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A Configuration Approach to Reduce the Risk of COVID-19 Employees Infection in the Manufacturing Firms: The Role of Machine Automatization

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Abstract. Does automation adoption mitigate the COVID-19 infection rate of employees? What resources and internal and external factors need to be configured with automation to mitigate COVID-19 contagion from employees successfully? According to the type of automation. What resources efficiently complement to mitigate the contagion rate from employers? From a fuzzy-set qualitative comparative analysis (fsQCA) approach, we analyzed 759 manufacturing firms in Finland, drawn from the World Bank 2020 Enterprise Survey; this study addresses the multiple configurations that drive pandemic risk mitigation and management. We find that configurations under automation reduce the risk of employee infection. Our results show the critical role of automation in employee safety. We argue that access to government support and the development of technological innovation are necessary conditions for implementing measures to prevent and mitigate the risk of contagion in the employee. In addition, the first configuration states that manufacturing firms employing soft automation can successfully mitigate employee exposure. The second configuration states that high human resource flexibility successfully complements firms with complex automation to achieve high mitigation. Finally, the third configuration shows those manufacturing firms that employ low-tech automation (manual processes); in this manner, digitization enables successfully mitigating pandemic contagion. Moreover, it suggests recommendations for policymakers and managers.

Keywords: COVID-19; Digitalization; fsQCA; Industry 4.0; Machine Automatization

1. Introduction

The death rate due to COVID-19 has increased already to three million people (Agus et al., 2021). Therefore, it is essential to know what strategies firms should implement to mitigate employee infection for welfare and safety in this "new normal." In such a manner, as resilient firms return to their activities, they must establish new safety and welfare measures for workers to mitigate the pandemic risk. Therefore, having better work

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conditions through high levels of safety and adequate worker health in a company plays a fundamental role (Levy et al., 2017; Berawi, 2021).

To achieve this purpose, Seale et al. (2020) state that physical distancing, use of masks, and hand hygiene, persist in being considered essential to deal with the pandemic. Therefore, firms present an essential role in caring for the welfare of employees who face high exposure to the virus they perform in essential activities (Rothan & Byraredde, 2020).

Currently, in the era of Industry 4.0 (I4.0), technological advances, such as Artificial Intelligence (A.I.) and automation, could play a key role in mitigating the infection of employees by COVID-19. In such a manner, automation processes generate greater interest in industries because it offers an opportunity for jobs without much contact with other people, drastically decreasing infections.

However, what conditions automation and digitization will reduce employee contagion remains unclear. Thus, the present study attempts to fill this gap by interacting with internal and external variables to understand the complexity and explain risk mitigation in this "new normal." In this sense, we address these challenges to develop an empirical model that seeks to explain the best practice strategies that allow high-risk mitigation in workers from a business perspective. So far, few studies seek to understand the mechanisms that lead companies to adopt risk mitigation measures (De Bruin et al., 2020; Koonin, 2020).

In addition, we seek to know the role of automation, so our research aims to fill this gap, provide good practices to companies, and work together with policymakers in this "new normality." We believe the automation variable alone does not mitigate contagions for the safety of workers. In this sense, we consider it essential to know which resources successfully complement each type of automation to mitigate the contagions in the workers of manufacturing companies. Thus, our objective is twofold. Firstly, to identify which factors lead to high-risk mitigation to build resilience that provides a better quality of life for workers and anticipate problems in the short term. Secondly, we seek to know the interactions of the factors that explain our objective. Third, analyze what type of automation is complemented by resources that could reduce the rate of contagion in employees.

Therefore, this study addressed two questions: (i) How do these factors interact, and under what context do they improve worker safety and mitigate risk during the pandemic? (ii) What type of automation improves worker's safety in developed manufacturing firms? According to the type of automation (iii), What are resources that efficiently complement to mitigate the contagion rate from employers? We employ an asymmetric methodology such as fuzzy-set qualitative analysis (fsQCA) to achieve our objective. It analyzes multiple causality and equifinality.

The research is structured as follows: a theoretical framework addressing the antecedents of firms with developed economies, the formulation of hypotheses, and developing of a proposed model. In addition, the presentation of the method and the results. Finally, we state the conclusions and give a discussion, respectively.

