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Digital Transformation Through the Lens of Digital Data Handling: An Exploratory Analysis of Agri-Food SMEs

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This study aims to explore digital transformation and the level of sophistication in the digital data handling strategy by agri-food small and medium-sized enterprises (SMEs). By developing an exploratory multiple-case study that involves fourteen food processing SMEs, this paper identifies a data processing flow made up of the following phases: data generation, data acquisition, data storage, data analysis, and data exploitation. In addition, it shows how data processing flow may occur in a number of ways, thereby classifying the agri-food SMEs' digital transformation as paper master, digital wannabe, and digital champion. Hence, the article contributes to providing the conceptualization of a data processing flow, which includes the progressive stages in data management identified across firms by proposing a data handling strategy framework. Such a framework offers a snapshot of firms at various levels of digitization in their handling of various kinds of data, thus clarifying how the strategies of data processing flow occur.

Introduction

In recent years, digital transformation has radically reshaped the way in which firms develop business activities. Such a phenomenon encompasses the integration and application of digital technologies on business models, processes, products, organizational structures and customer experience thereby creating more value for the firm (Barnes et al., 2012; Hess et al., 2016).

Particularly, digital transformation has contributed to the outstanding proliferation of *native digital data*—directly caught in a digital form (Piccoli & Watson, 2008)—which are utilized by firms in production, and in the management of agile decision-making (Fachrunnisa et al., 2020; Moi & Cabiddu, 2021; Sykuta, 2016). As a result, to strengthen their commitment toward the adoption of digital technologies, firms advocate developing more sophisticated competencies (Reis et al., 2018), especially in the "extraction and exchange of data, as well as the analysis and conversion of that data into actionable information" (Schallmo et al., 2017, p. 4), to successfully address high competition and fluctuating customer demand (Reis et al., 2018).

The process of change initiated by digital transformation has been long associated with large high-tech firms (Loonam et al., 2018; Sebastian et al., 2017). However, it is increasingly evident how the phenomenon is also involving smaller firms in several industries, for example, health care, ICT, tourism, retail, and financial services (Pelletier & Cloutier, 2019). Technology adoption by small and medium-sized enterprises (SMEs) is found to facilitate collaboration and communication and allows such enterprises to reach greater operational efficiency (Barnes et al., 2012; Burke, 2010; Eiriz et al., 2019; Rosin et al., 2020).

Over the years, the pace of change triggered by digital transformation has risen to such extent that even agri-food firms, which are mostly represented by SMEs (Grau & Reig, 2021), increasingly rely on digital technologies (Fachrunnisa et al., 2020; Sykuta, 2016). The agri-food system is "the way in which people organize themselves, in space and in time, to obtain and consume their food" (Malassis, 1994, cited by Meynard et al., 2017, p. 330); hence, it encompasses a series of related activities (such as processing, retail, distribution, and consumption). There is a growing body of knowledge that examines how agri-food firms use digital

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technology to develop new food products (Burke, 2010; Eiriz et al., 2019). A number of researchers have shown how agri-food firms exploit technologies to perform specific tasks, such as tracking or collecting data. For instance, firms can adopt radio-frequency identification (RFID) technologies to track products or commodities throughout each stage of the supply chain, distribution, and delivery to consumers (Andotra & Dr, 2009; Gautam et al., 2017). Other firms employ agri-IoT (Internet of Things) frameworks to gather and analyze real-time data streams and provide smart solutions to support agile decision-making (Fachrunnisa et al., 2020; Kamilaris et al., 2016; Moi & Cabiddu, 2021). Extant studies have also elucidated the advantages of adopting certain types of technologies in the agri-food industry, such as achieving high storage capacity (e.g., Gautam et al., 2017; Kumari et al., 2015) or improving farming operations and management (e.g., Cane & Parra, 2020; Kamilaris et al., 2016).

However, despite the salience of this topic, it is still unclear how agri-food SMEs handle digital data and how they use information gathered from such data to improve their performance (Barnes et al., 2012; Bhaskaran, 2006; Ivers et al., 2016; Morris et al., 2013; Schweitzer et al., 2019). In particular, "there is a lack of standardization in the digital solutions concerning data, generating problems with data use because of the disparate formats. There is no clarity about the properties of the data, and with that on who will have access to them and what can be done with it" (FAO, 2019, p. 2). In summary, there is little empirical research examining how agri-food SMEs "embrace" digital transformation by considering digital data as a discriminating factor (Barnes et al., 2012; Hess et al., 2016). Thus, despite the availability of massive volumes of digital data, concrete answers to the implementation of a data processing strategy and its extensive use by agri-food SMEs remain rather ambiguous (Lehmann et al., 2012).

The present study tries to close this gap by empirically investigating how various agri-food SMEs use technology in data management. Therefore, the present study answers the following question: How do agri-food small and medium-sized enterprises manage digital data? To conduct this study, we follow a theory-building process and develop an exploratory multiple-case study research design with a focus on food processing SMEs (Eisenhardt & Graebner, 2007). With this work, we contribute to the literature on digital transformation focused on digital data management by providing the theoretical and empirical conceptualization of a data processing flow, which includes the stages of data handling identified across agri-food SMEs. Furthermore, we extend earlier research by proposing a data handling strategy framework that explains how firms might differ in their digital transformation based on the strategy adopted in their handling of various kinds of data. More specifically, the framework identifies three diverse levels of "sophistication": paper master, digital wannabe, and digital champion. This article also provides useful insights to managers and practitioners of agri-food SMEs. The proposed framework could help them to better assess their current stage in the digitization process, as well as what key actions are needed to facilitate the implementation of a more elaborated data processing strategy.

