company tried to cope with orange taste variability and seasonality by standardizing the flavor of their MinuteMaid orange juices. They build an extremely rich model for measuring the taste of the source oranges, consumer preferences, and match them with the attributes of each batch of raw juice. Several external DDSs ranging from weather data, expected crop yields, cost pressures, satellite imagery to regional consumer preferences are combined for advanced supply planning.

The DDS provides a novel lens for discovering new value creation opportunities in the current sensorized, data field [33] and interconnected world [56–58], beyond the impact on decision-making and insight. The DDS lens can guide managerial decisions for extracting value from the increasing availability of digital representations of events [21]. In particular, we direct our attention to DDS-dependent strategic initiatives as a specific case of IT-dependent strategic initiatives [39]. DDS strategic initiatives consist of identifiable competitive moves that depend on the use of DDSs to be enacted [59,60]. Recent studies have discussed their impact on decision-making and operational processes [59,61], investments [59], and customer service [58], suggesting the investigation of core mechanisms of value generation, including process efficiency and product effectiveness. These competitive moves demand an organizational change whose smoothness depends on the organizational readiness for this change.

#### **4.2 From organizational readiness to DDS readiness**

Organizational readiness finds its origin in change management literature as the precursor to the successful implementation of a change. The conceptualization develops as an extension of Kurt Lewin's paradigmatic unfreeze-change-refreeze change management model [62,63]. The model, which has been foundational of the change management field, advances that a successful change includes three stages [62]. These stages cover from the perception of the need for change (the unfreezing stage), the actions and interventions that progressively engender the change (the changing stage), and that finally result in the consolidation of new practice (the refreezing stage). Then, readiness studies focused on proposing strategies that could positively affect change's outcomes [32,64] by essentially acting at the unfreezing stage.

Since its introduction, the concept of readiness has been applied in different domains [e.g., 29]. In IS, readiness is seen as the degree of the psychological, behavioral, and structural states of preparedness that are attained by an organization prior to the commencement of a specific activity [30]. When readiness refers to an organization, it can be observed from multiple levels: individual, team, department, or organizational level [64]. This conceptualization contributes to assessing the extent to which resources and implementation conditions favor an initiative's success [32]. Researchers worked to establish a link between organizational readiness and IT implementation success. While some studies observed a positive link between readiness and outcomes (e.g., [30,42,65]), others argued a lack of evidence [66], calling for the study of mediating dimensions [32]. Our work provides direct evidence of the link between readiness and outcomes and provides an assessment of the existence of a significant mediation effect.

Despite the call for an articulated operationalization of readiness, few studies considered extending their analysis beyond the structural dimension [22,32] or developing an operationalization of the mediating effects.

Following the organizational readiness rationale, to maximize the chances that a new IS implementation will be successful, organizations should commit to upfront preparation before investing time, money, and effort in a new IS [67]. This commitment is even more crucial when the required IT investment is large, as it is in many big data initiatives [68], and potentially risky.

The strong interest of academics and practitioners in understanding the implications of big data initiatives engendered a renewed interest in the development of big data readiness assessment [42,69–71]. These studies have focused on the employee level [71], and conservatively they adopted a simplified

conceptualization and operationalization of organizational readiness [42,70]. Instead, the studies that articulated organizational readiness in a more structured way considered the outcomes on decision-making (e.g., [72]).

More recently, the DDS readiness index was proposed as an integrative construct for capturing companies' organizational readiness to exploit real-time digital data, accounting for the specificities of these initiatives [68]. This DDS readiness index is composed of four dimensions, psychological and structural ones combined: mindset, skillset, toolset, and dataset [45]:

- *Mindset* (psychological) represents the organization's culture, strategy, and willingness related to investing in data-centric initiatives.
- *Skillset* (structural) denotes the organization's capability to manage DDS strategic initiatives, such as the acquisition and orchestration of all resources, including technical, business, and complementary resources, to deliver new products, processes, and decision-making routines.
- *Dataset* (structural) describes the organization's capability to identify, intercept, and access real-time data streams that match organizational needs for value creation.
- *Toolset* (structural) is the organization's capability to adapt to the new hardware and software required to intercept a DDS and harvest its content.

This theoretical proposal has been assessed through an extensive survey at the organizational level. The empirical evidence revealed that firms manifested different readiness patterns depending on industry and size, and a greater variance in the psychological trait of readiness than the variance of the structural traits [22]. While this study provided an integrative measure of organizational readiness, it did not explore the relationship between DDS readiness and outcomes, a gap we specifically address in this study.

### **4.3 DDS Readiness and outcomes**

A core aspect of IT value creation relates to the capacity of the organization to envision new uses of IT and design strategic initiatives capable to originate novel products and processes to generate benefits [39,41]. Nonetheless, both DDS and big data and analytics projects present peculiarities that require to consider specific elements of organizational readiness [21,53,68]. Therefore, the use of the DDS readiness index to assess organizational readiness would precisely provide the appraisal of the extent to which organizations may enhance their competitive advantage through DDS-dependent strategic initiatives. Accordingly, we consider DDS readiness to affect the success of a DDS-dependent strategic initiative directly.

We model the mechanism through which the DDS-dependent strategic initiative affect the firm's competitive advantage focusing on process efficiency and product effectiveness, established "vehicles" of IT competitive advantage [39]. DDS initiatives' success would then be reflected primarily in the achievement of (1) process efficiency and (2) product effectiveness [30,38,40,41], and indirectly in the achievement of firm's competitive advantage [11,38,39]. We consider the two direct outcomes of process efficiency and product effectiveness to be interrelated as a single DDS initiative may target or result in both process efficiency and product effectiveness (Figure 1).

