Data value creation during disruptive events

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Abstract

Medium-sized firms aspire to emulate larger corporations by enhancing their data-driven value-creation capabilities. However, previous research indicates that factors such as senior management attitudes, organizational culture, and preferred organizational learning capabilities also significantly influence data value creation. These factors are dynamic and evolve, particularly in response to adverse external conditions. This longitudinal study investigates two Canadian medium-sized enterprises in the electronic manufacturing sector, which experienced significant supply chain disruptions during and post the COVID-19 pandemic. Initial interviews were conducted with executives from these firms in 2017, pre-pandemic, and follow-up interviews were carried out in 2023 to understand the influence of their chosen organizational learning approach on data value creation and resilience in their data-driven transformation. Findings suggest that exploitation organizational learning capabilities appears to safeguard a firm's ability to sustain operational and strategic data value creation during disruptions. Conversely, exploration organizational learning capabilities seem to facilitate an increase in strategic data value creation during the recovery phase but has less impact on operational data value creation. Therefore, while there is a connection between data capabilities and data value creation, this link may not be taken for granted during periods of significant supply chain disruptions. Incorporating organizational learning capabilities into the study of value creation trajectories over time enhances our understanding of this process.

Keywords

Ambidexterity, supply chain resilience, data value creation [1]

1. Introduction

Supply chains in several domains were affected by various events in the last few years, but the supply of electronics components has been an exceptional challenge due to concurring events, which led to a decline in global sourcing of up to 22% by the end of 2022 [1], [2]. The rise of blockchain farming, floods affecting semi-conductors plants, the COVID-19 pandemic which considerably slowed down production, rising costs due to post COVID-19 economic start and the Suez channel incident all contributed to the difficulty for enterprises, especially smaller companies without a large buying power, to get the right components in time and at reasonable costs. While these turbulences are significant, nowadays it cannot be expected that they will be followed by a period of stability; instead, continuous perturbations are the norm, which means firms must build their adaptability and flexibility capabilities to be able to survive in a turbulent, continuous change environment [3]. Manufacturing flexibility is influenced by sourcing and delivery flexibility, themselves correlated with a digital transformation strategy and information processing capabilities [4]. Building data capabilities in the context of a digital transformation (DT) should allow companies to adapt their structure, including their technical infrastructure and their processes, in a continuous change logic [3]. Capabilities in information systems are the ability to repeatedly use organizational and technological resources in predictable patterns and are associated with value creation [5]. Thus, maintaining their data analysis and their data-driven digital transformation capabilities during turbulent times could help companies maintain their data value creation capacities. While external events affect all companies in a given industry, smaller companies, such as medium-sized enterprises employing more than 50 but less than 250 persons, have more limited financial resources than multi-national enterprises which may limit their ability to predict their requirements in inventories or maintain the development of data-driven projects when living through a crisis [6], [7]. Smaller firms also generally have a smaller margin of action when reconfiguring their resources is necessary, which means they often have a lower resilience [8]. There should however be a distinction made between medium-sized and

small-sized companies. The larger SMEs in the manufacturing sector are more likely to face uncertainty and turbulence in their environment by turning to information gathering practices [9]. Medium-sized companies are also more likely than smaller firms to invest in emerging technologies and to consider these investments a priority even in turbulent times [10].

This study aims to shed light on how the conditions specific to medium-sized companies may affect their capacity to maintain data value creation over a period of instability. We seek to address the following research question: *how do organizational learning capabilities influence the evolution of data capabilities and data value creation during supply chain disruptions?*

It is important to understand how the data value creation mechanisms evolve when firms face an unstable supply chain environment, a phenomenon that is becoming the norm [3]. It cannot be assumed that the behavior of firms and their entrepreneurs is stable and permanent in a turbulent environment [9]. To study the evolution over time of data capabilities and the impact of organizational learning capabilities, a longitudinal design is necessary, where the study time span over a turbulent, unusual event, as is the case with the electronic component supply chain between 2019 and 2023. This study would give valuable insights not only on the role of the various capabilities involved, but also in their timing, which could inform decision-makers concerning resources allocation challenges. The resources allocation question is especially relevant for smaller firms, especially medium-sized companies who do have financial and human resources to dedicate to data-driven transformation as a business survival and growth lever, but cannot invest in as many various areas as larger firms without trade-off [6], [10]. Practitioners and researchers both benefit from a better understanding of the consequences of such trade-offs, notably on data value creation at both an operational and a strategic level.

