

# Article

# Technological Innovation and Circular Economy Practices: Business Strategies to Mitigate the Effects of COVID-19

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**Abstract:** The Corona Virus Disease 2019 (COVID-19) has been a tough test on companies in the global food sector supply chain, exacerbating the realities and deficiencies it presents in developing economies. This situation has been reflected in the firm's performance (F.P.) due to the lack of business conditions to respond to the current pandemic. However, in some companies, the adverse effects of COVID-19 have been counteracted due to endowment and technological capabilities. Thus, this study examined the role of technological innovation (T.I.) and business data analytics (B.D.A.) in the F.P. of foods in Ecuador during COVID-19. A questionnaire collected the information from the food firms. Then, Covariance-Based Structural Equation Modeling processed the collected information. We found that (B.D.A.) mechanisms and different levels of T.I. within the developing market significantly shape the F.P. The results showed that the B.D.A. enables circular economy (C.E.) practices and the improvement of product delivery services, which constitutes an improvement of the F.P. The COVID-19 outbreak did not significantly affect T.I., unlike what happened with B.D.A. This study concluded that firms with the most extraordinary technological production processes have been the least affected during COVID-19. This study suggested that policy measures should boost food firms' technological endowment to improve their resilience in uncertainty and risk scenarios.

**Keywords:** technology innovation; supply chain disruption; digital enterprises; business data analytics; firm performance

## 1. Introduction

The Corona Virus Disease 2019 (COVID-19) outbreak caused by the contagious virus SARS-CoV-2 has generated a series of changes in all supply chains' production, due to the various lockdown measures and mobility restrictions facing in Latin America [1]. The food supply chain has been one of the most affected by the COVID-19 outbreak, causing supply and demand mismatch. This situation worsened with the food supply chain's weak business structure and low resilience [2]. The effect of COVID-19 has caused a decrease in prices, difficulties in moving food between the various stages of the supply chain, an increase in production costs, and difficulty in mobilizing workers [3]. However, circular economy (C.E.) practices have contributed to our understanding of how upcycling [4] and recycling initiatives influence firms to gain a competitive advantage [5]. Alternatively, the C.E. may develop some novel practices to support sustainable development initiatives [6].

This situation causes setbacks to achieve the Sustainable Development Goal (S.D.G.) of food security globally, even more so in developing countries during the COVID-19 era [7]. Developing C.E. practices can counteract against the current environmental challenges, supporting a firm's performance (F.P.) [8]. Given the importance of C.E., there is little understanding of the extent to which technology innovation (T.I.) capability explains the F.P. [9]. T.I. has moved beyond its early success as an accelerator of innovation and is now being used to support sustainable development goals [10].

Furthermore, [11] suggests that innovation provides a path to sustainable development and an essential means for addressing infrastructure resilience for sustainability challenges. Despite recent interest in understanding big data analyst effects on the C.E. [12], research on how uncertain environments affect F.P. has lagged. B.D.A. is particularly important because it can impact the F.P. [13,14]. The application of B.D.A. generates several competitive advantages in the firm [15], such as adopting C.E. practices and delivery efficiency [16], which mean improvements in business performance. As proof of this statement, B.D.A. allows the adoption of advanced machine learning algorithms. Furthermore, B.D.A. improves product design by reducing waste, lowering the product's final cost, and improving integration and adaptation in the supply chain [17]. Similarly, [18] showed that the application of B.D.A. allows the design of ecological products, which allow easy recycling or reuse, representing savings in firm costs. Similarly, due to the restrictions on opening stores to serve customers, the companies implemented B.D.A. to deliver products through drones, thereby improving the firm's level of sales and benefits [19].

Nevertheless, there is limited understanding of how firms' internal capabilities affect F.P. [20]. On the other hand, [21] revealed that T.I. does not always significantly impact the F.P. Recently, [22] established a positive relationship between T.I. and environmental performance. For example, [23] found that T.I. provides successful knowledge integration and transfer opportunities. At the same time, there is a wide range of viable adaptation mechanisms that can be used to minimize the uncertainty, such as T.I. and B.D.A. There is a lack of empirical consensus on the effects of B.D.A. and T.I. on F.P. [24]. In this study, our focus was on why and when firms learn to integrate T.I. and B.D.A. to compete in the market and increase performance in a COVID-19 context fraught with uncertainty. We argue that, in the wave of an uncertain environment, the firm is likely to undertake different types of actions to improve performance. The problems of the functioning of the supply chain are not new, such as with the COVID-19 outbreak; firms belonging to the food sector are vulnerable, and their restoration is slow [25]. Therefore, this scenario raises a series of questions of a supply chain that must have a better response capacity [26] in the face of risk scenarios, such as the one generated by the COVID-19 outbreak. These decisions should be defined carefully to consider all the supply chain agents to guarantee an adequate food supply in the current pandemic [27]. Our empirical setting is Ecuador's food sector. For this reason, the objective of this research was to examine how T.I., B.D.A., product delivery efficiency, and COVID-19 policies contributed to the F.P. during the COVID-19 pandemic. For this, preliminary information from firms in Ecuador's food sector was used, compiled through a questionnaire. Subsequently, Covariance-Based Structural Equation Modeling (CB-SEM) processed the firms' information.