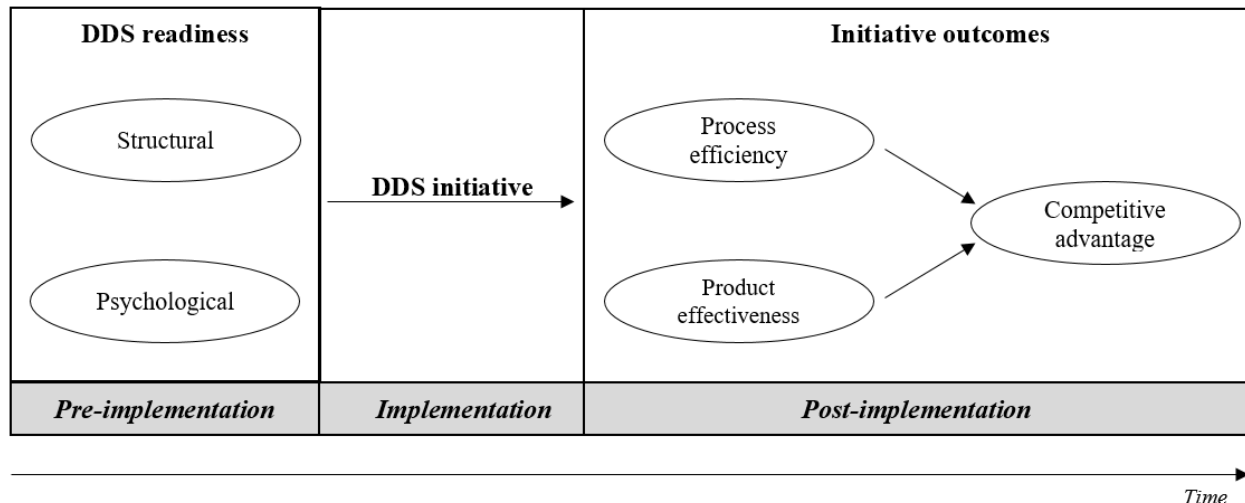


Figure 1 Overall conceptual framework of organizational readiness (adapted from [32])

Interestingly, while a link between organizational readiness and IT implementation success was already established in the literature, the results remained controversial. Some studies argued for a positive link between readiness and outcomes [30,42,65]; others remained inconclusive [66], eventually calling for the study of possible mediating factors [32]. With this study, we specifically address this research gap and contribute to advance our understanding of the mechanisms enabling firms to obtain competitive outcomes through the use of big data. Overall, the proposed conceptual model allows establishing the link between the organizational readiness to succeed and create value with DDS with the achievement of competitive advantage, by considering the implementation of DDS-dependent strategic initiatives and their direct outcomes. Furthermore, it allows us to study how these initiatives' outcomes contribute to competitive advantage by affecting process efficiency and product effectiveness.

## 5 Research model and hypotheses development

Based on the conceptual model, we advance a research model (Figure 1) and five testable hypotheses to assess the role of DDS readiness in affecting competitive advantage through both process efficiency and product effectiveness. We expect higher levels of DDS readiness to be positively associated with competitive advantage, indirectly, and through the mediating effects of the efficiency of processes and the effectiveness of the products and services delivered [73]. We separate process efficiency and product effectiveness, consistent with the logic that firms could focus more on one aspect over the other at the risk of “being left behind by competitors that focus on both” [38].

Process efficiency has already been used to measure the success of IS implementations [34–36] and IT-dependent initiatives [39,74]. The time passed, the money spent, and the quality achieved are the three general criteria employed to assess the efficiency of processes [32]. We expect that DDS readiness could favor process efficiency through its four dimensions. The mindset may provide the appropriate cognitive filters for being more apt to select and interpret available and collected data and improve decision-making, while the skillset may accelerate the managerial processes of assembling the required resources to deliver the DDS initiative [43]. The dataset could make seamless the processes of identification, interception and access of real-time data streams required for products and services. Finally, the toolset could make the use of software and hardware more efficient to both intercept a DDS and harvest its content, in addition to opening the organization to new opportunities. Hence, we hypothesize the following:

*H1. DDS readiness positively impacts process efficiency.*

A second classical dimension used to measure the success of an IS implementation or IT-dependent initiative involves examining the effectiveness of new products [30,34–36,39,74]. Quality and innovativeness are the two main criteria used to assess the effectiveness of new products [30,38], and we assert that the effectiveness of new products is a direct manifestation of DDS readiness. A company with a favorable DDS mindset, skillset, toolset, and dataset would take any opportunity to incorporate available DDSs or new

DDSs in its offer of goods and services. The firm would be willing to both invest in new data-driven goods and services and assume the associated risks [32]. The organization would have the ability to manage the integration of new goods or services in the organization's offer catalogue. Moreover, the firm would be capable of effectively identifying, intercepting, and accessing the DDS, which could benefit the product offered [73]. Finally, the organization would have available the appropriate software and hardware to both collect and provide the data streams required for the new offered product [75]. Hence, we hypothesize the following:

*H2. DDS readiness positively impacts product effectiveness.*

Correspondingly, competitive advantage is largely recognized as the overall dependent variable reflecting the success of an IT-dependent strategic initiative [76]. Research on the potential of IS and IT for creating competitive advantage is rooted in the very beginning of the IS discipline [77,78], and these roots are well grounded, as a literature review confirmed [39]. Moreover, recent investigations have consistently reaffirmed this theoretical paradigm [11]. Indeed, organizations should develop their readiness to increase their chances of success in the deployment of an IT-dependent strategic initiative and to take advantage of the potential of information systems and technologies [32,39]. In other words, organizational readiness is a critical precondition for the successful implementation of IT-dependent initiatives and IS projects [31,79], as a previous study demonstrated [80]. Consequently, we posit that in the specific domain of DDS initiatives, a positive relationship between DDS readiness and competitive advantage can be found. Hence, we formally hypothesize the following:

*H3. DDS readiness positively impacts competitive advantage.*

At the same time, leveraging DDS can be not a direct driver of company competitive advantage because there could be variables that mediate this relationship. Since process efficiency and product effectiveness have been shown to indirectly affect the competitive advantage of firms [38,39,81], we contend that DDS readiness can affect the competitive advantage of a firm through improvements to the effectiveness of the offered products and/or through increases in the efficiency of the organizational processes.

This happens because, due to DDS readiness, companies are able to produce products of higher quality and levels of innovativeness, which in turn means a better competitive advantage in the market. In other words, companies able to leverage streams of big data to gain a competitive advantage over competitors in the marketplace would do that through improvements in product quality, in product functionalities and in major product innovations. As a result, we hypothesize the following:

*H4. Product effectiveness has a mediating effect on the relationship between DDS readiness and competitive advantage.*

Complementary, DDS readiness allows companies to improve process efficiency. Even if the link between process efficiency and competitive advantage is underexplored in the big data context [53], we expect at least two kinds of links. First, process efficiencies could be related to enhanced information processes such as decision-making, managerial monitoring, information generation and dissemination [15,27,76]. Second, process efficiencies can take the form of accelerated business processes such as time to market at lower costs [82]. All of them would increase the competitive advantage compared to competitors. As a result, we hypothesize the following:

*H5. Process efficiency has a mediating effect on the relationship between DDS readiness and competitive advantage.*

In summary, Figure 2 shows the research framework of this study and the hypotheses tested.