Since data capabilities depend on the existence of resources, for instance, infrastructure, support of an Information Technology (IT) team and support of the senior management [5], a common question managers make is related to what happens when external perturbations, such as supply disruptions, change the available resources in a company. Specifically, we seek in this study to look at how external perturbations affect the capacity of firms with limited resources, such as medium-sized companies, to continue to generate value with their data capabilities. Notably, how the firm's organizational learning capabilities focus, which dictates how resources and capabilities are developed and prioritized, influences either strategic or operational data value creation. For this, it is necessary to observe companies at different points in time: first, in a period of relative stability, then after a period of major supply chain perturbations. A longitudinal comparative case study design is thus adopted, to be able to contrast the situation of two companies with different approaches to organizational learning and a different management style of their data value creation resources. To maintain comparability, the two companies are in the same industry, operate in the same region, the same Canadian province, and were of comparable size at the first time point of the study.

In the rest of this article, in Section 2, we define data value creation and the various factors affecting it, notable organizational learning ambidexterity and the concept of resilience. Next, Section 3 depicts the case study design, followed by a description of the two cases at the study's two-time points. Then, Section 4 puts forward a discussion of the factors influencing data value creation and finally, Section 5 outlines the discussion.

2. Data value creation and data capabilities

Commonly applied in information systems to explain performance increases, the resource-based view assumes that firm-specific resources are used in a way that makes them hard for competitors to imitate to drive business performance [11], [12]. Value creation derived from the use of information technologies is dependent on technological resources, user support and organizational resources necessary for business processes [13]. This resource-based view of the firm should be understood to hold if the firm is studied within its context, such as its industry and regional characteristics [13] or considering other contingencies, for instance, a firm's resilience [8] or data analysis and organizational learning capabilities [5]. As information technologies evolve from being a functional part to being a potential driver of competitive advantage, the concept of digital strategy emerges to describe how digital resources are used as a lever to create value in firms [14]. This move towards digital strategies has created a data-driven transformation

in companies, that supports the reorganization of processes, structures and decisions [3]. Thus, data value creation is dependent on resources, mediated by data capabilities, which can be defined as the way resources are organized and used in a repeatable pattern [12], [15].

A further distinction is made between operational and strategic capabilities and value creation. Strategic capabilities are related to the characteristics of the organization, such as the identification of business trends or differentiation, while operational capabilities are more closely linked to process optimization or cost management [5], [8]. Finally, there are capabilities relating to how a firm will evolve and reconfigure its resources and data capabilities, either from exploitation, related to efficiency and developing what is there, or exploration, related to innovation, or a combination of the two, in an ambidextrous way [5], [16]. Ambidexterity implies investing simultaneously or in short succession in potentially competing resources in the search for an optimal point [17]. When firms such as medium-sized companies must share the same infrastructure, staff and management resources on both innovation and efficiency, resource allocation compromises may have to be made [7].

Most of the studies cited above were either cross-sectional or considered the relationship between resources and capabilities, and capabilities and value creation to hold over time. The contingency approach on which the model is based, however, implies that the context surrounding the company is relevant [8], [13]. In turbulent times, the agility and ability to adapt and reconfigure aspects of a firm's supply chain management are directly linked to performance [18]. Although supply chain disruptive events are rare, when they do happen they have dramatic impacts, even so when they happen in short succession [19]. Resilience refers to the capacity of a firm to bounce back, a capacity that, in the era of digitally transformed firms, is influenced by enabler data-driven technologies and capabilities [20], [21]. At different phases of a disruption, such as readiness, response or recovery, different antecedents influence the capacity of a firm to react to the disruption in different ways [21]. We suggest in this study that organizational learning capabilities impact data capabilities and data value creation differently at different phases of a supply chain disruption, and seek to understand how in an explorative study.

3. Research Design

Two Canadian firms in the same industry, manufacturing electronics goods, were heavily affected by the perturbations of the supply chain of electronic components that coincided with the COVID-19 pandemic while they were engaged in a data-driven transformation of their operations. They are currently in the recovery phase. A longitudinal, comparative design is used to contrast the factors in each case that influence the recovery of each company, and the evolution of their respective data-driven transformation capabilities and data value creation. With two measurement points, one before the supply chain perturbances in 2017 and one after, 2023, the longitudinal approach allows to study of the sequence of effect [22]. Meanwhile, the comparative design allows us to contrast the situation of two firms which had, at the beginning of the study, two different approaches to organizational learning. Comparative designs allow us to understand the differences in two cases despite similarities and draw conclusions on the probable cause of the divergences, which offers a comprehensive perspective based on its context [23].