Our research contributes to the literature in some ways. First, our study provides robust results that help to understand the behaviour of food supply chain actors during the COVID-19 outbreak, which has been rare during the pandemic. In addition, due to the scarcity of information related to COVID-19, we have preliminary information from the supply chain agents, which were processed with rigorous statistical techniques that sustain its validity. Second, our study is motivated by the interest to understand the dynamics of a firm's internal capabilities better and by the desire to achieve F.P. during COVID-19. Previous research has investigated the pandemic's effect on F.P. We have contributed to the literature by developing an integrative framework of how B.D.A. and T.I. capabilities affect the F.P. in developing markets. We argue that T.I. capability with B.D.A. can improve food F.P. during uncertain scenarios. Third, our study seeks to advance the existing innovation

literature by explicitly exploring how firms respond in a pandemic environment. The F.P. in developing markets, such as Ecuador, is most significantly affected by T.I. The study supports a series of hypotheses described in Section 2. According to the detailed literature review, this study has been the first to be developed in Ecuador, allowing for the answering of several questions about the food supply chain in developing countries during the COVID-19 pandemic. Following the introduction, the research's structure is as follows. Section 2 contains the previous literature studies and the development of the study hypotheses. Then, Section 3 describes the data and methodology. Subsequently, Section 4 presents the discussion of results. Furthermore, finally, Section 5 develops the conclusions and policy implications of the study.

## 2. Literature Review and a Hypothesis Statement

The COVID-19 outbreak caused the F.P. in the food supply chain to depend mainly on aspects such as T.I. [28] and B.D.A. [29]. Business improvement through the use of Industry 4.0 technologies occurs because these improve resource efficiency and lead to the adoption of C.E. practices, representing increased profits for companies [30]. This situation is because the central aspect of the C.E. is the use and reuse of resources, based primarily on reduction and recycling. In addition, it is characterized by low consumption and discharge and high efficiency, with the sustainable use of natural resources, creating a maximum benefit in the firm [31]. Likewise, [32] indicated that the C.E. stimulates new lines of business and services, a reduction in inputs and raw materials, reuse of the waste produced, and lower costs. Finally, the adoption of computer mechanisms and platforms that allow for the tracing of products' routes is also the advantage of C.E. actions [33] that companies have implemented as a business strategy. This allows them to be differentiated, differences that are widely accepted by consumers [34].

Before the COVID-19 outbreak, several food firms had already opted for T.I. and B.D.A. as instruments to improve firm efficiency [35]. Therefore, the pandemic has constituted a scenario to demonstrate all the advantages of T.I. processes and B.D.A. in the F.P., since it improves response capacity and restoration in times of the COVID-19 outbreak [28]. Industry 4.0 technologies are promoted in pandemic times to mitigate adversity [36]. These have been artificial intelligence and robotization to replace labor shortages [37], big data analytics for the supply chain [38], and the Internet of things for C.E. [9]. In addition, B.D.A. (through deep machine learning, big data analytics, and high-performance computing (HPC), among others) contributes to the F.P., as it improves response capacity, resilience, and restoration during COVID-19 [29]. Firms that restored their way of selling products through e-commerce and improvements in product delivery have managed to increase their profitability [39]. According to [40], "the ongoing industrialization has led to enormous environmental challenges and issues from manufacturing industries" (page 7). However, for firms that have been able to re-emerge from the stoppage of productive activities, government assistance has been essential to remain in the market [41] to achieve sustainable development goals. In line with this, [42] argued that "unsustainable consumption practices increasingly manifest in manufacturing firms in developing countries, making sustainable development management failures evident and institutions relevant (page 89). To achieve sustainable development, firms need to develop organizational capabilities to reduce waste to make successful progress towards sustainability [43]. The COVID-19 outbreak has shown significant vulnerabilities in the food supply chain's resilience, because it has diminished some countries' food sovereignty [44]. The response capacity of some firms due to the pandemic has been slow. It affects the firm's results due to the perishability of grocery products, shortage of capital and workers, problems in the supply chain, and the decreasing return on investment [45]. Other firms, wholesalers, and retailers face uncertain scenarios due to the mismatch of supply and demand and low technology to respond to the food supply chain's needs that have been disrupted by the pandemic [2]. In these scenarios, the technological revolution is one of the main elements to counteract a crisis [46], and T.I. contributes to improving competitive advantage [47] and F.P. [22].

### 2.1. COVID-19 Policies and Firm's Performance

The containment measures to mitigate the adverse effects of COVID-19 were visualized immediately [48] since they directly affected the commercial operations of the companies [49]. The authors of [50] conducted a study in Wuhan after the COVID-19 outbreak. The authors found that due to lockdown and transfer restriction measures, the food supply chain was affected, representing a loss of 80% of the companies' income. Likewise, in India, [51] found that the measures to mitigate the spread of COVID-19, such as the lockdown or shortage of labor, meant alteration of market functioning and losses for food firms, compared to the previous year. In the same context in India, [52] found that fishing represented several losses due to the malfunction of the supply chain, which represented a loss on the exports of fishing companies. As there are restrictions to prevent the spread of COVID-19, the firm is limited to exporting food products. This circumstance is reflected in the publication by [53] in China. During February and March of 2020, all of the companies in the food supply chain recorded economic losses, mainly of agricultural products.