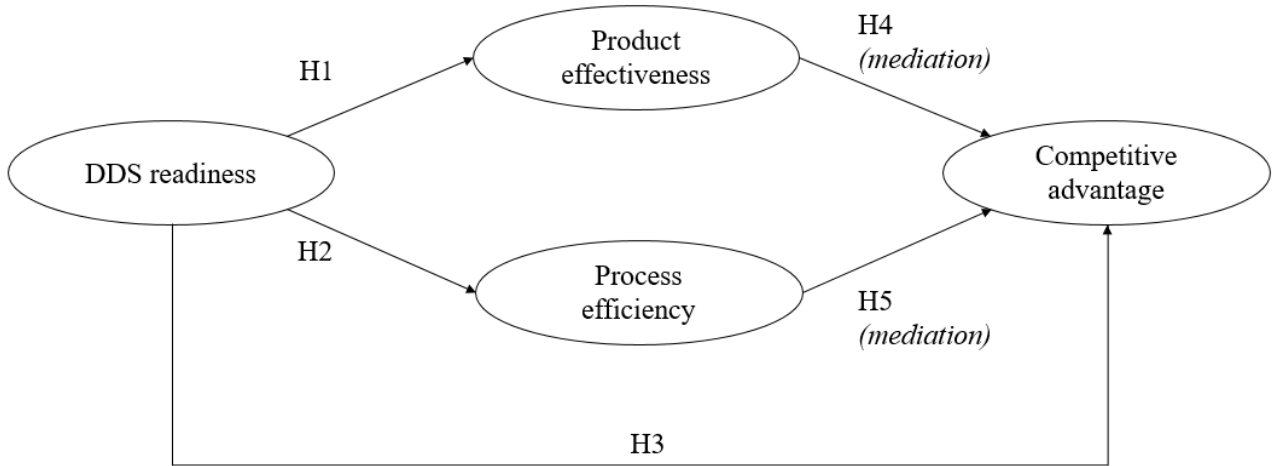


Figure 1 Research framework

## 6 Measurement development

Instead than opting for new scale development, measurement items were adapted from existing scales identified in literature and we considered the DDS initiatives as our unit of analysis. We operationalized DDS readiness as specified in previous research [22], with its four components: mindset, skillset, toolset, and dataset. Product effectiveness and process efficiency were adapted from existing and validated self-assessment performance measures, where process efficiency is about time to market at a low cost and product effectiveness is around product quality and innovativeness [38]. The items were slightly rephrased to adapt them to the study context. In particular, we kept items the most general as possible to be applicable to any industry, firm size, product offer, and process performed, while accounting for DDS. Concretely, we rephrased the original formulation that explicitly referred to new product development, to explicitly refer to the DDS initiatives, instead. These adjustments were completed without altering the constructs' psychometric properties (Table 1). We maintained the original formulation of the scales and asked the respondents to agree or disagree to a list of 22 items using a 5-point Likert scale.

Table 1 Constructs and items

Construct	Item (5-point Likert scale)	Reference
Mindset (DDSR1)		
M1	Our organization has a data-oriented culture.	[22]
M2	We believe in experimenting and testing innovative IT initiatives.	
M3	We use real-time DDS to envision and pursue new competitive strategies.	
Skillset (DDSR2)		
S1	We are good at designing new initiatives that exploit real-time DDS.	[22]
S2	Once we envision an application of real-time DDS, we know how to assemble the needed organizational, financial, and technological resources.	
S3	Once we envision an application of real-time DDS, we know how to exploit the data to deliver the benefits of the initiative.	
Dataset (DDSR3)		
D1	We have a clear data governance policy.	[22]
D2	We monitor the sources of the real-time DDS that we utilize.	
D3	We evaluate the quality of our internal DDS (e.g., timeliness, completeness, accuracy).	
Toolset (DDSR4)		
T1	We have the appropriate tools to integrate real-time DDS with current workflows.	[22]
T2	Our system architecture allows for real-time DDS to be dispatched to existing	

	systems.	
T3	We have the tools and the technical talent to create our own real-time DDS.	
Product effectiveness (PDEFF)		
PDFFE1	Our DDS initiatives resulted in improvements in product or service quality and functionality.	[38,40]
PDFFE2	Our DDS initiatives resulted in major innovations in products or services as a whole.	
PDFFE3	Our DDS initiatives resulted in our ability to develop new product or service concepts.	
Process efficiency (PCEFF)		
PCFFI1	Our DDS initiatives lowered the cost of impacted business processes.	[38,40]
PCFFI2	Our DDS initiatives increased the overall efficiency of impacted processes.	
PCFFI3	Our DDS initiatives increased the overall effectiveness of impacted processes.	
PCFFI4	Our DDS initiatives accelerated our time-to-market with new products or services.	
Competitive advantage (CA)		
CA1	Our DDS initiatives resulted in strategic advantages in the marketplace over our competitors.	[38,40]
CA2	Our DDS initiatives resulted in a competitive advantage.	
CA3	Our DDS initiatives resulted in better financial results than our direct competitors.	

Specifically, *product effectiveness* reflect the extent the DDS initiative affects product quality, innovativeness, and innovation and is measured with three items [38,40]. *Process efficiency* is conceptualized as the extent to which the organizational processes were affected by the DDS initiative decreasing time to market, costs and increasing their ability to produce the intended results [38,40], and was measured with four items. *Competitive advantage* represents the extent to which a firm performs better, comparatively to its competitors, on the market [38,40]. We asked respondents to evaluate the degree to which they perceived the DDS initiatives resulted in a strategic advantage in the marketplace, a competitive advantage, and to a better overall financial performance.