The remainder of this paper is structured as follows. First, we review the literature on digital transformation and digital data management with a focus on SMEs and the agri-food sector. After that, we present the details of our research design and the findings of our analysis. In the discussion section, we debate the study's theoretical and practical implications and highlight a number of avenues for future research.

Theoretical Background: Digital Transformation for Agri-food SMEs

Firms that successfully thrive in today's business contexts suitably deploy digital technologies (e.g., embedded devices, analytics, cloud computing) to reshape their business models or streamline their business operations (Fitzgerald et al., 2014). Indeed, digital transformation encompassing in-depth improvements in organizational resources, capabilities and outcomes driven by information technology (IT) influences all aspects of human life (Cha et al., 2015; Li et al., 2018).

Particularly, smaller firms have been facing an important revolution driven by digitalization over the last few years. The rapid growth of digital technologies and the large amount of data that devices can collect daily are increasingly driving SMEs to transform the business model through which they create and appropriate value (Frau et al., 2018; Pelletier & Cloutier, 2019).

Prior literature recognizes that technologies help SMEs induce major strategic changes, as well as better understanding, customer service and order processing (Li et al., 2018). Technologies support SMEs in improving their ability to be flexible and responsive to shifting market dynamics, thus increasing their competitiveness (O'Connor & Kelly, 2017).

Digital transformation represents a key growth path for SMEs in the contemporary economy, especially in the agri-food industry, which is dominated mostly by SMEs (European Commission, 2002; Garzoni et al., 2020).[1]

Agri-food firms are increasingly involved in innovation in terms of products and processes (Strøm-Andersen, 2020). The increasing demand for food products of greater quality and the necessity to optimize processes have forced firms to collect more data to increase the trustworthiness and capability of their manufacturing processes (Omri et al., 2020). In the modern manufacturing industry, manufacturers' ability to collect, store, and process data is significantly enhanced. Additionally, data analysis techniques have

1 In Europe, agri-food SMEs generate a turnover of 629 billion euros and 2.8 million workplaces for a total of 103 billion euros in added value (Grau & Reig, 2021).

evolved increasingly to valorize these data and extract knowledge from them (Omri et al., 2020).

In the agri-food industry, the extensive and ever-growing rate of technology adoption has enabled the rapid dissemination of large volumes of digital data from different sources and in different formats (for example, weather stations, social media feeds, and mobile phones) (Burke, 2010; Cane & Parra, 2020; Eiriz et al., 2019). These data are employed to extract useful insights to optimize processes, lower risk management, forecast market opportunities and trends, and improve agility in production and management decision-making (Fachrunnisa et al., 2020; Sykuta, 2016).

Regarding the management of data in the agri-food sector, data collection is supported by technologies such as RFID and agri-IoT. By using RFID technologies, firms can monitor and report real-time critical information on the entire food supply chain, building of safety controls, and traceability systems (Andotra & Dr, 2009; Magalhães et al., 2019). Notably, using sensors embedded with RFID tags, agri-food firms capture data on temperature, humidity, pH, the concentration of gases, vibration, and the presence of light (Gautam et al., 2017). The adoption of RFID to collect digital data offers several benefits for agri-food firms, such as greater efficiency and speed, accuracy, and reduced labor costs (Kumari et al., 2015). Even IoT platforms enable better acquisition of massive volumes of sensor data streams. The agri-IoT platform allows agri-food firms greater access to real-time data streams to manage operations, facilitate automation and the exchange of information among different components, and lower risks (for example, the risk of vendor lock-in) (Bollweg et al., 2020; Cane & Parra, 2020; Kamilaris et al., 2016). As remote-sensing technologies, the IoT considerably reduces human intervention in the measurement of spatial variability, farm conditions, irrigation planning, and harvesting, among others (FAO, 2019).

Thus, digital data are stored and made available for firms in different formats depending on the technology used. In the agri-food sector, firms can leverage technologies such as cloud computing and blockchain to perform data streaming. Cloud computing defines “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (for example, networks, servers, storage, applications, and services)” (Mital et al., 2015, p. 163). Through cloud computing architectures, firms can considerably reduce costs by quicker deployment of computer resources and improved information transparency (Gautam et al., 2017). Blockchain technology is defined as a “distributed database of records in the form of encrypted ‘blocks’ (smaller datasets) or a public ledger of all transactions or digital events that have been executed and shared among participating parties and can be verified at any time in the future” (Antonucci et al., 2019, p. 6129). Hence, blockchain technology improves food safety and security, thereby preventing food waste and ensuring source identification through traceability (that is, the authenticity of food products) (Ahmed & ten Broek, 2017; Antonucci et al., 2019; Magalhães et al., 2019).

Finally, for data analysis, firms may adopt a series of technologies that help in extracting information and knowledge to make more informed decisions on strategies and operations (Bollweg et al., 2020; Eiriz et al., 2019). For example, agri-food firms are increasingly focusing on big data analytics (BDA) applications (O'Connor & Kelly, 2017). Such applications help manage the massive volume of data generated, for example, by sensors or satellites, and help in sensing, monitoring, and optimizing farm operations (Faulkner et al., 2014). Indeed, “the tools that big data analytics can provide in the food production industry extend beyond providing transparency to consumers, as they can also provide stakeholders with new abilities including enhanced demand forecasting and increased optimization of procedures” (Astill et al., 2019, p. 244). Meanwhile, machine learning (ML) is a technology that “gives machines the ability to learn—from ‘experience’ (training data)—without being strictly programmed to perform a task” (FAO, 2019, p. 114). In the agri-food sector, ML facilitates functions such as crop, livestock, water, and soil management (Bollweg et al., 2020).