In this study, the first company, nicknamed M1 (medium company 1), had at the first measurement point a heavy focus on exploitative learning, especially the improvement of internal efficiency as a value-creation mechanism. They realized comparatively few explorative learning activities, such as market expansions. The second company, M2, was comparatively a "jack-of-all-trades", splitting their efforts between exploration and exploitation as value creation mechanisms. This contrast within the same industry was the main motivation for choosing these two companies to study the differences between organizational learning approaches in value creation through data-driven transformation capabilities. Because the two companies rely on similar components and were in the same category of medium-sized enterprises at the first time-stamp, the supply chain perturbations they faced were comparable and allowed to contrast the other factors. The informant of M1 is the administrative vice-president, who has been working for years within this company. Amongst other responsibilities, this senior manager supervises the information technology team and champions digital transformation and data valorisation initiatives in the company, which makes them a key informant for this study. At M2, a period of

instability caused several changes in the management. Whereas in 2017 the interview was realized with the CEO, in 2023 another senior manager was interviewed, namely the director of development and service. This director manages the product development teams, which are seen in this company as the core value-bringer and the center of innovation in the company, and thus drive the data valorization initiatives. The change of interviewee introduces potential limitations in the interpretation of the perception-based questions, but reflects the profound changes the company faced in the last years, which must be considered in a study on the impacts of disruption. The definition of the OECD is used for a medium enterprise, employing between 50 and 249 people [24]. While both companies lost employees to a mix of layoffs and retirements without replacements, M1 saw an increase in their turnover thanks to an increased presence in its sector, while M2 brought back their turnover to the pre-pandemic levels after some rough years. It should be noted that both firms faced significant price increase from their materials and components, and thus, the increase of turnover of M1 does not translate to higher profits. Instead, both companies saw a diminution of their profits over the turbulent period.

The interview guide started with open-ended questions to get a better understanding of the context surrounding the data-driven transformation in the company, as well as questions regarding the consequences of the supply chain perturbations on their activities. Then came a series of statements concerning the factors in the theoretical model [5], which use perception-based Likert scales. Finally, in the last part of the interview, we came back to some aspects which were not part of the guide but could help form a comprehensive picture of the situation of the firm. The full list of questions is available on request.

For the content analysis of the open-ended questions and the commentaries of the interviewees in the later part of the interview, a mix of explorative and descriptive design were used [25]. A deductive, descriptive approach was used for the categories related to the path from resources and capabilities to data value creation, based on the theoretical model presented in the previous section. Elements of the interviewee's discourse were paraphrased then generalized and associated with the different categories to facilitate the analysis. An inductive approach was used when the existing categories did not properly explain the observed phenomenon, to take advantage of the richer context offered by the interviews. The perception scales are used to determine a level for the key variables of the conceptual models, informed by the contextual information derived from the rest of the interviews.

4. Results

In several aspects, M1 and M2 are similar. They operate in the same Canadian province but have customers worldwide. Both companies are developing turnkey solutions in addition to offering a catalogue of base products with personalization options. They have large design and engineering departments, from which a large part of the value creation comes. They have internal information technology teams and do not rely on outsourcing a lot to fill their IT support or development needs. At the first time point, in 2017, they had similar turnover and number of employees, although M2 in 2023 now fits in the small enterprise category. There are also many elements that differentiate the two companies.

4.1. M1: strong data management and operational focus

At M1, operational excellence and the manufacturing process were always at the core of the business. They are present in different sectors, notably healthcare and household electronic wares. In 2017, the projects they had planned in the context of their data-driven transformation was to leverage their Customer Relationship Management (CRM) software by including sales prediction models. They wanted to decline their Business Scorecard into more specialized variations for the lower hierarchical levels. At the time, the middle managers already had access to a customized list of Key Performance Indicators (KPIs), the main objective of the project was to give them more flexibility to explore the data relevant to their responsibilities. The core of their data-driven transformation would be the implementation of a Manufacturing Execution System (MES), to integrate data from the different manufacturing systems in a unique platform,

connected to the Enterprise Resources Planning (ERP) system. Having access to live data in the electronic manufacturing sector is a significant advantage considering the cycle time.