## 7 Data collection, analysis, and findings

### 7.1 Sample and data collection

To test our hypotheses, we administered a questionnaire to a sample of firms with the support of Qualtrics (<http://www.qualtrics.com>), a company that specializes in data collection and analysis. We expressly targeted CIOs, CTOs, and senior IT managers in North American companies with more than 10 employees and annual revenues higher than 1 million dollars. Of the 732 responses received, 320 (43.7%) qualified based on those criteria. We considered targeting CIOs, CTOs, and senior IT managers because they are typically aware of the major IT-based projects, and initiatives and have visibility on the success of these projects as they directly require the involvement of the IT department or unit.

We further tightened our quality requirements (time to complete the survey, coherence, and variance in the answers, use of DDSs, absence of missing values) and ultimately retained 302 (41.3%) respondents (see Table 2 for the sample composition).

The questionnaire consisted of three main sections. The first section covered the respondents' demographics, and we asked about their title, the firm size, the annual revenues of the company, and their sector. The second section focused on the four dimensions that compose DDS readiness. Finally, the third section included questions about the process efficiency, product effectiveness, DDS usage, and the competitive advantage of the companies investigated.

Responses were collected mainly from manufacturing (18.87%), consulting (15.89%), telecommunications (9.27%), software publishing (8.94%), financial services (7.62%), construction (5.63%), medical and health services (5.63%), and wholesale / distribution (5.30%) (Table 2).

The final sample of 302 companies is composed of companies that have high DDS readiness as well as low DDS readiness levels. We observed significant differences among firms of different size and industry. For example, in the telecommunication sector, structural readiness components were on average higher than in healthcare, which, in turn, exhibited a lower mindset.

*Table 2 Demographics—Respondent characteristics*

<b>Characteristics</b>	<b>Frequency</b>	<b>Percentage</b>
Title of the respondent		
IS/IT Senior Management	223	73.84%
CIO/CTO	79	26.16%
Firm size (employees)		
10–50	18	5.96%
51–100	24	7.95%
101–500	57	18.87%
501–1000	54	17.88%
1001–5000	72	23.84%
5001–10000	31	10.26%
10000+	46	15.23%
Annual revenues (US dollars)		
1–10 million	18	5.96%
11–50 million	24	7.95%
51–100 million	57	18.87%
101 million—1 billion	54	17.88%
1–10 billion	72	23.84%
10–50 billion	31	10.26%
More than 50 billion	46	15.23%
Sector		
Manufacturing	57	18.87%
Consulting	48	15.89%
Telecommunications	28	9.27%
Computer Software Publishing	27	8.94%
Financial Services	23	7.62%
Building Construction/Engineering/Design	17	5.63%
Medical and Health Services	17	5.63%
Wholesale/Retail Trade/Distribution	16	5.30%
Transport	10	3.31%
Other sectors	59	19.54%

Among these companies, some of them leverage on DDS for process innovation while others for product innovation. More specifically (Table 3), in terms of usage, firms targeted DDS initiatives to support their decision-making processes (39%), their internal operation (37%), highlighting a proficiency in leveraging data on their internal operations. Interestingly, they leveraged DDS potential to service the customer (36%), aggregate them, and make DDS available to other users (29%), and make DDS available to other business partners as part of their business (25%).

*Table 3 Demographics—DDS usage*

<b>Real-time digital data streams (DDS) use</b>	<b>Frequency</b>	<b>Percentage</b>
Process, analyze, or visualize real-time DDS for better decision-making and to develop superior business insight or knowledge (e.g., business metrics monitoring, data mining, and analytics).	119	39%
Optimize internal operations or to track business performance.	113	37%
Provide services to consumers or to improve the service quality.	108	36%
Collect and aggregate real-time DDS, and make them available to other users.	89	29%

Generate real-time DDS and provide them to customers or third parties as part of the business.	77	25%
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## 7.2 Measurement model

To verify the hypotheses of this study and the psychometric properties of the constructs, we used SmartPLS 3.0 [83]. SmartPLS is similar to PLS-Graph and is a component-based path modeling program that is based on partial least squares (PLS). We chose PLS path modeling because PLS makes fewer demands on the underlying data distribution than does covariance-based structural equation modeling [84]. Indeed, the PLS method was more suitable for the analysis because it does not require the data to be normally distributed [85]. Furthermore, PLS can be a valuable tool in explorative research and for theory development and hence was suitable for this study [86].

The estimation of hierarchical construct models was conducted to decrease model complexity through PLS analysis [87]. Figure 3 highlights that the measurement of DDS readiness is an aggregate of four dimensions (mindset, skillset, toolset, and dataset), confirming previous studies [22]. The resulting measurement is a 12-item instrument that can be operationalized as a second-order factor model, in which a latent factor (i.e., DDS) governs the correlations among its dimensions.