Methodology

The present study explores the digital transformation of various SMEs operating in the agri-food industry from the digital data handling point of view. Given the exploratory nature of this study, we adopted an exploratory multiple-case study research design to verify the replication of emergent findings in more cases and achieve greater generalization during theory building (Eisenhardt & Graebner, 2007). To conduct this study, we followed four pivotal criteria in qualitative research: credibility, transferability, dependability, and confirmability (Shah & Corley, 2006). *Credibility* concerns the validity of the researchers' interpretation. To ensure credibility, we constantly clarified our interpretation during the interviews and conducted a number of peer debriefings. *Transferability* concerns the high contextualization of information. To accomplish this criterion, we conducted interviews with strategic informers in different job positions (see Table 1 for the list of informers) to collect rich data from heterogeneous perspectives and took detailed notes about emerging concepts. *Dependability* regards the reliability of the whole research process. Such criterion was fulfilled in diverse ways. For instance, we protected respondents' confidentiality. Additionally, two of the coauthors analyzed and coded the data simultaneously and independently. Last, *confirmability* is about providing evidence of our understanding of the phenomenon investigated through the in-depth support of the gathered data. Regarding this aspect, we recorded and transcribed interviews and quoted interviewees' words repeatedly.

Table 1. Overview of the case studies

Case study	Business area	Case description	Size[a]	Informer	Data Sources	
					Primary	Secondary
1	Fruits and vegetable processing	The firm processes bio and local fruits to produce pulps, smoothies, juices, and vegetable products such as tofu, tempeh, and seitan.	Small	CEO	Interview, 38 minutes	3 web pages
2	Fruits processing	The organic farm produces and commercializes kiwis, citrus fruits, jams, marmalade, juices, and extra virgin olive oil.	Small	CEO	Interview, 35 minutes	4 web pages
3	Olive oil production	The firm is a cooperative of businesses that produce various kinds of extra virgin olive oil.	Medium	IT specialist	Interview, 38 minutes	3 web pages and 1 report
4	Dairy products	The firm focuses on dairy production, agricultural, and cow breeding sectors. It also produces raw materials and transforms sewage into electricity.	Medium	CEO	Interview, 43 minutes	3 web pages and a visit to the production plant
5	Dairy products	The firm is a cooperative of shepherds that deals with the transformation of cow milk obtained from the farms of members and the production and distribution of dairy products.	Medium	CEO; IT specialist	2 interview, 39 and 36 minutes	5 web pages and 1 report
6	Dairy products	The firm takes the highest-quality sheep milk and whey and processes it to obtain powdered products, combining the natural properties with the benefit of longer shelf life and high solubility.	Small	CEO	Interview, 41 minutes	3 web pages and 2 report
7	Dairy products	The firm processes milk and produces mature sheep and goat cheeses.	Small	Marketing Director	Interview, 44 minutes	2 web pages
8	Poultry products	The firm is a specialist in the poultry market. It manages the entire integrated production cycle: the selection of raw materials, rearing units, hatcheries, feed facilities, food processing, packaging, and distribution.	Medium	Head of IT & Digital Transformation; Head of R&D	2 interviews, 63 and 59 minutes	5 web pages and 1 report
9	Pasta and sweet products	The firm has been operating for over 30 years in the production of regional fresh and dry pasta and local sweets.	Small	CEO	Interview, 40 minutes	3 web pages and 1 report
10	Fresh pasta	The firm produces fresh pasta such as tortellini, ravioli, and gnocchi for its shops.	Small	CEO	Interview, 36 minutes	1 web page and a visit to the production plant
11	Fresh pasta	The firm produces fresh pasta such as tortellini, ravioli, and gnocchi for organized large-scale distribution.	Small	CEO	Interview, 37 minutes	2 web pages and 2 report
12	Dry pasta and rusks	The firm produces several types and shapes of dry pasta as well as various kinds of rusks.	Medium	Quality Manager; Head of R&D	2 interviews,	3 web pages and a visit to the

					68 and 55 minutes	production plant
13	Food supplements	The firm develops, produces, and markets food supplements such as amino acids, creatine, protein, and energy bars for athletes.	Small	Technical director	Interview, 47 minutes	5 web pages
14	Cured meat	The firm processes and sells top-quality pork products, and it is an important market player in a number of states of the European Union.	Medium	Managing director	Interview, 41 minutes	6 web pages and 5 reports

[a] Large business size: Staff headcount > 250; Average annual turnover > 50 mln€ or Balance sheet total > 43 M€; Medium-sized business: Staff headcount < 250; Average annual turnover ⩽ 50 mln€ or Balance sheet total ⩽ 43 M€; Small business: Staff headcount < 50; Average annual turnover ⩽ 10 mln€ or Balance sheet total ⩽ 10 M€. When the firm is part of a group, according to EU Commission Recommendation 2003/361, we considered turnover and total balance sheet data gathered from the holding 2018 consolidated financial statements.

Research Sample and Case Selection

In the study, we followed a theoretical sampling approach to select cases "which are likely to [...] extend the emergent theory" (Eisenhardt & Graebner, 2007, p. 537); in other words, cases that better address the theoretical purposes and the research question.

With few exceptions (Barnes et al., 2012; Ivers et al., 2016), digital transformation and digital data management were mainly studied in large and/or high-tech firms (e.g., Loonam et al., 2018; Sebastian et al., 2017). However, digital transformation has also progressively affected small and medium-size enterprises (Pelletier & Cloutier, 2019).

We chose to focus on Italian agri-food SMEs because despite their relevance in terms of income generation and employment rate worldwide (Strøm-Andersen, 2020) and the increasing importance of digital transformation, it is still unclear how agri-food SMEs handle digital data and how they use information gathered from such data to improve their performance (Barnes et al., 2012; Bhaskaran, 2006; Ivers et al., 2016; Morris et al., 2013; Schweitzer et al., 2019).