We are talking seconds, minutes per pieces. We still have work to do on the shop floor [concerning live data monitoring], but what is there is well implemented. I would say, the main problem is displaying the data.

At the initial time point of this study, the culture of data-driven decisions was well implemented. Data-driven transformation is part of the firm's strategy. Managerial performance indicators boards were already in place when the interviewee started working for the company, 20 years earlier. Data governance was regularly discussed at the board level, including discussing which indicators should be on the scorecard and how additional indicators could be computed, when relevant. The internal IT team at M1 is small, but answered directly to the administrative chief officer, thus the team has a business support orientation. The IT team manages the infrastructure, then the departmental managers develop their applications as needed.

We have processes concerning the network, which data can be stored where. After that, it's more decentralized.

They can also count on a centralized operational platform, their ERP, in addition to their KPI and scorecards that are regularly used in decisions, which means they have good data capabilities both at an operational and a strategic level.

[At the board level] we have around 30 indicators. It's enough for us, we can see what goes well or not. We follow internal performance.

Finally, concerning organizational learning, M1 had a focus on exploitative abilities. The product catalogue is kept up to date, and additional services and options are offered to existing customers or within the established target market. The priority of data transformation projects lies where they could help control operational costs. On the other side, while M1 does look for new customers, they have a growth objective they feel is reasonable for their capacity and are not looking to expand this capacity. They also did not focus their efforts on developing new lines of products or innovations outside of their identified core business. Overall, in 2017, the interviewer felt that M1 was in a good situation compared to the competition.

When we compare, we're not bad at all. I would say we are a little more reactive [than competitors].

In 2023, M1 is entering the recovery phase after several shaky years. There are still at the time of the interviews late orders and the sales are still slowed down, but the trend is reversing.

In the first year, sales were good, you know, because of hospital beds. We had increased our inventories of components based on our sales projections.

Eventually, the supply problems of the electronic components became a challenge and the inventories were consumed. Supply delays led to delivery delays, sometimes by several months. Most IT and data transformation projects were paused because being led by the different departments instead of central IT, the managers did not have sufficient time to manage the development projects in addition to emergencies. This led to delays in the major data transformation projects planned. Furthermore, they realized their ERP, dating from 2013, should be changed, since the one they had had been heavily customized to their needs, which meant the update was more complex. The ERP implementation should be completed next year and the MES project will follow. The new CRM, which is expected to support sales and development analytics capabilities, is also delayed and should be reevaluated next year. Their data-driven transformation investment, apart from the ERP, was focused on the integration of connected manufacturing equipment, which sends production data directly to the existing operational systems and will eventually be connected to the ERP.

We know what [data] we have access to, but we have to search a lot for it.

This situation leads to the evaluation of their level of infrastructure support to be lower than in 2017. The senior managers are aware of this and continue to set priorities concerning the data-driven transformation projects and the standards they should meet, according to the interviewee, a little more than before. Additionally, there were no major changes in the organization of the IT team. Concerning capabilities, despite the difficulties concerning the infrastructure due to being in between systems, the habit of basing both operational and strategic decisions on data remains. Data is available, even if managers need to look for it when the wished data is not included in the main KPIs. Thanks to the equipment investments, the capacity for real-time analysis of operational processes is higher.

Concerning organizational learning, their exploitative activities have not changed significantly. They invest a little more effort in explorative activities. As a response to the external perturbations, they seek to diversify the markets in which they are present, to mitigate the risks

involved in stagnation or complete stop of orders in a domain. The new markets should however stay within their product niche. This is to maintain the advantage over their competitors that their operational excellence is granting them.

The domain is really competitive, we are fighting over a couple of percentage points of market shares. We need to invest just to be able to stay where we are.

Thus, developing completely new products would represent a risk they are not willing to take. When discussing their business performance and the value they were getting out of their data transformation initiatives, the interviewee mentioned they feel the need to invest just to be able to maintain their performance, let alone increase it. From an operational perspective, the inventories are now kept higher to counter a possible new components crisis, which comes with additional storing costs. Although their turnover has increased, it is mainly due to material costs being much higher. They also have to make do with fewer employees and there is a transition plan in place for the family owning the company, which will likely lead to another period of potential instability. In summary, M1 managed to get through the crisis without major losses but did not get the improvements they were expecting in 2017.