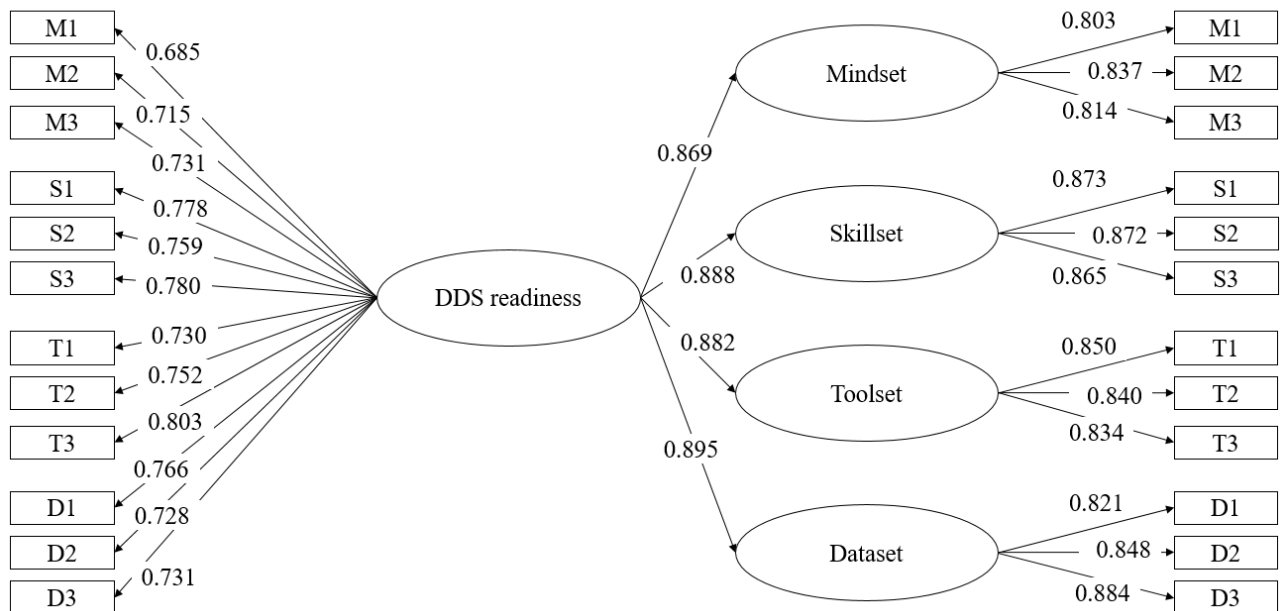


Figure 1 Second-order model for DDS readiness

We applied PLS modeling to validate the model constructs. To measure the model, we assessed indicator reliability, construct reliability, convergent validity, and discriminant validity. First, indicator reliability was evaluated based on the criteria that the loadings should be greater than 0.70 [88]. As shown in Table 4, this criterion was met. Second, construct reliability was tested using composite reliability (CR). All constructs have values above 0.8, suggesting that the constructs are reliable [88], thereby fulfilling this criterion. Third, convergent validity was tested using average variance extracted (AVE). If the coefficient is above 0.5, the latent variable explains more than half of the variance of the indicators [89]. Based on Table 4, we can conclude that all constructs have an AVE above 0.5, fulfilling this criterion.

Table 4 Psychometric table of the measurements

	Construct	Loading (t-values)	t-values	R-square	AVE	CA	CR
DDS readiness	DDSR1	0.836	26.653	n.a.	0.517	0.928	0.927

	DDSR2	0.798	17.241				
	DDSR3	0.881	28.856				
	DDSR4	0.847	24.491				
Product effectiveness	PDFFE1	0.805	21.831	0.789	0.673	0.861	0.861
	PDFFE2	0.829	30.513				
	PDFFE3	0.827	28.485				
Process efficiency	PCFFI1	0.712	15.731	0.655	0.638	0.839	0.841
	PCFFI2	0.777	20.677				
	PCFFI3	0.814	26.200				
	PCFFI4	0.836	28.839				
Competitive advantage	CA1	0.768	20.418	0.932	0.632	0.832	0.832
	CA2	0.811	21.344				
	CA3	0.788	18.535				

Note: n.a. stands for “not available”.

Finally, the discriminant validity of the constructs was assessed [89]. We computed the square root of the AVE for the constructs (diagonal elements of Table 5) and found that they are greater than the correlation between each pair of constructs (off-diagonal elements of Table 5). Thus, discriminant validity was met. Thus, in brief, construct reliability, indicator reliability, convergent validity, and discriminant validity of the constructs were satisfactory.

*Table 5 Discriminant validity (diagonal elements are square roots of the average variance extracted)*

N.	Variable	Min.	Max.	Mean	St. Dev.	1	2	3	4
1	DDS readiness	1	5	3.773	0.874	0.719			
2	Product effectiveness	1	5	3.791	1.018	0.657*	0.820		
3	Process efficiency	1	5	3.700	1.028	0.653*	0.721*	0.799	
4	Competitive advantage	1	5	3.748	0.999	0.680*	0.693*	0.695*	0.795

Note: \*p-value<0.5

Before running the models, we tested for multicollinearity by computing the variance inflation factor (VIF) values. All the variables had acceptable VIF values (minimum VIF was equal to 1.471, maximum VIF was equal to 2.678, and average VIF was equal to 1.973). Therefore, multicollinearity did not appear to be a problematic issue.

### **7.3 Structural model and mediation analysis**

SmartPLS was employed to assess the structural model (see Figure 1 for the full structural model) and to determine whether our hypotheses were confirmed. The analysis was divided into two parts. In the first part, we tested the direct hypotheses (Hypotheses 1–3). In the second, we tested the mediation hypotheses (Hypotheses 4 and 5).

Table 6 presents the results for testing the direct hypotheses. To provide support for Hypothesis 1, we evaluated whether DDS readiness impacts process efficiency by lowering the cost of impacted business processes, increasing the overall efficiency and effectiveness of impacted processes, and accelerating time to market for new products or services. As shown in Table 6, this hypothesis was supported given the direct, positive, and statistically significant effect of DDS readiness on the variable of impact considered.

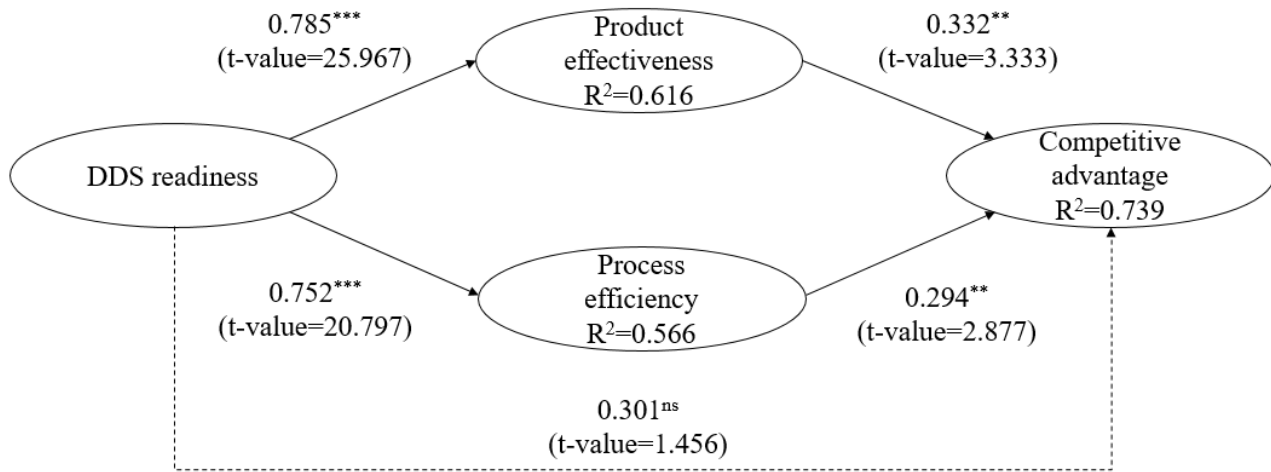
We observed a direct, positive, and statistically significant effect of DDS readiness on product effectiveness, providing support for Hypothesis 2, in which we stated that DDS readiness positively impacts product effectiveness. This result provides evidence that DDS initiatives affect product or service quality and functionality and companies’ ability to develop new product or service concepts (Table 6).