Requests were made to the leading Italian organizations dealing with digital transformation in the agri-food industry, a national public economic body, a private association of public and private organizations, and a research center yielding a list of firms. However, only 5 firms agreed to participate in the research. To extend the study sample of food processing firms, we obtained a list of 228 firms from the Italian Chamber of Commerce, 27 of whom consented to participate in the study. We then identified a final pool of 32 firms. To facilitate rich theory building and improve the generalizability of the findings (Eisenhardt & Graebner, 2007), we chose to include firms of varied sizes (small and medium-sized firms).

We analyzed the data using the theoretical saturation methodology (Saunders et al., 2018). Saturation occurred in the 14th case (Table 1).

Data Collection

To enhance the quality of our results, we combined data from various sources (Miles & Huberman, 1994).

We used semi structured interviews with key informants from the selected cases to gather primary data. They demonstrated in-depth knowledge of the organization's use of technology to manage digital data (for example, chief executive officers, information technology leaders, research and development managers, and digital transformation specialists). The interviewees for each firm formed one unit of analysis and were representative of their respective firms (Eisenhardt & Graebner, 2007). We used video calls as a medium to conduct interviews, thereby overcoming the social distance detected by the COVID-19 pandemic and to overcome the geographical distance between the researchers based in Sardinia and the interviewees located across various regions in Italy (for example, Calabria, Emilia Romagna, and Veneto).

We followed an interview protocol comprising seven questions to administer the semi structured interviews. The questionnaire explored how firms manage digital data, for example, how does the firm save/store data concerning food processing, and how does the firms use data on food processing? Interviews were properly recorded, transcribed, and coded. We conducted 17 interviews, administered for 14 case studies, each lasting between 35 and 68 minutes.

Then, we used NCapture, a browser application of NVivo software, to collect secondary data through official websites, online newspapers, and social media. Secondary data were also collected in the form of internal reports and meeting notes. Table 1 summarizes detailed information of our sample and the overall data collected.

Data Analysis

We performed both within-case and cross-case analysis (Eisenhardt & Graebner, 2007), and we ran them across four coding stages, moving from specific to more generalized codes (Cabiddu et al., 2018; Saldaña, 2015) (Figure 1). We used NVivo 10 software for coding and data analysis. Two of the coauthors were responsible for categorizing the emerging constructs and their relationships. At each stage, the coders individually and separately analyzed data and compared their categorization until they reached an agreement. We verified the robustness of the codes by running a *coding comparison query* and treated the inconsistencies until the value of the k coefficient was above 0.75.

We started with a preliminary within-case analysis of the 14 cases and their characteristics by reconstructing the summaries of individual case studies. Summaries were created by reviewing primary data such as interview transcripts and secondary data such as reports, and firms' web pages.

First, following a data-driven coding scheme, the data were grouped, and key codes were identified (Miles & Huberman, 1994). The outcome of this stage was a list of seven descriptive codes: technology adoption; digital data capabilities; seeking agile decision-making; pursuing efficiency; and using analog data, digitalized data, and native digital data.

Second, we started the abstraction process, categorizing new data under existing codes, grouping similar codes, or creating new ones. We then analyzed the previous descriptive codes, considering the interpretative codes based on the researcher's understanding (Miles & Huberman, 1994). This iterative process resulted in the identification of five higher-order interpretative codes: data generation, data acquisition, data storage, data analysis, and data exploitation.

Third, in the abstraction process, data generation, data acquisition, data storage, data analysis, and data exploitation were included in the general pattern of the data processing flow.

Finally, we compared the various steps of the data processing flow across cases by performing a cross-case analysis. As a result, we grouped the firms that similarly managed the data process into three ideal classes: **paper master**, **digital wannabe**, and **digital champion** (see Table 2).

In conclusion, our framework outlines the various stages in the overall digital transformation of agri-food firms based on the data handling strategy framework, which is the strategy adopted by firms in their digital data handling.

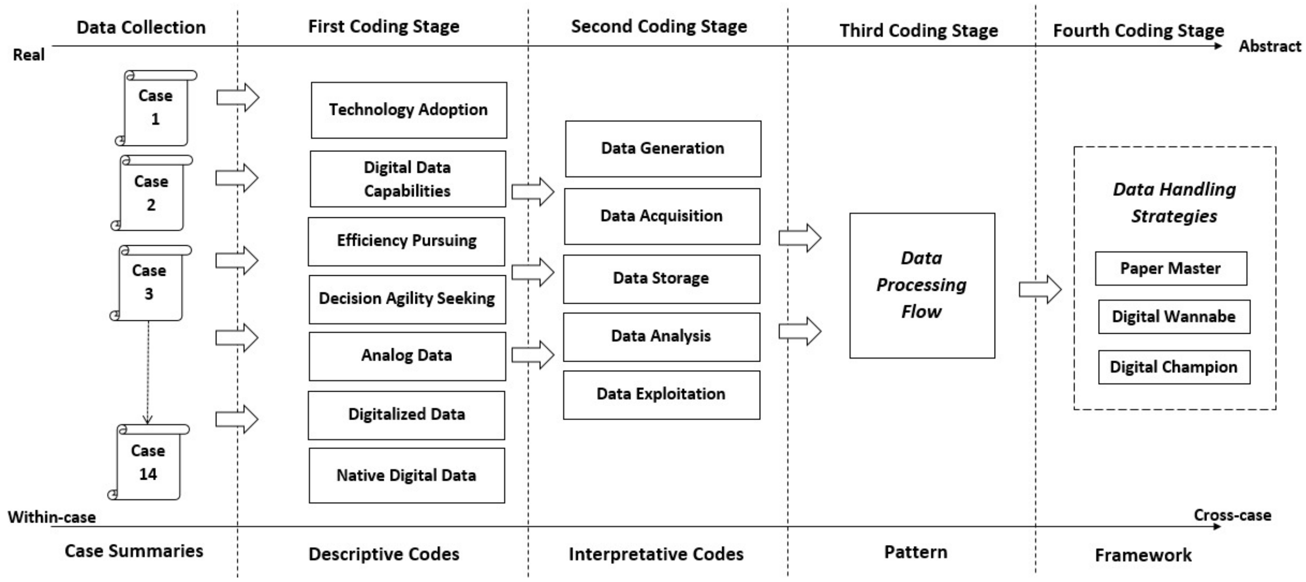

Figure 1. Data analysis process. Adapted from Saldaña (2015)