In the same way, small companies exporting agricultural products were affected [54], which registered significant losses; some others closed due to COVID-19 policies. The authors of [55] identified, in their study, that COVID-19 policies generated imbalances in demand in Africa, generating high economic losses in companies. On the other hand, [56] explained that due to COVID-19 policies, the food supply chain was altered, generating scarcity and rising prices, which meant significant losses for Brazilian companies.

**Hypothesis 1 (H1).** *The Corona Virus Disease 2019 has an inverse effect on a firm's performance.*

### 2.2. Business Data Analytics Applications and Firm's Performance

While it is true that T.I. allows for improvement of the productivity of the firm, nevertheless, the data analysis complements itself. It allows the firm to extract information on the market's behaviour and operations to adapt production and respond better to a pandemic [2]. B.D.A. contributes to the firm's adequate decision-making and final product quality, generating great added value to the firm and food supply chain [57]. It allowed firms in the sector to increase their response capacity and resilience by using information technology systems to be better prepared than other firms that lacked these technologies [29]. The management of firm data to understand the market's behaviour and the consumer is critical since it allows the firm to adapt its operations to the emergency [58]. Thereby, firms that belong to the modern food system have tools, such as big data or learning machines, to better respond to risk scenarios. These can generate behavioral forecasts using algorithms [59]. Since the pandemic altered the supply chain, big data analytics contributes to making forecasts to predict the behaviour of demand and supply, reducing the shortage or oversupply of products [60]. Otherwise, in developing economies where food firms do not have intelligent processes, such as big data, it leads to a minimal response capacity and leads to bankruptcy [61]. This beneficial scenario for companies is because the technological capabilities of big data in food companies is a conductor of the C.E. and the F.P. [62]. As proof of this, the study carried out by [63] found that the adoption of big data contributes to decision-making, which represents savings in the use of resources for the firm and, consequently, improvements in the monetary income of companies. Likewise, [64] examined the barriers to adopting the C.E. practices in Turkey. Their findings stated that big data solutions contribute to the implementation of clean production. Furthermore, [65] affirmed that big data contributes to exchanging information between companies to make joint decisions on the sustainable use of resources and improvement of sustainability, representing an economic benefit for the stakeholders.

Similarly, B.D.A. constitutes a business advantage aimed at improving the efficiency in the delivery of food products [66], since a high quality constitutes positive customer satisfaction and represents profit for the firm [67]. The authors of [68] mentioned that the efficiency of product delivery in China has increased notably since companies in the sector have developed applications to improve customer requirements based on big data. As a

result, their sales have increased. These findings agree with [69], who affirmed that home delivery service notably improves due to big data analysis. Since it reduces delivery times, it positively impacts customer satisfaction and improves business income.

**Hypothesis 2 (H2).** *The Corona Virus Disease 2019 positively affects adopting business data analytics.*

### 2.3. Technological Innovation and Firm's Performance

The resilience of the food supply chain has been strongly affected by the COVID-19 outbreak. However, the modernization of suppliers of food wholesale and retail firms through the Internet of Things (IoT) [70], blockchain, robotics, and others have helped these food firms not to run out of supplies [71]. Meanwhile, food firms with Industry 4.0 technologies are the ones that have shown the best response capacity, resilience, and restoration in the food supply chain at the time of the COVID-19 outbreak [36]. According to [72], “the generation of sustainable innovation can keep up the corporate sustainability agenda in a larger biophysical, ecological, and Human ecosystem” (page 9). Therefore, the T.I. and B.D.A. are essential for a modern firm to improve the food supply chain's sustainability and reduce the risk of adverse events, such as the COVID-19 outbreak [28]. An example is blockchain-based T.I. [73]. Thus, blockchain technology makes it possible to monitor production and reallocate the surplus supply of products and their new production. These advantages allow for a reduction of waste and contribute to the fluidity of the supply chain, which manages to reduce the risk of market shortages [74]. Besides this, the task automation in product crops (automation of irrigation, agricultural processing equipment) and processing plants (robotization in packaging or cold chains) are novel processes. Consequently, firms recover and face the shortage of handwork due to the lockdown and mobility restrictions due to the COVID-19 outbreak [28]. Other firms have based their T.I. on artificial intelligence to automate processes that require many workers, which has become scarce due to mobility restriction measures [75].

**Hypothesis 3 (H3).** *The Corona Virus Disease 2019 positively affects the adoption of technological innovation.*

**Hypothesis 4 (H4).** *Technological innovation improves the efficiency and effectiveness of business data analytics.*

**Hypothesis 5 (H5).** *Technological innovation has a positive effect on firm performance.*

### 2.4. Business Data Analytics, the Efficiency of Product Delivery, and Firm's Performance

Advancing innovative production systems for green production remains a crucial priority for manufacturers [76]. Similarly, efficiency in delivering products to the final customer is another characteristic of the F.P. and B.D.A., especially in responding to social shocks such as a pandemic [77]. In times of the COVID-19 outbreak, efficiency in delivery allows for overcoming labor shortages and food waste and efficiency in the last mile delivery of food [39]. For example, food firms have looked for alternatives to deliver products using drones, which respond to transport difficulty or customer lockdown [25]. Since the definition of lockdown policies and the restriction of mobility, the firms have decreased sales. However, their ability to respond to the emergency and the food delivery service both improved due to technological applications and electronic commerce that allowed for offering products without customers' need to consume physically at the sites [36].