4.1. M2: balancing efficiency and innovation while building for growth

M2 started the year 2017 with a major expansion of its presence on another continent, with a series of large contracts. Their lines of products and engineering teams had been consolidated to eliminate some less-performing products and focus their resources on the most profitable ones. The company was getting ready to introduce a new product line that would take advantage of data connectivity to offer additional services to customers and would reduce their dependency on physical electronic components. M2 is a comparatively smaller player in this industry dominated by a few giants, but still derived a competitive advantage from its design and engineering teams as well as a strong sales force. This focus is reflected in their management of IT and the resource distribution for their data transformation changes: support priority is given to operational systems, and the management is less supported. Vendors are also less supported individually; they rely on vendors who use different personal systems to gather their notes, contacts and other relevant market information, although a CRM is available.

IT will debug production systems as soon as possible, but they won't offer more advanced support, for instance with reports, and they don't take initiatives [to improve existing systems].

The data-driven transformation is thus led mainly by the business lines, be it the design teams for the products or the sales team for their own needs. Internally, the data transformation projects include inventory management for the electronic components based on predictive models, gathering and analyzing data concerning customer satisfaction, notably based on customer services (support, returns). They also want to promote the sales of data-based services. This is reflected in a major digitalization project that aims to gradually dematerialize one of their products, an infrastructure element of telecommunications networks.

We are trying to promote services around our products, to generate recurring revenues, based on data, but the lack of market data makes it hard.

An objective of the management is to gradually transition to mainly digital products which could be installed on a variety of computers, reducing the requirements of specific electronic components and greatly simplifying their supply chain management. Finally, a weakness identified by the CEO is the lack of data on the concurrence, which leads to the board having to make market orientation decisions without objective data, based on their perceptions.

If we go in this direction, we want data to show us this is the right way.

The senior management teams thus wish to orient the company to base more of their decision on data, but the decentralization of information systems projects makes this more difficult. There are a few established architecture requirements, but most of the projects are realized in silo, which makes integration of data difficult. For instance, to calculate the capacity of development teams to take on additional projects, the managers have to gather data from several systems into Excel. This means that while managers are careful to base their decisions on data, since no single central infrastructure is provided and in some business lines no or few KPIs are available, data is mainly used to identify the potential areas of improvements, on a strategic level, and have a lesser role in day-to-day operations. Regarding organizational learning orientation, M2 seeks to split its resources between exploitative and explorative activities. For instance, they continuously

improve their existing products with added features targeting both existing and new potential customers. They accept customization demands from their customers, even if this would take their products offering in a new technological direction. They seek to diversify their sources of revenues with service infusion. However, they are limited in their human resources, thus, they cannot invest a lot in either type of activity and have to balance the two. This balance means that while they have a good value creation out of their data transformation activities from an operational perspective, the lack of data on competition and the difficulty in analyzing data distributed in several systems diminished the potential strategic value creation.

In 2023, the situation at M2 has changed considerably. The company had financial difficulties that resulted in the loss of a major financial partner. Most of the management team was replaced or quit, including the CEO. This interview was realized with another senior manager, who already worked for the company in 2017. Then the pandemic forced a temporary stop to their activities, followed by the supply problems of the electronic components. At the worst of the crisis, the lead time on major components reached 52 weeks when the containers were stuck, which affected delivery times since M2 did not have sufficient inventory levels to fill all orders. When the back-up inventory was used, price increases had to be passed on to customers and some orders when cancelled or delayed. All non-essential projects were halted, including the data-driven transformation initiatives. At the time of the interview, in September 2023, M2 was still catching up on its backlog: the production department worked on orders confirmed in 2021. The interviewee attributes the survival of the company to the margin of profits before the crisis, which gave some margin of action to the sales teams to avoid increasing the prices as much as the increased price of the components. After lay-offs and voluntary departures, M2 has to work with less specialized developers than in 2017, which means the capacity to start again some of the paused projects is limited. Even if the company envisions a recovery period in the coming months, it seems unlikely to the interviewee that they would find enough developers.

Nobody who left stayed without a job for long; it's hard, we need very specialized skills, and the pool of developers is small.