Table 2. Case study classification

Case Study	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Classification														
Paper master		X							X	X	X		X	
Digital wannabe		X	X		X		X	X		X			X	
Digital champion	X		X	X	X	X		X				X		X

Findings

Data Processing Flow in Small and Medium-Size Agri-food Firms

The outcomes of this study show that there is an extensive data processing flow representing the data pathway identified across agri-food SMEs. The data processing flow may be grouped into distinct phases, namely, data generation, data acquisition, data storage, data analysis, and the final phase of data exploitation, which is the use of data put in practice by the firm.

Data generation is the measurement of a physical quantity using machines when an event occurs and converting the data into numeric values. The study sample shows that small and medium-sized agri-food enterprises specifically generate three kinds of data: analog, digitalized, and native digital. The taxonomy reflects the heterogeneity in the range of data that firms can use to support their strategic and business decisions. ***Data*** are ***analogous*** when there is a machine such as a thermostat indicating a signal like a number, which is the measurement of a physical quantity, e.g., temperature: *"To detect the electricity consumption during a given production period, I ask the employee to check the electricity meter"* (CEO, Case-2). Conversely, we observed the generation of ***digitalized data*** in such cases where technology includes a more prominent role. Firms originally created such data as analogs, for example, barcodes and worksheets, and then converted them to a computer-readable digital format through computer tools, such as barcode scanners and keyboards: *"The employees write data related to the food processing in structured sheets. At the end of the process, the line coordinators input the data into the information system"* (Case-3, IT specialist). Finally, a highly sophisticated category of data is ***native digital data***. Firms directly create such data in a digital format through advanced technologies that communicate with each other, for example, RFID, GPS, automated systems for analyzing nutritional values, and IoT: *"Data are created thanks to sensors located in different points of the production process"* (Head of the R&D, Case-12).

Once generated, data become available, owing to the **acquisition** phase. Here, numeric values are transmitted by various means such as paper, cables, and Wi-Fi, to be saved for later handling: *"Data are transmitted through the optical fiber to the information system"* (Head of the R&D, Case-12). Data acquisition is a crucial part of the overall data processing flow. There are a number of ways in which data acquisition takes place. As a result, they not only directly influence the next stages of data processing flow, such as data storage, analysis and exploitation, but they also determine the data handling strategy an agri-food firm may adopt. We observed that data acquisition occurs manually for less technological companies. Nevertheless, even the more digitized agri-food firms face issues such as connectivity and data upload/back-up frequency. All these features impact the data quality downstream.

After the acquisition, data pass through the **storage** phase, where firms archive them into a medium: *"Our management software runs and stores data in an external cloud, therefore all data storage is done on an external server"* (Technical director, Case-13). A number of firms store data in paper, binders, and archiving rooms or use computer technologies, such as Excel sheets and hard disks. Others adopt more comprehensive systems such as servers, the cloud, or even blockchain.

Firms then analyze the data when necessary. **Data analysis** is the phase at which firms remove useless data from the data processing and transform clean data into helpful information for decision-making. Based on the kind of data obtained, firms may be able to analyze their datasets entirely or partially: *"We extract large quantities of production data from our databases and use business intelligence tools"* CEO, Case-6. Technologies such as BDA and ML play a critical role in data analysis, for example, Case-12 and Case-14. These technologies allow a wide range of sophisticated elaborations. For example, they predict the performance of raw materials or machinery maintenance.

Finally, firms **exploit** the insights extracted from the data analysis stage to support business decisions: *"We have a technology that exploits the milk conductivity to detect inflammations in cows' udders. This piece of information helps select the type of care for mastitis and how to manage sick members of the herd"* IT specialist, Case-5. Firms can exploit various pieces of data their type. For example, while analog data can help in making ex post decisions, such as checking what happened to many defective goods, native digital data aid in conducting real-time decision-making, for example, modifying the recipe in the middle of food processing to achieve a better output. Thanks to data exploitation and the degree of digitization level, agri-food firms can easily make decisions about a variety of issues, such as resource efficiency (Case-2), cost reduction (Case-6), production standardization (Case-12), and environmental sustainable production choices (Case-14).

The Data Handling Strategy Framework

Although, in general, the analyzed firms are committed to a data processing flow, empirical evidence shows that there is great heterogeneity across cases. In particular, the analysis shows that firms do not exhibit the same level of sophistication in the *data processing flow*. More particularly, the study recognizes the three main categories of firms: *paper master, digital wannabe,* and *digital champion*. This classification outlines the different strategies in digital data handling by small and medium-size agri-food enterprises. We synthesized such a classification in a theoretical framework for which several types of data processing flow strategies across cases are identified (Table 3).