Above all, firms seek to restore themselves through the ability to deliver food products due to the market's new characteristics. Thus, the increase in sales of Italian retail firms during the pandemic is because these offered their products through the online market [78]. In turn, there were severe changes in jobs in the restaurant sector, and some small restaurants closed; restored restaurants are those that managed to stay on the market. The online ordering system became a contact mechanism with their customers, which allowed them

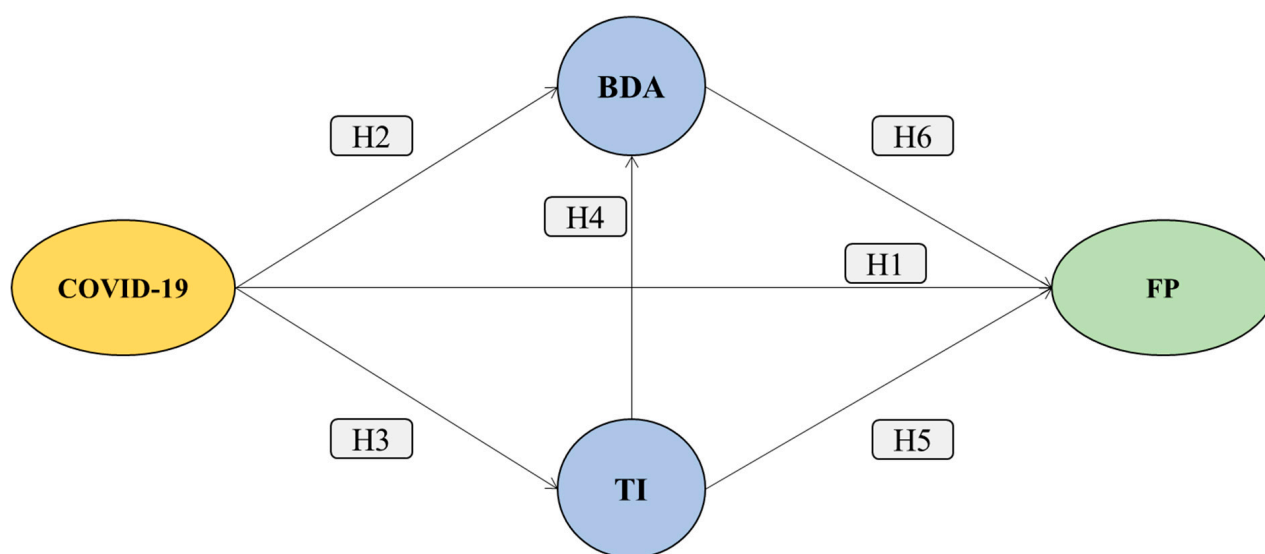
to stay in the market, covering their operations [79]. However, the online ordering system does not constitute a 100% guarantee that their sales will increase.

Nevertheless, the customer's perception values aspects such as waiting time or the type of transport through which the ordered products are delivered [80]. These initiatives are because firms have implemented digitization, and they adopt greater importance in restricted mobility where there is a great physical distance between sellers and end consumers [81]. Another delivery mechanism is the "shared store". It consists of hiring inactive people from other sectors to store food products and provide food to customers close to their location using mobile applications [82].

**Hypothesis 6 (H6).** *Business data analytics has a positive effect on F.P.*

### 3. Data Source and Research Methods

The present research aimed to examine the relationship between the COVID-19 outbreak and the F.P.; for this reason, a questionnaire was developed and applied to 344 firms belonging to Ecuador's food supply chain. Table A1 contains the description of the questionnaire applied to the firms. Subsequently, the information collected was processed using econometric techniques that facilitated primary information and examined the relationship between constructs based on the information generated by their factors [83]. Furthermore, it allowed simultaneous investigation of various relationships between interrelated constructs [84]. Besides this, to verify the factors and constructs, statistical tests of the convergent and discriminant validity criteria were performed to determine the model's suitability to be investigated [84]. Figure 1 indicates the proposed model.



**Figure 1.** Proposed model. Note: COVID-19 = Corona Virus Disease 2019 outbreak. BDA = Business data analytics. TI = Technological innovations. FP = Firm performance. H1–H6 = Hypothesis 1–6.

Thus, this research used covariance-based structural equation modelling (CB-SEM) to examine the relationship between constructs [85] and the effects of latent interaction and moderation [86]. The CB-SEM approach potentiates the independent variables' indicators, managing to generate moderating variables to measure the level of interrelation in the route model [87]. Consequently, CB-SEM allows for having a baseline to examine the factorial structure [85]. Furthermore, CB-SEM makes it easier to relate several variables with their factors, improve the robustness of the estimators, optimize the results for the interpretation of the interaction effects, and efficiently control the measurement error [88].

## 4. Results

### 4.1. Model Measurement

The measurement model is used to corroborate the latent constructs' validity, reliability, and dimensionality [89]. Dimensionality establishes that a series of characteristics or factors must represent a construct's measurement; that is, a set of features must explain a variable [90]. These characteristics are the factors that define the construct [91]. In other words, the constructed variables must comply with the convergent validity [92] and the discriminant validity [83]. Table 1 shows that each indicator's loading factor value is more significant than 0.6 [93]. It indicates that the indicator is valid; otherwise, it should be eliminated as an instrument to determine each construct [84]. Likewise, the values of the constructs obtained by Cronbach's Alpha and Composite Reliability (C.R.) are higher than 0.7, as well as the values of Average Variance Extracted (AVE), which are more significant than 0.5 [94].