2. Theoretical Background

2.1. Industry 4.0 technologies and post-pandemic era "new normal."

The fourth Industrial Revolution (I4.0) represents the technological evolution achieving a transformation in production (Naruetharadhol et al., 2022). Smart manufacturing and the intensive use of technology are paying increasing attention (Liao et al., 2017) through a relationship between workers, machines, and the internet fulfilling an essential role in firms making better decisions and automation systems. Studies by Szajna & Kostrzewski (2022) argue that the aim of Industry 4.0 is to enable good digitization and machine automation where the participation or interaction of human interventions is necessary.

2.2. Smart Manufacturing

New technologies imply new forms of autonomous, reconfigurable and flexible smart manufacturing in firms to improve their existing operations (Zheng et al., 2018). Technological adoption in manufacturing firms allows for generating innovation, and productivity, decreasing the error rate (Andrews et al., 2016) and increasing efficiency in the different processes of manufacturing firms.

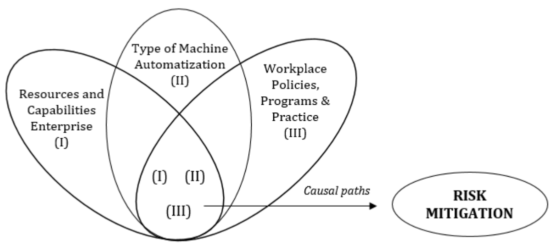
2.3. Role automatization in the safety workers

The pandemic outbreak generated significant societal changes and concerns for workers' safety, health, and welfare (Dennerlein et al., 2020). Therefore, adequate safety and well-being of workers allow decreasing the anxiety and fear of workers. Levy et al. (2017) argue the importance of adequate conditions in the workplace to maintain adequate infection control, such as better air ventilation and physical barriers between workers and clients. Thus, the pandemic outbreak increased best practices for risk mitigation (Koonin, 2020).

2.4. *Proposed model as a framework to analyze safety in manufacturing firms*

We identified three components to understand the factors that mitigate the risk of pandemic in industrial workers in developed economies (i) company resources and capabilities; (ii) levels of machine automation; and (iii) workplace policies, programs, and practices. This study considers digitalization and technological innovation as the resources and capabilities of firms (Heredia et al., 2022). In addition, soft automation, complex automation, and manual manufacturing as levels of machine automation. Finally, human resource flexibility and government support as workplace policies, programs, and practices.

Therefore, based on the above, we present the proposed model (see Figure 1) through a Venn diagram to explain how the set variables enable successfully mitigate employee infection. This representation (Venn diagram) is widely used in recent research using a fsQCA approach (Chuah et al., 2021). In this sense, we believe that analysis from three different perspectives can achieve that automation combines internal and external factors to mitigate employee infection successfully.



Resources and Capabilities Enterprise	Digitalization; Technology innovation; Human resources flexibility
Type of Machine Automatization	Soft Automatization; Hard Automatization; Manual manufacturing
Workplace Policies, Programs & Practice	**Micro-environment:** Informal competition
	Macro-environment: Support Government

Figure 1 Proposed Model

3. Methodology

3.1. Sample and Data

We obtained data from the "Enterprise Survey" database published in 2020 by the World Bank. The survey data for this study include 759 manufacturing firms in Finland. The survey was structured to address general aspects of firms. The data allow us to study the behavior of enterprises and the impact of the COVID-19 pandemic on manufacturing firms. In contrast to other countries, Finland firms as a case of developed economies, the impact of the COVID-19 pandemic was unpredictable, but with rapid control to stop the spread of the virus (Tiirinki et al., 2020).

3.2. Research Design

This study employs a fuzzy-set qualitative comparative analysis (fsQCA) to determine a set of causal variables (Ragin, 2000), using Boolean algebra and fuzzy sets as a mathematical tool (Rihoux & Ragin 2009). The methodology is prominent in business and management research (Manzo & Rodríguez, 2022). Fiss (2011) argues that fsQCA focuses on different combinations (configurations) to achieve the desired result. An essential feature of fsQCA is its ability to analyze complex causality, a situation in which a given outcome can result from several combinations or configurations of different causal conditions (Rihoux & Ragin, 2009). FsQCA is an extension of QCA (Ragin, 2000) through a more exhaustive analysis that enables the analysis of values in 0 and 1 (Fiss, 2011). Thus, the term configuration combines factors or antecedents that lead to high worker safety.