The difficulties in the supply of components only cemented the idea that more digital, hardware-independent products are the right direction. This digitalization would allow them to develop new markets, instead of catering to customers in a mature market mainly buying products for their legacy, physical telecommunication networks. This project corresponds to a greater emphasis put on innovative development compared to 2017. Unfortunately, the project was delayed due to the departures of the two managers of the production department. The transition was made more complex by the lack of a centralized data infrastructure. While there is an ERP in place, it is not used at its full potential.

We got a bunch of Excel files and a database running on an outdated tech. Every time someone has to search for something we know it'll be a time sink.

In addition to changes in the senior management, the culture of data-based decisions was also affected. Looking in the different systems to find the information they need would be a considerable effort for the members of the board of directors, and they do not do it.

There is no "culture of data". We have a Jira for production and engineering, but [the board] doesn't look into it.

A project was recently discussed to introduce a user-friendly data exploration platform for operations, which could be made available to the board, but they have yet to decide which platform would be the most appropriate. This would help bridge the ERP, CRM and the various databases used in the different departments. A major change compared to 2017 was the addition of several employees to the IT team. The goal is to centralize the knowledge.

Concerning the evolution of data value creation, it is clear M2 has not yet fully entered the recovery phase, with a backlog in their production order book and sales that are not back to pre-disruption levels. The operational costs are lower because the workforce is smaller and with remote working, they could rent a smaller office space. These savings are largely annulled by the much higher material costs, not all of which have been passed to the customers. From a strategic perspective, despite higher delivery times, the satisfaction of the customers is rising, according to the impressions of the sales force. Notably, this is related to the new, more modern product offering and a quality level that stayed stable despite the disruptions. In the industry, their reputation is on the rise, despite internal difficulties. Their next challenge is to find their ideal platform that would replace both their EPR and their CRM in a more modern system, ideally with business intelligence and analytics capabilities.

We are constantly talking about it in meetings, but there is a reticence to getting a monthly-subscription cloud system, so that limits our options.

The main bloc is a cultural one, that might be solved by educating the managers on data-driven decisions and their advantages, as well as a convergence of expectations on the decision process.

5. Discussion

Initially, M1 showed high levels of the three types of resources: their senior management was closely involved in the development of data-driven changes and had a culture of making decisions based on data. Their data infrastructure was centralized and their IT staff supported the users, while letting the different work teams take the lead of the projects. Their data capabilities, both operational and strategic, were also high thanks to a culture of data-driven decision, real-time data analysis and business orientations based on market and customer data. Still, their operational and strategic value creation were only moderate, based on the perception of the interviewee compared to the competition and based on the evaluation of the researcher involved in the interviews. There are competing explanations. M1 in 2017 had a focus on exploitation activities, with a low focus on exploration. Organizational learning ambidexterity is thought to be a moderator of value creation, thus a firm with a low ambidexterity would have a lower benefit from its data capabilities [5]. Another explanation is given by the interviewee: the competitive environment is so fierce that it is necessary to invest a lot of resources simply to maintain its position. This is where the difference between medium and larger enterprises may be more apparent: for medium-sized enterprises, there are fewer resources dedicated to the development of data-driven changes when these changes are not part of the core business [7]. The managers responsible for data-driven changes split their time and efforts between the operations and the search for innovative solutions, which leads to fewer opportunities being captured.

In 2023 M1 maintained its position regarding operational and strategic value creation. On the one hand, it could have been expected that with higher operational and strategic data capabilities and more focus on innovation activities, value creation would have increased [5]. On the other end, M1 faced major challenges in terms of inventory supply, delivery time and production costs. In terms of anticipation of the disruption, M1 could count on predictive sales models that reacted as soon as orders started to drop. Their production and inventory management indicators also allowed them to react and increase the inventories to get a larger buffer. During the disruption, information visibility was made more difficult by the transition between the ERP, but was still possible, albeit with a little more work. The operational efficiency at M1 allowed them to adapt and stay afloat, although with higher lead times and lower margins of profits. These elements are known to contribute to the resilience of a firm to supply chain disruptions [19]. The challenges at M1 appear mainly in the recovery phase. The firm has the competencies and the information-sharing practices in place to help recover from the disruption, but the challenges considering the visibility of data spread across different systems and velocity of the systems (challenges in displaying real-time data, the MES implementation project being late) are key links that are missing for a prompt recovery [21]. In other words, the comparatively lower emphasis on explorative activities meant the data capabilities were developed with a more operational focus in mind, which impacted the development of more advanced analytics applications. These advanced analytics could have a moderating effect on the link between data-driven transformation and resilience capabilities [20]. M1 limited their potential value creation out of their data capabilities with a lower focus on exploration, but their exploitation level were enough to maintain their data value creation levels through the disruption.