**Table 1.** Reliability and Convergent Validity.

Variables	Indicator	Factor Loading	Cronbach's $\alpha$	CR	AVE
COVID-19					
Personal perceived risk (aa1)	The situation of COVID-19 is much worse in the workplace, and the health is at risk.	0.787	0.855	0.861	0.633
	An employee is willing to go to the workplace, but his family's health is at risk.	0.862			
	If an employee does not go outside, he and his family will suffer from a shortage of money.	0.841			
Policies (aa2)	Wearing a mask makes him uncomfortable in the workplace.	0.856	0.915	0.919	0.834
	Body temperature checks at the workplace increase his stress level.	0.901			
	Lockdown's policies put his life in great difficulty.	0.906			
	Frequent use of sanitizer increases anxiety at the workplace.	0.912			
Business Data Analytics Applications					
Delivery (bb1)	Online product offering improves product delivery efficiency.	0.889	0.931	0.925	0.731
	Efficient information management reduces product delivery time.	0.922			
Circular Economy Practices (bb2)	The firm's production process prioritizes the consumption of raw materials and energy.	0.811	0.889	0.901	0.714
	The firm's initiative improves the energy efficiency of production equipment.	0.834			
Technological Innovation					
Information sharing ability (cc1)	The firm uses technologies in production processes.	0.841	0.832	0.817	0.628
	The application of technologies generates information on the production processes.	0.879			
	Having more information contributes to proper decision-making.	0.838			
	Artificial intelligence applications help workers' tasks.	0.877			
	The use of software helps the processing of large amounts of data.	0.849			
	Technology allows for the obtaining of reliable information on the production process.	0.792			
	The firm shares information digitally.	0.812			
	The adoption of technology improves the use of resources.	0.872			

Table 1. Cont.

Variables	Indicator	Factor Loading	Cronbach's $\alpha$	CR	AVE
Coordination ability (cc2)	The use of technology makes it possible to improve the delivery and receipt times of products.	0.842	0.868	0.884	0.771
	The use of technology improves the processes of transport, distribution, and storage of products.	0.865			
	Technology reduces the costs and management time of the firm.	0.816			
	Technology improves sales coordination among agents in the supply chain.	0.834			
	The use of technology improves the efficiency of the firm in the supply chain.	0.852			
	Technology allows for a redistribution of product delivery and reduction of waste.	0.798			
Integration ability (cc3)	Technology allows the firm to predict market demand.	0.863	0.791	0.856	0.737
	Technology improves the design of new products.	0.876			
	Technology allows for improvement of the firm's response to adverse natural events.	0.844			
	Technology allows flexibility and improvement of the operational processes of the firm.	0.937			
Firm Performance					
Profitability (dd1)	There is a decrease in the consumption of energy, water, and other supplies in the workplace.	0.876	0.848	0.865	0.729
	Increase in daily sales.	0.858			
Market share (dd2)	The firm can quickly modify its organizational structure to respond to business conditions.	0.834	0.862	0.769	0.684
	The technology allows for the coordination of the delivery of products with third parties.	0.751			

Note: CR = Composite reliability. AVE = Average variance extracted.

On the other hand, the [95] criterion examines the correlation of the latent variables with the square root of the AVE values. These values are greater than the correlation with another construct of the model, as shown in Table 2, that is, the discriminant validity of the variables was confirmed [96]. For this reason, it verified that the items and constructs met the convergent and discriminant validity and reliability criteria [97].

Table 2. Reliability and Discriminant Validity.

	Delivery	Circular Economy Practices	Information Sharing Ability	Coordination Ability	Integration Ability	Profitability	Market Share	Personal Perceived Risk	Policies
Delivery	<b>0.855</b>								
Circular Economy Practices	0.599	<b>0.845</b>							
Information sharing ability	0.495	0.659	<b>0.793</b>						
Coordination ability	0.544	0.621	0.794	<b>0.861</b>					
Integration ability	0.533	0.679	0.790	0.654	<b>0.878</b>				
Profitability	0.631	0.553	0.627	0.543	0.767	<b>0.854</b>			
Market share	0.480	0.591	0.569	0.601	0.740	0.779	<b>0.827</b>		
Personal perceived risk	0.370	0.666	0.418	0.494	0.580	0.700	0.527	<b>0.796</b>	
Policies	0.387	0.533	0.491	0.481	0.625	0.373	0.565	0.793	<b>0.913</b>

Table 3 describes the model constructs' validity and reliability, confirming an acceptable model measurement fit and fitting the collected data [79]. The results showed compliance with the parameters, and the chi-square/df ratio ( $\chi^2/df$ ) was less than 3. The

root mean square error of approximation (RMSEA) was less than 0.08; the goodness-of-fit index (G.F.I.) was higher than 0.9. Furthermore, the adjusted goodness-of-fit index (AGFI) was higher than 0.08; the normed-fit index (NFI) was more significant than 0.9. Similarly, the Tucker–Lewis index (TLI) was higher than 0.9, and the comparative fit index (CFI) was higher than 0.9. These tests that corroborated the validity and reliability of the constructs and their factors allowed us to continue estimating the CB-SEM.