In this sense, causal complexity is a set-theoretic analysis based on three elements (i) conjunction, (ii) equifinality, and (iii) asymmetry. Equifinality enables different paths leading to the same result (risk mitigation). The principle of causal asymmetry, based on the fact that the conditions that explain the presence of the outcome may be different in the analysis of the absence of the same outcome (Fiss, 2011) and conjunctural causation considers that a single condition is insufficient and must be combined with another to achieve the desired outcome. FsQCA overcomes the limitations of traditional quantitative methodologies where effects are analyzed separately. Configurations that examine the antecedents' relationships lead to an outcome (Ragin, 2000).

There are two fit parameters in the fsQCA approach (consistency and coverage). Consistency measures the degree of necessity relationship between a causal condition and the outcome (Ragin, 2000). Research by Gonçalves et al. (2018) argues that consistency is similar to significance in regression models. Coverage refers to the degree of the empirical relevance of our proposed model, i.e., it measures the degree to which the solution explains the result. Stroe et al. (2022) argues that when the coverage has higher values, the configurations are more relevant to explain our results. In this sense, both parameters (coverage and consistency) have values between 0 and 1.

3.3. Coverage and Consistency

The fit parameters in the fsQCA are consistency and coverage; these measures allow us to validate our model and understand the extent to which the data fit a relationship of necessity or sufficiency (Schneider & Wagemann, 2012). Consistency measures the degree of a necessary relationship between a causal condition and the outcome. Coverage, on the other hand, indicates the degree of empirical relevance. Its values respectively lie between the values of 0 and 1. Acceptable consistency for solutions is established at (>0.80), which is above the recommended minimum threshold of 0.75 (Ragin, 2000).

3.4. Models and Sufficiency Analysis

The results of the fsQCA model can produce three different solution analysis results (complex solution, parsimonious solution, and intermediate solution). The first solution is safe and radical by prohibiting rests, but it is difficult to interpret. The parsimonious solution uses the rests as "easy" and "difficult" with greater ease of interpretation. Finally, the intermediate solution uses the "easy" counterfactuals (Schneider & Wagemann, 2012).

4. Results and Discussion

This section specifies the model results (see Table 1), which shows the consistency of 0.92, representing 92% of memberships of the outcome represented by solutions. Coverage of 0.27 represents 27% of all manufacturing firms mating. In this sense, our results aim to explain three different "paths" or configurations that lead to the same result through causal pathways, that manufacturing firms implement high measures to mitigate pandemic risk in this "new normal." Regarding the presentation of the findings shown in Table 1. Generally, the presence of a condition indicates a black circle (•), the absence/denial with a blank circle (○), and the "do not care" condition with a blank space (Fiss, 2011). The results indicate that technological innovation and access to government support are necessary conditions for firms to implement strategies to mitigate the pandemic risk.

Table 1 Configurations leading to more risk mitigation in manufacturing firms

	Solution		
Configurations	First	Second	Third
Use Soft Automatization	●	○	○
Use Manual Manufacturing	○	○	●
Use Hard Automatization	○	●	○
Belongs to the Manufacturing Industry	●	●	●
Technological Innovation	●	●	●
Informal competition	○	○	○
Support Government	●	●	●
Human Resources Flexibility	-	●	●
Use of Digitalization adoption	○	-	●
Raw Coverage	0.15	0.08	0.05
Unique Coverage	0.15	0.08	0.05
Consistency	0.95	0.9	0.88
Overall solution coverage		0.27	
Overall solution consistency		0.92	

Conditions in the solution terms are represented by "●" (presence) and "○" (absence); a blank space indicates an "a do not care" condition.