Paper master. We define "paper master" as the agri-food firm that extensively uses paper-based filing systems at the end of the data processing flow to keep track of their food processing activities (Case-9 and Case-11). For such firms, digital transformation is still in a rudimentary stage. The cross-case analysis shows that paper masters often have no alternative other than using physical media to keep track of the main food processing aspects. For example, tracking quantities of raw material, temperatures, and electricity consumption, as their technological equipment **generates** mostly analog data. Hence, paper masters prefer to use paper to **acquire** data even when machines can generate them in a digital format: "*Data collection is manual, and there are many data that are detected by the machine, which can be downloaded onto a USB stick and then transferred to a computer, but... these measurements are written on paper,*" CEO, Case-9. Little use of digital channels is mainly due to the lack of digital abilities among employees: "*Often, even if you have particularly good workers if you ask them to turn on a PC... They know how to go on Facebook, they know how to post any kind of content... then you ask them to open an Excel sheet and upload some data, the panic starts!*" CEO, Case-9. Consequently, shallow digital skills lead to extensive use of paper in the firm, which leads to problems in smooth data processing flow. For example, analog data require a large **storage** space. Indeed, firms report analog data on sheets of paper and then file them in ring binders. Subsequently, they keep ring binders as archives on shelves in dedicated storage rooms. Thus, every time the firm needs to **analyze** analog data, a person must consult the archive, search the binder needed, and then bring it to the place where it is required. This process is time-consuming and expensive. Moreover, it is difficult to process analog data. Firms can examine them by looking at the records but need to digitalize them for further analysis. Thus, paper masters face huge challenges in **exploiting** such data. They can control when a problem occurs, but analog data provide minimal support to the decision-making: *"When we need to understand what happened with a batch of product, for example, 5 months ago, I have to take a log and scroll backward through the pages until I find what I need,"* (CEO, Case-11). Therefore, paper master firms are far from complete digitalization because of their extensive use of paper throughout the data processing flow. In the category of paper masters, we observed small firms (see Table 2).

Digital wannabe. In the context of the agri-food industry, "digital wannabes" are firms that endeavor to digitize data related to food processing activities to better manage the data processing flow (Case 7). Such firms are halfway toward digital transformation, as it is a step of transforming analog data to digital form. However, digital wannabes have different purposes for generating digital data. For example, some digital wannabes **generate** digital data to accomplish a specific requirement (Case-2, Case-10, and Case-13) such as a legal obligation, a specific request from powerful clients, or quality certification bodies: "*Many of our records such as heat treatments, ingredients used in production, products used in cleaning are kept to conform to the requirements for obtaining quality certifications,*" CEO, Case-10. Others, such as Case-3 and Case-8, are aware of the benefits of generating native digital data: "*I come from the ICT sector, I am perfectly aware of the importance of digital data. Even when data do not seem useful, after a while or when certain things happen... data become useful,*" CEO, Case-8. Digital wannabes exhibit a two-step data **acquisition** system. First, they transform analog data into physical media. Second, they digitize data using keyboards, manually input analog

Table 3. The data handling strategy framework

Phases of the data processing flow		Paper master	Digital wannabe	Digital champion
Generation	Data generation is the phase in which measurements (e.g., temperature, pressure, power, and speed) are made by the machines and converted into numeric values.	Firms use machines that can transform important food processing activities into quantified **analog data**.	Firms convert analog data into a computer-readable format (**digitized**) by operators (e.g., typing data and scanning).	Firms use machines to create **data** directly **in digital format** and immediately readable by computers and other technologies.
Acquisition	Data acquisition is the phase in which firms channel numeric values and make them available for manipulation.	Firms acquire analog data when they write them on paper-based filing systems.	Firms first channel digitized data in physical media and then acquire them through digital media.	Firms transmit native digital data from their sources and acquire them upon their creation.
Storage	Data storage is the phase of archiving data into a medium.	Firms file analog data on physical media (e.g., binders in an archiving room).	Simple technology (e.g., hard disk devices) allows storing the data in digitized format.	Firms save native digital data into clouds or owned databases.
Analysis	Data analysis is the phase of cleaning, exploring, transforming, and modeling data to create information.	Firms consult analog data by directly viewing the medium acquiring the data. Further data analysis is difficult to perform.	Digitized data can be analyzed using uncomplicated techniques and tools (e.g., Excel sheets).	Firms can process native digital data by exploiting complex techniques (e.g., business intelligence, data mining, and big data).
Exploitation	Data exploitation is the phase of employing information to draw conclusions and support decision-making.	Firms utilize analog data to verify what happened once a problem occurs.	Firms use digitized data to pursue efficacy. They check the food processing activities and employ correcting actions.	Firms employ native digital data for not only pursuing efficacy but also taking real-time decisions.

data into the information system, or scan paper sheets to obtain digital copies. Hence, in such firms, employees have at least basic IT abilities. Owing to the two-step data acquisition system, data **storage** deals with analog and digitized data. Therefore, the use of digitized data helps digital wannabes leverage digital transformation. For example, they have quick access to digitized databases, which can be **analyzed** anywhere when needed.

Furthermore, it is easier to employ digitized data by organizing them in a spreadsheet and run a calculation software on the spreadsheet to extract pieces of information and load such information into Excel and an information system. Moreover, firms **exploit** such information in operation management, for aspects such as better standardization of production and improved accuracy of quality control: *"We have several milk suppliers, all the data related to the milk analysis are [manually] uploaded to files and stored. We use these data to evaluate milk quality and decide whether to continue the commercial relationship with a milk supplier or not and estimate what price to pay for. Therefore, recorded data are used to make daily decisions."* Marketing Director, Case-7.

Nonetheless, the use of digitized data has limited applications when compared with native digital data. Firms use digitized data to verify whether production complies with planning and implement corrective actions if necessary. Moreover, the cross-case analysis in this study also shows that data digitization has "side effects." For example, digital wannabes suffer excessive costs of data analysis and exploitation, time-consuming data acquisition activities, and poor data quality because of errors in typing activity or missing information. Such problems may affect data processing flow at separate phases, which prevents digital wannabes from complete digital transformation. In summary, digital wannabes would strive to improve their digital conditions while they are in the middle of the digital transformation. In general, they struggle to digitize data, but their technologies and capabilities limit full transformation. A balanced number of small and medium-sized firms was classified as digital wannabes (see Table 2).