M2 had in 2017 a low level of IT support, focusing mainly on maintaining the operational systems instead of supporting data-driven applications. This translated into lower operational data capabilities, as expected from the literature [5] since the employees of the various work teams had to develop their own applications, which were then not integrated with each other. Their operational value creation, however, was moderate compared to the competition, based on the interviewee per the researcher's evaluation. This could be explained by the ambidexterity of their development team, including their quality control team, since ambidexterity is known to be linked to several types of performance [17]. The development, based on short agile cycles, allows M2 to be flexible and adaptable in the development and delivery of products, which is linked to

more value derived from data-driven activities [18]. An inverse phenomenon may be observed on the strategic side. Despite a data-driven culture, central systems such as an ERP and a CRM being available and managers making the effort to use them, strategic value creation is low. The interviewee insisted at several points during the interview that data on the competition and the state of the market in general is hard to use, either because it is not integrated with the CRM, or because it is mainly a perception of the different vendors. Thus, despite good skills at using what they have, what they have does not appear to be sufficient to be able to anticipate market trends, and opportunities of new features or products or gain market shares.

In 2023, M2 derived less operational value from its data, a phenomenon that seems to be linked with the perturbations in the upper management that caused slowed or stopped operational data-driven transformation projects, combined with a low starting level of operational data capabilities. Operational data capabilities are directly linked to operational value creation [5]. Further, in the pre-disruption phase, operational skills such as inventory management, as well as information sharing and visibility impact the firm's ability to overcome a supply chain disruption [19]. At M2 some data concerning inventory levels related to expected production is available, but the visibility is low due to the systems not being convenient combined with a low level of integration, which means to get access to the indicators, data manipulation has to be done. Even if operational managers wish to be transparent and share information, in situations of emergencies the additional effort to compute the data and present it in a form useful for upper management is unlikely to be done. Strategic value creation has taken an opposite path at M2, despite operational problems caused by the supply chain disruptions. This is partly due to their new, innovative product family being less dependent on electronic components, and thus, the disruptions have a lesser impact on the development and production process. A similar phenomenon is observed in companies using additive manufacturing to gain flexibility and improve the ability to quickly reconfigure production [26]. In both cases, there is a reduction of the dependence on classical manufacturing and supply, based on innovative technologies. Still, the development of this product at this point was not a pure coincidence. For years the management at M2 has known this avenue represented a market development opportunity and has prepared its introduction. Innovation performance is influenced by explorative learning capabilities in addition to data capabilities [27]. The increase in strategic data value creation is the direct result of a focus on exploration capabilities.

Both firms increased their operational and strategic data capabilities over time, regardless of changes in the availability of resources. Organizational learning capabilities have also a tendency to augment over time. This suggests a learning effect, where the path of data capabilities is rising even with stable resources. The same cannot be said of value creation in the context of external perturbations, as sown in **Figure 1**.