**Table 3.** Goodness-of-fit of structural equation model.

Fit Index	Chi-Square/df	Root Mean Square Error of Approximation	Goodness-of-Fit-Index	Adjusted Goodness-of-Fit-Index	Normed-Fit Index	Tucker-Lewis Index	Comparative Fit Index
Recommended criteria	<3	<0.08	>0.9	>0.80	>0.90	>0.90	>0.90
Model results	2.611	0.061	0.911	0.837	0.932	0.945	0.946

#### 4.2. The Structural Model

After validating the questionnaire’s suitability for firms in the food supply chain, the next step was to interpret the model’s coefficients. Table 4 presents the coefficients of the regressions obtained by CB-SEM. Faced with the appearance of the COVID-19 outbreak, the personal risk of contagion and the lockdown policies directly affected the F.P. However, B.D.A. and T.I. have played a vital role in F.P. during the COVID-19 outbreak, in which firms have had to adapt the “new normal” [98]. Figure 2 presents a graphic abstract of the results found.

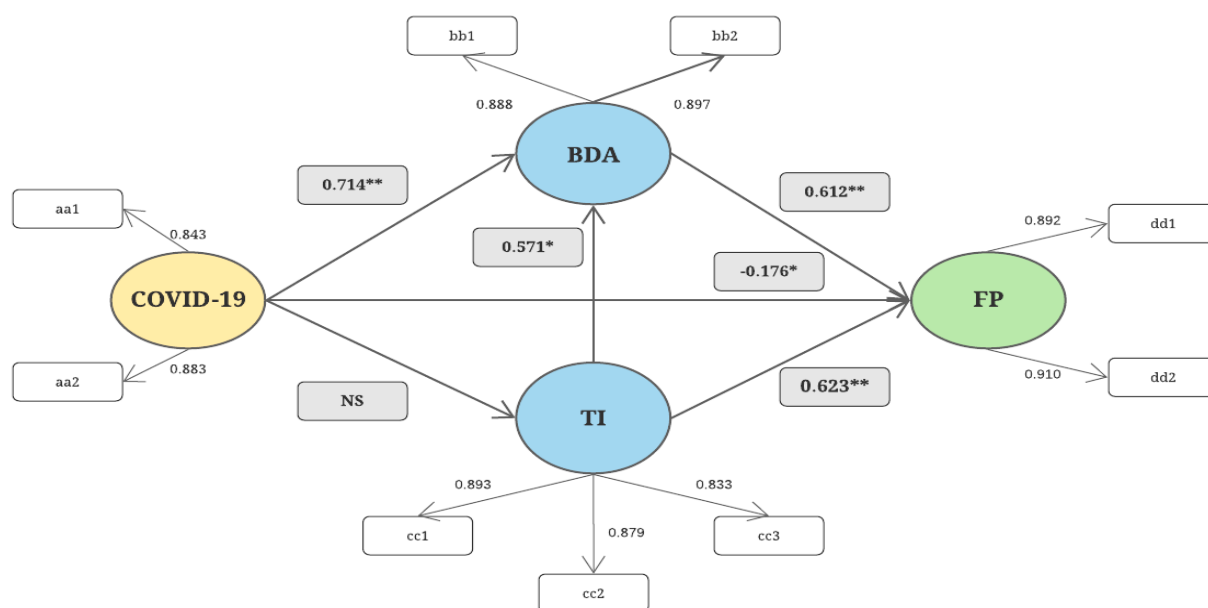
First, the COVID-19 outbreak showed a positive and statistically significant relationship with B.D.A., confirming the validity of H2. These findings are corroborated by [39], who indicated that the B.D.A. became a business strategy in food products firms and took greater prominence during the pandemic. This is because B.D.A. improved food firms’ response to market uncertainty caused by the COVID-19 outbreak. B.D.A. applications, such as machine learning, deep learning, or big data [59], contribute to generating behaviour models or predicting supply/demand in risk scenarios [60].

Furthermore, COVID-19 had an inverse and significant relationship with F.P., confirmed by H1. As an evident situation that has become widespread worldwide, it has caused firms’ profits to decrease due to the standstill of economic activity. In other cases, it has led to several firms closing their operations. This situation happened in a very adverse scenario for firms with an insufficient response capacity to adapt to an economic recession. Most of them did not have a mitigation plan to handle an eventuality caused by the COVID-19 outbreak. The results showed that COVID-19 caused workers not to attend their workplace for fear of contagion of the disease, causing a decrease in the operating capacity of the firm and a decrease in sales.

**Table 4.** Standardized parameter estimates for the structural model.

Hypothesis	Paths	Standardized Estimate	p-Value	Results
1	The Corona Virus Disease 2019 has an inverse effect on firm performance.	−0.176 **	0.003	Supported
2	The Corona Virus Disease 2019 has a positive effect on the adoption of Business data analytics.	0.714 **	0.001	Supported
3	The Corona Virus Disease 2019 has a positive effect on the adoption of technological innovation.	0.823	0.454	Not supported
4	Technological innovation improves the efficiency and effectiveness of business data analytics.	0.571 *	0.021	Supported
5	Technological innovation has a positive effect on firm performance.	0.623 *	0.026	Supported
6	Business data analytics has a positive effect on firm performance.	0.612 **	0.000	Supported

Note: \*\* and \* indicate significance at 1% and 5% respectively.