In Hypothesis 3, we presumed that DDS readiness positively impacts competitive advantage. This relationship was supported by our analyses, as shown in Table 6. Thus, Hypothesis 3 was confirmed.

Table 6 Direct effects

Direct effect	Path coefficient	t-Value	Standard deviation
DDS readiness ➤ Process efficiency	0.753	17.795	0.040
DDS readiness ➤ Product effectiveness	0.785	22.577	0.035
DDS readiness ➤ Competitive advantage	0.783	24.620	0.032

Concerning the two mediation hypotheses, by adopting bootstrapping procedures with 300 replications, we considered the SmartPLS outputs on total indirect and specific indirect effects [90,91]. Our results show that there is mediation in our model since the p-value of the total indirect effect is statistically significant. This result concerning the total indirect effect does not take into account the effects of the separate mediation variables. For evaluating them separately, it is necessary to consider the specific indirect effects. Results of the specific indirect effects confirm the existence of the two mediation effects being the p-value of both statistically significant (see Table 7). Specifically, our model is characterized by a full mediation effect since the direct effect of DDS readiness on competitive advantage is not significant in case the two mediating effects are included in the model (Figure 1). Accordingly, Hypothesis 4 and Hypothesis 5 were confirmed.



\*\*\*p-value < 0.1%; \*\*p < 1%; \*p < 5%; †p < 10%

Figure 1 Full structural model

Table 7 Total and specific indirect effects

Type of effect	Mediating effect	Original sample	Sample mean	Standard deviation	T Statistics	P-values
Total indirect effect	DDS readiness ➤ Competitive advantage	0.481	0.482	0.066	7.245	0.000
Specific indirect effect	DDS readiness ➤ Product effectiveness ➤ Competitive advantage	0.260	0.250	0.056	4.657	0.000
Specific indirect effect	DDS readiness ➤ Process efficiency ➤ Competitive advantage	0.221	0.232	0.066	3.352	0.001

(R<sup>2</sup>) and the significance levels of each path coefficient [92]. The R<sup>2</sup> values ranged between 0.566 and 0.739, and each path coefficient of the model was significant. We also evaluated our model by calculating the goodness-of-fit (GoF) score as In assessing the structural model, we first evaluated the overall model using the coefficients of determination a global fit measure for PLS path modeling, bounded between 0 and 1 [93]. The GoF was 0.837. The GoF cut-off value for a model with large effect sizes should be 0.360 [94]. Because our value exceeded this recommendation, we concluded that our model fits well.

## 8 Discussion

### 8.1 Theoretical contributions

These results contribute to the enrichment of the body of research investigating the impacts of big data investment on firm performance, in several directions.

This study integrates the organizational readiness perspective, complementary to the resource-based view and dynamic capability theories [95], and the conceptualization of DDS initiatives to investigate the link between big data and performance. The advantages of this choice were twofold. On the one hand, it enabled us to look beyond the direct decision-making performances [4,44,72,96], down to the competitive advance measures. On the other hand, it contributed to fill the theoretical gap that saw organizational readiness to be largely disregarded [70] in previous big data studies despite its proven usefulness for studying IT adoption [97]. More specifically, our results provide an essential complement to current capability-based theorizations contributing to the assessment of the extent to which resources and implementation conditions favor an initiative's success [32] and how a DDS initiative interacts with complementary capabilities to contribute to organizational benefits and competitive advantage [98]. Compared to previous studies on organizational readiness [29,30][32][70], and its more recent operationalization in the domain of big data studies [22], we provide a finer-grained analysis of the link between readiness and performance. At present, no previous study in IS rooted in organizational readiness investigated how competitive performance was achieved, only focusing on establishing and sizing the effect of the relationship (e.g., [30]). We indeed expand the current research on organizational readiness testing the mediating role of product effectiveness and process efficiency. We underline how the present paper provides several confirmations to relevant propositions concerning big data use [53]. We show the positive effect that the dimensions of DDS readiness have on the specific IT initiatives we focused on. More specifically, we contribute to theory on three complementary aspects.

First, we highlighted that the DDS initiative effects and success are influenced by “people aspects, organizational aspects and systems, tools and techniques” [53]. While the effective use of big data was hypothesized to be affected by these themes, we provide an additional operationalization of these themes into construct's dimensions. Additionally, we statistically confirm the propositions coming from a literature review (Table 8). The DDS readiness combining both structural and psychological aspects and operationalizing mindset, skillset, toolset significantly converges toward the proposed comprehensive theorization, despite being differently derived, strengthening each other results. We then contribute to the growing body of literature investigating the relationship between the use of big data and business value, providing in this way “a more nuanced understanding of effective use of big data” quantitatively substantiating the prepositions advances from the review of the existing literature [53].

*Table 8 The correspondence of the themes and factors influencing effective use of big data [52] with the construct's dimensions of DDS Readiness*

<b>Theme</b>	<b>Factor</b>	<b>DDS Readiness construct's dimension</b>	<b>Supported proposition</b>
Supporting mechanisms	Organizational aspects	Mindset	3
	Systems, tools, and techniques	Toolset	3
	People aspects	Skillset	3
Operational	Data privacy and security and governance	Dataset	2
	Data quality	Dataset	2
	Process management	Skillset	2
Motivational	Perceived organizational benefit	Mindset	1

The conceptual framework derived from the literature review [53] is consistent with the suggested conceptualization of organizational readiness as a multidimensional construct composed of four dimensions, psychological and structural ones combined: mindset, skillset, toolset, and dataset [45]. While the framework was initially discussed considering a dynamic capabilities lens, our results support the adequacy of organizational readiness theorization for exploring the factors affecting the effective use of big data and providing an initial set of measurement items validated on a significant sample.

Second, we illustrated that the expected benefits of the DDS initiative's expected benefits, which we specifically captured through the assessment of the organizational mindset dimension of the DDS readiness, positively affect the success of the initiative itself and its contribution to competitive advantage.