Digital champion. In this study, we define "digital champions" as agri-food firms that can make real-time decisions regarding their food processing activities, given a fast data processing flow fueled by native digital data (e.g., Case-1, Case-5, and Case-14). Digital champions are at the highest level of digital transformation, as their adoption of advanced technologies plays a pivotal role. The sampled firms adopted a number of technologies, such as anthropomorphic robots, remote-controlled machines, automated systems for analyzing nutritional values, machines for verifying the suitability of the recipe, and computer vision, such as defect recognition. The use of technologies such as IoT, for example, balances, thermostats, and water or electricity meter sensors, RFID, and various programmable logic controller hardware help **generate** data directly in a digital format from the measurements of the physical phenomenon, such as temperature, pressure, power, and speed. Thus, firms have native digital data available to them through their own creation, and they directly **acquire** data through cables (fiber optical) or wireless transmitted (GPS). Firms can analyze digital data instantly to produce real-time information. Otherwise, firms send native digital data to **storage** for future use and save them on clouds, hard drives, or servers (Structured Query Language databases): *"The data, directly in digital format, are stored on the company's internal servers,"* claimed the Head of R&D, Case-12. Digital champions own digital technologies such as BDA and sensory analysis applications to **analyze** data related to the entire food processing chain, from the supply of raw materials through sales: *"To give you some examples [...] number of hectares cultivated; the real-time quantity of product harvested by a machine; product humidity; in which warehouse must the product be stored, to whom and at what price should we sell the product or whether it is a product that is intended to be consumed internally and what use should we put it to [...]"* CEO, Case-4. Software such as information system, enterprise resource planning or management software supports data analysis, which in turn, uses techniques such as longitudinal analysis to identify correlations between the use of certain raw materials and the quality of outputs or the ML technique to predict performance, for example, maintenance. Firms use these advanced data analysis techniques to improve business decisions and strategies. Thus, digital champions **exploit** available information to make real-time decisions: *"Comfortably seated in our office, we receive a variety of information available in real-time. Based on this information, we advise the employee using the machine. So, it is a great advantage to have all these pieces of information available in real-time!"* said the CEO of Case-4. Digital data employed by the information system quickly generate accurate and easy-to-use information, which in turn, fuel agile decision-making. Digital champions reach a high level of efficiency because greater control of the production process improves quantity, speeds up production, and lowers costs: *"Based on the data collected during the production process, we look for a correlation between the flour mix and the finished product yield and quality. If we see that there is a negative trend, we can strategically choose to modify the flour mix. In contrast, if a production process has a very steady trend, we decide to have a longer production run to get a larger quantity and a better outcome,"* Quality Manager, Case-12. Nevertheless, in a number of cases, firms do not fully exploit the potential of digital technologies, such as Case-6 and Case-14. The lack of digital data capabilities negatively impacts digital transformation, thereby leading to digital involution: *"With the advance of working methods based on the use of technology, the lack of employees' ability to fully exploit the potential of modern technologies leaves the firm with many problems. Unfortunately, we use 30–40% of the potential of the technologies we have available because we do not have the right people to use them"* CEO, Case-14. Digital champion's category included medium-sized enterprises (see Table 2).

Even though we detected three distinct categories, we also observed another hybrid typology that can be seen as a transition from a digital stage to another more evolved stage: **Digital migrant**. We define a "digital migrant" as an agri-food firm that is creating and employing a double data system to keep track of their food processing activities and that is transitioning from a simple data processing flow to a more evolved one (e.g., Case-13 and Case-3). When moving from paper master to digital wannabe, digital migrants recognize the advantages linked with digital data but still acquire the appropriate technologies (Case 13). According to our analysis, the simultaneous use of analog and digitized data is typical of this digital migrants category of, as the CEO of Case 10 stated, "*We have a sort of dual data acquisition system... some technologies are already able to create digital data, with others we still rely on paper*". Our analysis also displays digital migrants transitioning from digital wannabes to digital champions when agri-food firms employ digitized and digital data at the same time. In this case, the dual data creation process is due to the coexistence of older and more modern technologies, as explained by the IT specialist of Case Study 3: *"In an old company like ours there are different levels of digitization in different areas of the firm. Therefore, being able to integrate data from different generations of technology is a complex process. This is an extremely important aspect of all firms that have production plants created over the years."*

Discussion

Building on past studies, the present study examined how data may be considered a discriminating factor to discern the digital transformation of small and medium-sized agri-food firms. First, we presented a theoretical and empirical conceptualization of the data processing flow, which includes the stages of data management identified across various agri-food SMEs. Second, we propose a data handling strategy framework, which highlights how firms might differ in their strategies of data handling, thus elucidating practical guidelines for driving agri-food businesses toward a digital transformation process.

The data processing flow. Previous research has advanced knowledge about how the phenomenon of digital transformation strongly impacted the agri-food sector, highlighting the increasing use of technologies for a number of purposes. Among them, considerable attention was given to the study of technologies adopted to track products, collect and analyze real-time data streams, optimize processes, lower risk management, forecast market opportunities and trends, and improve decision-making in production and management (Eiriz et al., 2019; Gautam et al., 2017; Kamilaris et al., 2016; Sykuta, 2016). However, extant studies have not explained how agri-food SMEs handle digital data and how they use information gathered from such data to improve their performance (Bhaskaran, 2006; Morris et al., 2013).

For firms involved in digital transformation, the empirical analysis performed in this study contributes to extending previous research by conceptualizing an integrated data processing flow that captures the different nuances of the digital transformation process using digital data handling as a discriminant factor. In other words, by looking at how firms manage data, the proposed data processing flow increases the understanding of whether agri-food SMEs embrace digital transformation.