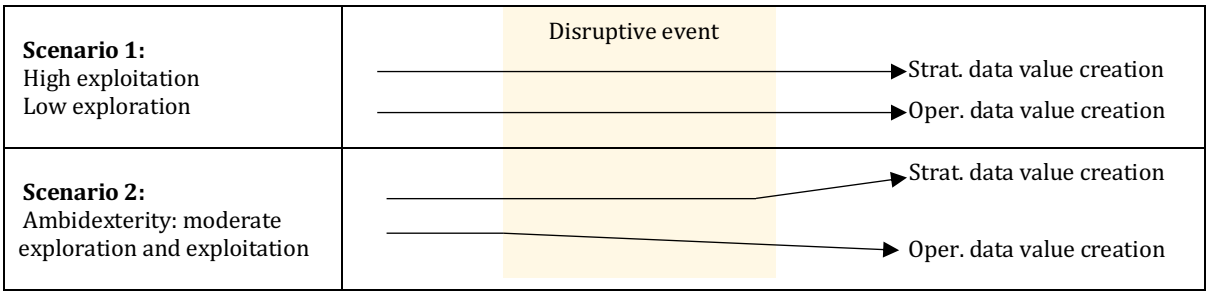

Figure 1: Effect over time on data value creation under disruption

In the first scenario, the focus on exploitation leads to constant data value creation during the disruption. High exploitation capabilities before and during the disruption seem to have a protective effect on firms' value creation out of data capabilities. Specifically, it seems to help shield the firm from the adverse effects of the disruption and help the firm maintain equal levels of value creation. While M1 benefited from this effect, at M2 compromises had to be made because of limited resources and explorative learning had to be maintained. The protective effect of high exploitation could be due to anticipation and early detection of the impact of the disruption on the manufacturing and delivery process, data visibility, transparency and information sharing seem to play a role. When the operational processes are more efficient, costs and processes are optimized and the firm is used to implementing gradual improvements, reconfiguration to adapt

to the disrupted situation is easier. Still, a firm which focuses neglects exploration risks becoming obsolete [17]. The management team at M1 is well aware of this, which is why efforts have been dedicated to augment explorative capabilities in the last few years.

In the second scenario, ambidexterity leads to a trade-off of a diminished operational data value creation during the disruption in favor of an augmentation of strategic data value creation in the recovery phase. Exploration capabilities seem to have a ramp effect in the recovery phase for strategic value creation, and based on M2, this effect may likely be felt even at moderate levels of explorative capabilities. From an operations perspective, M2 in 2023 is still in a recovery phase, with a production backlog of several months. However, the focus of the firm on innovative new products and developing new market segments has allowed them to continue to develop their brand. The satisfaction of their customers is rising and the firm has improved its market position both in terms of market share and in reputation in its industry. How this position would evolve over time remains to be seen, since long-term survival does require operational value creation, notably financial. A firm which has a high exploration level but comparatively low exploitation would be unlikely to be able to continuously capture the value of its innovations [17]. They could even see their performance impaired by this imbalance [16].

If a cross-sectional survey shows a direct link between data capabilities and value creation [5], [18], this study shows that more complex effects are involved when the evolution of data value creation is observed over time. This study also suggests considering the impact of exploitation and exploration at different phases of a disruption. When a firm is going through a disruptive event, particularly a medium-sized enterprise where those in charge of the data-driven transformation also have operational responsibilities, fewer resources may be dedicated to innovation and the focus will turn to operational efficiency. Having a higher level of exploitation capabilities before the disruption may help limit the value creation loss. The impact of exploration appears to be felt later, when resources can once again be dedicated to innovation.

The study is limited by the inclusion of only two companies of the same size, in the same industry. These similarities allow us to compare their differences concerning organizational learning capabilities, but generalization is not possible. In the same vein, the study included a company with a high level of exploitation and a low level of exploration, and a company with a moderate level of both. It would be interesting to include a company with a low level of exploitation and a high level of exploration, for instance, a young company with a heavy innovative focus, to see if the observed impact of organizational learning capabilities on data value creation is also valid for these types of company. Only one informant per company per time point were used, which potentially introduces personal bias, which is why care for taken to select informants most likely to provide insights on data value creation and digital transformation initiatives in their respective companies. Finally, although a detailed interview guide was used to ensure a sufficient variety of themes was covered, the study has the same limitation as other interview-based studies: there is a potential bias introduced by the interviewee or interviewer.

6. Conclusion

This study observed the evolution of data value creation of two medium-sized companies in the electronic manufacturing industry of a Canadian province at two points in time, first at the beginning of a digital transformation exercise in 2017, then in 2023 after a period of successive supply chain disruptions of electronic components due to the COVID-19 pandemic. If external perturbations such as supply chain disruptions were punctual events, a premise could be made that operational and strategic data capabilities are directly linked to respectively operational and strategic data value creation. The rare, punctual perturbations change the environment premise followed by a period of stability, however, is disputed in recent literature in favor of a model of continuous change with periods of turbulences [3]. Managers thus benefit from considering the role of organizational learning capabilities and researchers gain a better understanding of the value creation mechanisms over time by including. The current study is limited to two firms that share several similar characteristics. These common characteristics, however, are what allows the comparison based on the differentiating factors, notably the differences in organizational learning capabilities. This should be investigated in a variety of firms and industries to gain better insights into the precise role of organizational learning capabilities in a variety of contexts.

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