Third and finally, we provided evidence that process and data management and governance dimensions, and data quality [53], that we capture through dataset and skillset dimensions of the DDS readiness, positively influence DDS initiative business value.

Complementary, we fine-grained the relationship between big data and performance, at the organizational rather than employee level [42,71], looking at a specific type of big data initiatives: the DDS-dependent strategic initiatives. If by one side, with this choice, we limited the scope of our potential contribution, on the other side, we were able to deepen our understanding of the mechanisms linking big data to performance. By focusing on DDSs as a specific instance of the broader big data phenomenon, we employ DDS readiness to indicate the extent to which resources and implementation conditions favor DDS initiatives' success. We employed a richer and conceptually articulated version of the organizational readiness than what was previously employed [42,70]. Our results show that DDS readiness is positively linked to a firm's competitive advantage, confirming Hypothesis 3. Preparing in advance to face the changes involved in IT-dependent strategic initiatives leads, with higher probability, to better performance. While these results confirm the findings of previous studies [67,70], we adopted an alternative model, based on the organizational readiness, that provides complementary evidence of the contribution of IT-dependent strategic initiatives and related investments to a firm's competitive advantage.

Our relevant contribution, in this sense, is to provide the empirical support to the mediating conditions that can affect firms' competitive advantage. Indeed, we measure, for the first time, the mediation effect of process efficiency and product effectiveness. This result finds a complementary confirmation in the recent study by Mikalef et al. [4] that found big data capabilities indirectly affect both marketing and technological capabilities, which could result in higher competitive performance. Additionally, our conceptualization provides further evidence of the role played by complementary dimensions related to big data, including nontechnical ones, and that their synergistic effect is what drives renewal of operational capabilities [4], which, we advance, can be captured through DDS readiness, and its four dimensions.

Therefore, and considering the results achieved, the positive relationship between DDS readiness and process efficiency confirms *Hypothesis 1*, extending the current body of knowledge linking big data initiatives with performance. While in our study, we opted for a general evaluation of process efficiency, our results support the idea that organizational routines and business processes are among the main contributors to firms' competitive advantage. In this sense, DDS readiness's role seems to reflect the capacity of an organization to accommodate and enact, at the process level, the opportunities for an IT-induced change. DDS readiness might then measure the extent to which the organization is ready to evolve its capabilities for harnessing DDSs [60]. At the same time, DDS readiness is linked to product effectiveness, confirming *Hypothesis 2*. This result supports previous studies on the overall capacity of the firm to innovate its products, which has traditionally been considered a classical dimension with which to measure the success of an IS implementation [35,36,99]. This finding confirms early theorizations on IT-dependent strategic initiatives [39], supporting the idea that IT contributes to a firm's overall competitive advantage when it affects customers' value creation and appropriation processes. Compared to product efficiency, product effectiveness relates to product-specific characteristics and how customers perceive these product characteristics, including product quality, innovativeness, and innovation. In the big data domain, these product characteristics generate from big data, enabling competitive moves, leveraging product-specific value drivers, increasing customers' willingness to pay, and fostering the creation and appropriation of economic value [39]. The competitive advantage is achieved when the firm creates, with its products, a unique value that no competitor can offer, and realizing a positive difference between customers' willingness to pay and the firm's costs. On the opposite, through process efficiency, the big data initiative would mainly



generate lower costs, but this gain is less associated with competitive advantage. This result hints then that customers put greater importance on the added value of big data–enhanced good and service bundles.

The study of the mediation effect of process performance and product effectiveness complement our current understanding of the mechanisms that affect the different impacts of DDS initiatives on firm competitiveness. Current studies have demonstrated that the impact on competitive advantage and profitability are different and explained such differences based on the maturity of the technology, related complexity, and organizational capabilities to manage them [54]. Others suggested a limited effect on firms' productivity compared to financial performance and market value [7]. Our results again extend and complement these findings showing a different contribution of DDS initiatives based on their focus, suggesting that strategic, product effectiveness–related initiatives provide greater chances of generating a competitive advantage when the organization manifests an adequate readiness. A recent study has suggested that absorptive capacity plays an important role in the organizational assimilation of big data–related competencies [13], indirectly influencing competitive advantage. In terms of organizational readiness, it contributes to the stream of research, investigating its relationship with performance. The link between organizational readiness and performance IS generally established but hardly characterized. These results suggest the need for further study of different dimensions mediating the relationship and resulting in big data initiatives affecting firm's competitiveness.

Furthermore, our results revealed a significant difference between process efficiency and product effectiveness that was not observed in previous studies [38], in which these two variables influenced performance to a similar extent. We observed that DDS initiatives manifest a greater connectedness with the effectiveness attributes of the goods and services delivered by firms, than the connectedness with the efficiency of the internal processes performed by the firms. This original contribution suggests that while DDS investment may affect profitability through its impacts on the internal operational efficiency, this effect is less evident than when it is used more strategically to enhance product effectiveness. This hints at a more nuanced view of the elusive link between IT investments that affect operational aspects and competitive advantage, confirming that new technologies may indeed open novel pathways to new strategic opportunities for value creation [100].

Besides, in line with the assumption that DDS readiness indirectly affects competitive advantage through process efficiency (*Hypothesis 4*) and product effectiveness (*Hypothesis 5*), we observed a fully mediated relationship between DDS readiness and competitive advantage. Therefore, firms capable of leveraging DDSs can build their competitive advantage by improving product quality and functionality, introducing new products or product innovations and developing initiatives that produce efficiency gains by reducing development costs, improving processes, and accelerating product time to market.

In conclusion, while the overall idea that organizational readiness impacts performance and indirectly, organizational readiness affects competitive advantage is not new, our original specification, operationalization, and findings provide a richer and more detailed picture of how big data impact performance.

## **8.2 Implications for practice**

These results advance the critical role that big data initiatives play in firms' competitiveness and the appropriate level of priority these initiatives should have on CIOs and other officers' agendas. As far as DDS readiness can be a source of competitive advantage, it would be worth assessing and monitoring it regularly, as a critical success factor [101]. Moreover, practitioners should consider that DDS readiness demands the iterative development of both technological and organizational capabilities [102] and that organizations require flexible processes and routines to adapt, on the one hand, their culture and strategy and, on the other hand, their resources and capabilities. Firms need to prepare themselves beyond the IT department's boundary, developing an appropriate mindset and skillset in addition to leveraging their dataset and toolset.