More specifically, previous research in the agri-food sector, acknowledges that the different stages of data management, such as data collection, storage, and analysis are supported by the use of several technologies. For example, RFID and Agri IoT help to collect massive real-time data streams (Bollweg et al., 2020; Cane & Parra, 2020; Kamilaris et al., 2016; Magalhães et al., 2019), while cloud computing and blockchain technologies strongly support data storage to make digital data available for future usage (Antonucci et al., 2019; Mital et al., 2015). Furthermore, BDA and ML technologies are commonly used to elaborate data and extract more sophisticated information, thus supporting the decision-making process (Astill et al., 2019; FAO, 2019). In the agri-food industry, this study enhances previous studies, by showing that digital data stream takes the form of a more extensive data processing flow representing the data pathway identified across agri-food SMEs. Such a data processing flow is articulated in the following phases: data generation, data acquisition, data storage, data analysis, and data exploitation which describes the final practical use of data by the firm.

The data handling strategy framework. By developing the data handling strategy framework, this study explains how agri-food SMEs have various levels of advancement in terms of their digital transformation process. This shows the more advanced nature of some firms compared to others in managing their data processing flow. Thus, this study contributes to advancing the understanding of how agri-food SMEs handle and use digital data to improve their performance (Barnes et al., 2012; Bhaskaran, 2006; Ivers et al., 2016; Morris et al., 2013; Schweitzer et al., 2019), elucidating how data processing flow may shape different classes of firms based on the strategy adopted in data handling, namely, paper master, digital wannabe, and digital champion. The literature addressing digital transformation is mainly focused on the technology adoption part of digital transformation (e.g., Ahmed & ten Broek, 2017; Burke, 2010; Cane & Parra, 2020; Eiriz et al., 2019; Kamilaris et al., 2016; Kumari et al., 2015), and provides a partial view of such a complex phenomenon. Additionally, previous research on SMEs highlights that few firms are inclined to adopt automated data collection approaches (Andotra & Dr, 2009; Ivers et al., 2016). The study findings extend prior studies and show that small and medium agri-food enterprises exhibit great heterogeneity in the digitization process starting from the data they generate (analog data, digitalized data, and native digital data). For example, firms that use paper (paper masters) deal with a slow, expensive, and inefficient data processing flow. Conversely, firms that recognize the advantages of managing digital data are committed to digitizing their data (digital wannabes). However, such firms still encounter some problems in their data processing flow (for example, excessive costs of data acquisition). Finally, the present study shows that firms with the most sophisticated class of digital transformation are those that generate native digital data, which in turn, speed up the data processing flow (digital champion). In conclusion, scholars should not strictly see digital transformation as a sequence of stages. Some firms adopt a strategy like digital champions and manage digital data from the start. These firms have never belonged to the paper master or digital wannabe categories. Others are used to manage analog data (paper master) or digitized data (digital wannabe) and show little interest in transforming their data handling strategy to a complete digital transformation. Other firms are attempting to transform themselves, going through more advanced levels of digital transformation, seeking to redefine their strategies in handling data, thus improving the quality of data processing flow.

Managerial Implications

This study could guide managers and practitioners in terms of the practices that they should adopt in the implementation of an effective data processing strategy by enhancing their level of understanding of the digitization process. Greater awareness of the importance they should devote to developing their digital data handling is pivotal for addressing today's marketplace. Let us think about the rapid and unexpected changes that may occur in the industry, such as the digitalization of processes and activities that followed the lockdowns imposed by governments worldwide due to the outbreak of the COVID-19 pandemic. Managers who recognize following less advanced digital data handling should start taking a digitization path to prepare for and respond to ever-changing environmental scenarios. For example, if managers realize that they are at the digital wannabes stage; thanks to this study, they could understand how to move to the higher digital champions level, thereby generating native digital data across the entire data processing flow (for example, by adopting digital technologies in each phase of the flow). Therefore, to move along the digital transformation process, they should recognize that the process of fully exploiting such a phenomenon involves creating data directly in digital format. Hence, they should be provided with suitable technologies but more importantly should acquire key technological capabilities, such as digital data capabilities. Indeed, as shown in the findings of the present study, firms that own brand-new technologies cannot fully benefit from digital transformation because their human resources lack the appropriate technical skills in native digital data exploitation.

Limitation and Future Research

The exploratory design of this research has limitations that suggest further avenues for theoretical and empirical research on this topic.

Our research considers the production firm's point of view. However, digital transformation also involves a number of players within the food industry, and each player may affect the digitalization process differently. Therefore, future research could consider a multi-actor perspective to analyze the same phenomenon by involving software houses specialized in developing solutions for agri-food firms, digital data analysts, and machinery suppliers.

Moreover, we opted for a qualitative methodology given the exploratory nature of our research question. Among the constructs that make up the data processing flow and digital transformation development, antecedent, moderator, mediator, and independent variables can be specified, hypotheses can be shaped, and a model can be created. The hypotheses and model can be evaluated with quantitative methods such as structural equation modeling. This pluralistic approach to the research design and a focus on distinct contexts may be utilized to provide a more holistic perspective and further insights.

Furthermore, it would be interesting to investigate what could be the potential drivers of digital transformation. Future studies could further extend this topic to capture whether several types of drivers may also lead to various kinds of data handling strategies.

Additionally, in this study, we did not focus on the potential barriers or limitations to progressing with digital transformation. Future studies could increase our understanding of what types of constraints or limitations may hamper transformation efforts.

Finally, it would be interesting to update this topic in light of the recent COVID-19 pandemic. Indeed, it would be interesting to understand how deep of an impact the pandemic triggered in digital data management.

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