First configuration state that this group of Finnish manufacturing firms employ soft automation. This middle-level of automation enables firms to have greater control of the safety and welfare of workers through less interaction and involvement with other workers. Thus, through soft automation, manufacturing firms can serve as a mechanism to protect workers through adequate communication, physical distancing, and hygienic measures to achieve high efficiency in firms in a pandemic context (de Bruin et al., 2020). In this sense, we can indicate that a medium level of automation generates strategies to mitigate the risk of infection of workers. Therefore, with minimal people working and a soft automatization, firms can mitigate the pandemic risk, avoiding a high concentration of people.

Proposition 1: *"In a pandemic context, government support and technological innovation are necessary conditions to mitigate the pandemic risk. In addition, a company that adopts soft automation can have greater control of the safety and welfare of workers, avoiding a high concentration of people during the work."*

The second configuration states that this group of Finnish manufacturing firms employs hard or high-impact automation such as computer numerical control (CNC-Machine). De

Souza et al. (2020) argue that mechanized control development of the CNC-Machine enables monitoring remotely through cloud computing. In contrast to the first configuration, where the firms present medium-level automation. This group of firms with a high level of automation enables to development of quickly successful strategies to prevent and mitigate infection in workers by combining human resources flexibility to reduce employers exposure. These workers could present better capabilities to use more sophisticated tools such as CNC-Machine, decreasing the likelihood of infection in workers in this "new normal". Therefore, firms improve working conditions through adequate flexibility, breaks, and alternative schedules (Hurtado et al., 2015). Therefore, adequate human resource management (reducing industry capacity) allows a balanced interaction between man and machine.

Proposition 2: *"In a pandemic context, if a manufacturing firm employs hard automation in combination with human resource flexibility, it allows for greater control, avoiding a high concentration of people."*

The third configuration states that this group of Finnish manufacturing firms presents low technological impact through manual processes. In addition, compared to the first and second configurations, this group of firms requires digitization through outsourcing to suppliers and customers to reduce the risk of infection of workers and the implementation to improve the building-air cleanness and open work environment. Based on the above, manual automation where the risk of workers increases due to increased interaction and probability of contagion. Therefore, digitization emerges as a tool to achieve success in employee conditions.

Proposition 3: *"In a pandemic context, if a firm employs manual manufacturing (low technological level), it, therefore, needs human resource flexibility and to adopt digitization to achieve greater control, avoiding a high concentration of people."*

Based on the previous results, this study proposes three propositions according to the obtained configurations, representing groups of companies with different factors that manage to implement measures to mitigate the risk of workers. We are increasingly aware that companies are adopting new technologies and automation to improve operational processes in production and decrease the error rate increases the efficiency of companies. However, in agreement with Kavitha & Vallikannu (2022), we argue that automation can sustain a link in the industrial safety of workers. Thus, our study investigates a previously unstudied context as a pandemic where it is a threat that affects workers' health (Mithani, 2020).

5. Conclusions

The present study explores how to overcome employee safety and risk mitigation during the COVID-19 pandemic. In such a manner, we know that workers' safety, health, and welfare have become the focus of attention to analyze during the pandemic. However, our study seeks to propose the roles of automation and technology in manufacturing firms through new strategies and tools to prevent and mitigate the risk of infections in employees. In conclusion, automation is essential in strategies to prevent and mitigate worker infections. In addition, our study contributes to knowing the set of resources that successfully complement each other in manufacturing firms according to each type of automation, thus exploring the companies' capabilities in managing strategies depending on the company's decisions. According to our results, successfully digitalization complements companies that use a low level of automation (manual processes) to jointly generate preventive measures for workers' safety. Finally, we propose the need for a relationship between business and government to mitigate the pandemic risk. In addition, we provide practical implications for managers to look at the internal factors (resources and capabilities) that mitigate employee infection.

6. Future Research

As firms' decisions to implement measures to mitigate pandemic risk in developed economies, future research may consider other contexts that allow us to generalize the results. Also, propose research to understand the configurations that lead a firm to decide not to adopt social innovation as a strategy. Therefore, it is necessary to consider the asymmetry of the fsQCA methodology. Finally, the authors consider analyzing the adverse effects of atomization and their consequences on unemployment and the relocation of workers. Therefore, it is recommended to evidence new variables that help intensify the success of implementing measures to mitigate the pandemic risk.

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