**Figure 2.** The results of the S.E.M. model. Note: COVID-19 = Corona Virus Disease 2019 outbreak. BDA = Business data analytics. TI = Technological innovations. FP = Firm performance. aa1 = Personal perceived risk. aa2 = Policies. Bb1 = Delivery. bb2 = Circular Economy Practices. cc1 = Information sharing ability. cc2 = Coordination ability. cc3 = Integration ability. dd1 = Profitability. dd2 = Market share. Note: \*\* and \* indicate significance at 1% and 5% respectively.

In the same way, COVID-19 policies, such as lockdown, meant that workers could not move normally to their workplace, which hindered the availability of labor and the malfunction of firm activities. These results are consistent with [99]. They mentioned that government measures of COVID-19 (lockdown and mobility restriction, among others) affected the performance of food firms, since they did not allow the mobility of labor or the transfer of products from small producers. Furthermore, the profitability of the food products firm was affected by the COVID-19 outbreak, and this was due to transport restrictions. On the contrary, in India, China, or the United States, there were financial aid policies for fishing [52], which contributed to counteracting the economic losses generated from COVID-19 and its possible closure of operations.

COVID-19 did not present evidence in favor of H3. This was due to the uncertainty generated by the pandemic, which became unfavorable in a scenario of high economic risk [59]. In contrast, T.I. had a direct and significant relationship with B.D.A. and F.P., respectively. With the above, hypotheses H4 and H5 were confirmed. This relationship showed the evidence favoring those firms with T.I. processes before the pandemic. Consequently, T.I. allowed them to perform better than firms that did not have it or that had insipient T.I. development.

On the one hand, firms with a good T.I. endowment could generate information and apply B.D.A. This is because T.I. works with automated processes that generate inputs to improve their business decisions through the use and application of B.D.A. The findings showed that T.I. caused the firm to improve its ability to generate information about its processes. Furthermore, T.I. offered the ability to coordinate and integrate with other agents in the supply chain. Thus, it generated the availability of information to be processed with the tools of B.D.A. This affirmation corroborates the findings of [60], which mentioned that T.I. and B.D.A. are tools of Industry 4.0 that improve food results firms. These have also allowed firms' response capacity and resilience to improve and adapt to the food market's new characteristics in the pandemic [28].

On the other hand, firms with modern T.I. improved their ability to coordinate operations and integrate efficiently in the supply chain, which allowed an improvement in F.P. that led to higher benefits. This scenario was associated with the fact that the firm had better technological conditions that allowed it to be better than other agents in the supply

chain. It allowed more efficiency in receiving and selling products, efficiently adapting to rigidity and malfunction of the supply chain due to COVID-19. These findings coincided with previous research [36,71,74]. These authors mentioned that food firms with better T.I., such as automation, robotization, and blockchain, among others, have had the best response capacity to COVID-19 and have allowed them to continue with their operations. Likewise, the authors of [28] mentioned that robotization in food product packaging had been an operational advantage to cover the labor shortage, and it allowed firms not to reduce product sales. Finally, the use of B.D.A. constituted an advantage for the management and operations of firms. There has been a lack of studies on B.D.A. on F.P. [100]. It presents a positive and significant relationship with the F.P., complying with H6. In other words, firms with data analysis tools could better respond to market uncertainty caused by the COVID-19 outbreak, since they could forecast scenarios and adapt to adverse situations. Through B.D.A. management, the firm could design applications to improve delivery services to the end customer. As a sample of this result, B.D.A. allowed the processing of information for adequate decision-making in efficient resource use. It allowed for a reduction of waste or a reduction of costs and time, which contributed to CE adoption, which was reflected as savings for the firm and economic gain [101]. The authors of [65] reached similar findings, who affirmed that big data analysis contributes to an adequate definition of decisions for the efficient use of resources. Furthermore, C.E. practices allow redistributing merchandise that does not reach its final destination, reducing waste, improving delivery mechanisms, and increasing its profitability [39]. Likewise, B.D.A. improves the quality of product delivery service, which improves customer satisfaction and the firm's sales level. As indicated by [67], improving the quality of product delivery improves the perception and reputation of the firm, leading to an increase in the firm's sales. In addition, these results agree with the findings of [78,79], respectively, which mentioned that the supply of food products online and the agile delivery of products allowed firms to improve their sales, which declined at the beginning of the pandemic.