Even though DDS readiness affects product effectiveness and process efficiency, managers should privilege initiatives affecting product effectiveness, more than process efficiencies, when looking for competitive advantage. An increase in product effectiveness has a higher impact on the competitive advantage than the same increase in process efficiency. In practice, managers looking for the most significant returns on their IT investments, specifically their DDS investments, need to prioritize initiatives that impact their goods and services' effectiveness. The positive outcomes obtained through the internal efficiency of processes

translates into competitive advantage unfavorably compared to initiatives directly impacting the product. This result stresses the need to seek big data opportunities beyond the IT department and through a synergic approach with new product development teams [40]. This may, in turn, require firms to consider big data investment for a more fundamental and transformational role [103].

## 9 Limitations and future research

This study enriches the literature on the business value of DDS and the competitive advantage of firms. While we provide evidence of the relationship between DDS readiness and competitive advantage through the mediation of product effectiveness and process efficiency, we cannot exclude the influence of other mediation effects. For example, the absorptive capacity [104] of companies, namely, the contextual ability of companies to translate change into performance, could play a mediating role, as could other managerial capabilities.

In this study, we specifically targeted senior IT managers and executives, as informants. While having access to a broader set of respondents for each organization, coming from different areas of the business, would have reinforced the confidence in our results, we believe that because of the focus on DDS initiatives, senior IT managers and executives are well placed to understand the impacts of a DDS initiative. In particular, they have the visibility of both IT-enabled product and process innovation, and the managerial experience to provide pertinent answers having developed, in the majority of cases, strategic, operational, and leadership skills (e.g., [105]). Furthermore, IT leaders have been shown to be at the forefront of digital innovation playing a significant role leading these strategic initiatives [106,107].

This study, even though robust from a methodological point of view, could be improved by longitudinally surveying the same companies to assess the consistency of the findings and the existence of time-dependent phenomena [108]. Future studies could also consider the moderating effect of additional variables, either organizational or environmental, as they may affect economic returns from investments in the industry in which these firms act.

## 10 Conclusion

This study represents one of the first attempts to measure the mediating effect of product effectiveness and process efficiency on the relationship between DDS readiness and competitive advantage. To fill the gap in the literature on big data readiness, with this paper, we answered the following research questions: “*To what extent does digital data stream readiness impact the competitive advantage of companies?*” and “*To what extent do product effectiveness and process efficiency mediate the relationship between digital data stream readiness and competitive advantage?*”. We investigated these research questions with a sample of 302 companies that received and completed a questionnaire.

Accordingly, this study’s main contribution is that it provides evidence of a significant mediating effect between organizational readiness to profit from DDSs and competitive advantage. The positive association of readiness and performance measure and support the need for a comprehensive approach to big data, extending beyond the boundaries of the IT department. We demonstrated that companies that can increase their process efficiency by decreasing development costs and accelerating time to market and are ready to enhance product effectiveness by improving product quality and functionality are better equipped than other companies to leverage DDSs for competitive advantage gains. Specifically, we identified that initiatives targeting product effectiveness are more likely to be associated with a firm’s competitive performance. These results assess, for the first time, that the positive outcomes obtained through the internal efficiency of processes, translate into competitive advantage unfavorably compared to initiatives directly impacting the product.

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## Appendix

*Table A1 Summary of the most relevant articles on Big data and Competitive advantage published in European Journal of Information Systems, Information & Management, Information Systems Journal, Information Systems Research, Journal of the Association for Information Systems, Journal of Information Technology, Journal of Management of Information Systems, Journal of Strategic Information Systems, Management of Information Systems Quarterly, to end of 2019.*

<b>Big data (independent)</b>	<b>Mediators</b>	<b>Moderators</b>	<b>Competitive Advantage (dependent)</b>	<b>Source</b>
Analytic leadership, enterprise-wide analytic orientation, well-chosen targets, extent to which evidence-based decision making is embedded in the DNA of the organization, functional fit of business analytic tools, readily available high quality data, analytical people, overcoming organizational inertia	Use analytic resources → Insights → Decisions → Intendedly value-creating actions that use the organisation's existing resources	Organizational Resources	Organisational benefits	[55]
IT-supported data infrastructure	IT-enabled agility → Advanced customer analytics capability portfolio → Improved customer lifetime value & customer equity		Strategic value	[43]
BDA infrastructure (BD assets, analytics portfolio, human talent)	BDA capabilities → Value creation mechanisms → Value targets		Impact (functional value, symbolic value)	[11]
Big data analytics use		Environmental dynamism	Asset productivity, business growth	[42]
Business intelligence & analytics	Absorptive capacity → Innovation ambidexterity		Firm performance (sales growth, ROA)	[18]
Portability and interconnectivity	Work practice-working with big data in practice, Organizational-Developing organizational models, Supra-organizational-dealing with stakeholder interests		Social and economic value	[109]
Motivational, operational, supporting mechanisms			Value realization	[53]



<b>Big data (independent)</b>	<b>Mediators</b>	<b>Moderators</b>	<b>Competitive Advantage (dependent)</b>	<b>Source</b>
Structuring big data and business analytics resource portfolio	Orchestrating big data and business analytics resources to build capabilities → Business capability for exploiting market opportunities → Value creation streams	Environmental uncertainty	Competitive advantage	[5]
Social media analytics, social media diversity		Firm size	Market performance (total sales)	[110]
Data quality (completeness, accuracy, format, currency)		Process sophistication	Competitive advantage (strategic performance, financial performance)	[54]
Business analytics competency	Organisational absorptive capacity → Business analytics assimilation		Competitive advantage	[13]
Big data analytics capability (tangible, human skills, intangible)	Dynamic capabilities, market capabilities, technological capabilities		Competitive performance (profitability, market share, growth, innovativeness, cost leadership, delivery cycle time)	[4]
Analytics resources (analytics technology assets, business analytics capability)		Analytics value enhancer, organizational level variables	Business performance (organizational benefits from analytics use, return on investment)	[95]
Big data analytics capability (tangible, human skills, intangible)			Market performance, operational performance	[3]
Digital Data Stream strategic initiatives	Process efficiency, product effectiveness		Competitive advantage	The present study