## 5. Conclusions

Firms are increasingly improving themselves into digital enterprises by integrating T.I. and exploiting big data analytics. This study analyzed Ecuador's food products' F.P., produced by restrictive mobility and confinement measures since the COVID-19 outbreak. A questionnaire collected information from 344 firms in the food sector in Ecuador. This information was then statistically validated to be later processed using econometric techniques of CB-SEM. The results that were achieved showed enough evidence to affirm that the COVID-19 outbreak negatively affected the performance of the food products' firms. Some cases closed their operations, and, in some others, they could continue in the market. We found that big data analytics mechanisms and different levels of T.I. significantly shape the F.P. B.D.A. enhances the firm's capabilities to adopt C.E. practices, since it has the quality of information to reduce the waste of resources and, consequently, reduce costs and increase profits for the firm; likewise, B.D.A. provides the firm with tools to improve the delivery of services, which provides the firm with economic gains due to increased sales. These findings were obtained because T.I. started long before the COVID-19 outbreak. Consequently, the pandemic was a scenario that exposed the benefits of T.I. to business operations. Thus, the T.I. generated an implementation of B.D.A. to improve the C.E. practices and delivery quality, representing a reduction in costs for the firm and an increase in its economic benefit. However, the COVID-19 outbreak did not represent an implementation of T.I. This study has become the pioneer in addressing this issue in the country. Its objectivity constitutes a valid contribution to the academic and scientific field.

This study also has some limitations, and these can be further investigated in future research studies. First, the empirical context of the study focused on Ecuador. Thus, future research could apply an institutional approach to exploring the F.P., since institutional development has varied effects on the F.P. Second, we investigated the mediation role of big data analytics and T.I. Future research studies could investigate information processing

capability and knowledge combination capability as mediators between an uncertain environment and F.P. From the findings found in this research, the following policy and business implications emerged:

1. Firms' modernization in the food supply chain must be promoted, which is very sensitive and is affected by uncertainty such as the pandemic. The government should encourage programs to improve the endowment of technology and B.D.A. in firms in the sector. These technological improvements contribute to the firm's better response capacity and avoid bankruptcies in risk scenarios, such as those currently experienced.
2. Government incentives must be created for firms to invest in automating their operations and being less dependent on manual activities. Firms should also be required to offer their products through an online market to speed up their sales.
3. Firms must have technological tools or information technology systems that improve their operations' performance and integrate effectively into the food supply chain. They must also invest in technologies to improve their C.E. initiatives in food distribution, avoid waste, and improve food storage management.
4. The business implications suggest that companies must have plans to respond to adverse events, such as the pandemic or any risk event. Similarly, companies in the sector must maintain operational protocols that allow them to be coordinated when there is a malfunction in the supply chain; likewise, the guidelines of the T.I. and B.D.A. should be directed to the F.P., always considering the efficient use of resources in adopting C.E.

The study is considered a pioneer in the country, with significant knowledge. It contributes to the current literature. Furthermore, it helps to understand the firm's behaviour during COVID-19. Furthermore, considering the methodology used and the findings, this study can be replicated in countries with similar economic structures. Like most scientific research, this study has some limitations, which have been considered future extensions for research. One of the main ones is that T.I. was considered; however, it was not identified which type of technology was the one that contributed the most significantly. In addition, B.D.A. was considered, but it would be essential to know how the workers' skills affect the information analysis. Therefore, future research should consider these aspects.

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## Appendix A

**Table A1.** Questionnaire.

Constructs and Variables		
COVID-19		
Personal perceived risk (aa1)	aa1 aa2 aa3	The situation of COVID-19 is much worse in the workplace, and the health is at risk. An employee is willing to go to the workplace, but his family's health is at risk. If an employee does not go outside, he and his family will suffer from a shortage of money.
Policies (aa2)	aa4 aa5 aa6 aa7	Wearing a mask makes him uncomfortable in the workplace. Body temperature checks at the workplace increase his stress level. Lockdown policies put his life in great difficulty. Frequent use of sanitizer increases anxiety at the workplace.
B.D.A.		
Delivery (bb1)	bb1 bb2	Online product offering improves product delivery efficiency. Efficient information management reduces product delivery time.
Circular Economy Practices (bb2)	bb3 bb4	The firm's production process prioritizes the consumption of raw materials and energy. The firm's initiative improves the energy efficiency of production equipment.
T.I.		
Information sharing ability (cc1)	cc1 cc2 cc3 cc4 cc5 cc6 cc7 cc8	The firm uses technologies in production processes. The application of technologies generates information on the production processes. Having more information contributes to proper decision-making. Artificial intelligence applications help workers' tasks. The use of software helps the processing of large amounts of data. Technology allows for the obtaining of reliable information on the production process. The firm shares information digitally. The adoption of technology improves the use of resources.
Coordination ability (cc2)	cc9 cc10 cc11 cc12 cc13 cc14	The use of technology makes it possible to improve the delivery and receipt times of products. The use of technology improves the processes of transport, distribution, and storage of products. Technology reduces the costs and management time of the firm. Technology improves sales coordination among agents in the supply chain. The use of technology improves the efficiency of the firm in the supply chain. Technology allows for the redistribution of product delivery and the reduction of waste.
Integration ability (cc3)	cc15 cc16 cc17 cc18	Technology allows the firm to predict market demand. Technology improves the design of new products. Technology allows for improvement of the firm's response to adverse natural events. Technology allows flexibility and improvement of the operational processes of the firm.
F.P.		
Profitability (dd1)	ee1 ee2	There is a decrease in the consumption of energy, water, and other supplies in the workplace. Increase in daily sales.
Market share (dd2)	ee3 ee4	The firm can quickly modify its organizational structure to respond to business conditions. The technology allows for the coordination of the delivery of products with third parties.

Note: COVID-19 = Corona Virus Disease 2019 outbreak. BDA = Business data analytics. TI = technological innovations. FR = Firm performance.

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