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The impact of digital transformation on innovation performance in SMEs

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Biographic Note

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Cláudia obtained the bachelor's degree in Management at Faculty of Economics of University of Porto, in 2016. In the same year, to deepen her knowledge, she joined the Master in Management at the same faculty, ending in 2021 with the present dissertation.

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Abstract

Purpose – The purpose of this study is to determine to what extent the adoption and implementation of digital technologies in Portuguese manufacturing Small and Medium sized Enterprises (SMEs) are impacting their innovation performance.

Design/methodology/approach – A questionnaire was made available in the Qualtrics online platform for 1.000 manufacturing SMEs in Portugal. A sample of 109 responses, collected between March 2021 and May 2021, were analysed though linear regression.

Findings – The findings show that both the level of implementation and the adoption of digital technologies positively impact innovation performance of SMEs in the manufacturing sector.

Implications – The results contribute to deepen the topic of digital transformation and innovation performance in the context of SMEs. The findings of the research may be used by managers who seek to improve innovation performance, a core process for competitive advantage and for companies' survival, by means of practical implications of digital transformation.

Originality/value – This study adds to the literature by combining digital transformation with innovation performance in the context of SMEs, concepts whose relationships among themselves are unexplored in the literature. It also focuses on Portugal, a country that does not received significant attention from researchers, being this, to the best of our knowledge, the first study to examine the impact of digital transformation on innovation performance in Portuguese SMEs.

Key Words: Digital transformation; Digital technologies; Innovation performance; SME; Portugal

JEL Codes: L60; O30; O33

Resumo

Propósito – O objetivo deste estudo é determinar em que medida a adoção e implementação de tecnologias digitais nas Pequenas e Médias Empresas (PMEs) industriais portuguesas, estão a impactar o seu desempenho da inovação.

Design/metodologia/abordagem – Foi disponibilizado um questionário na plataforma online da Qualtrics para 1.000 PMEs da indústria transformadora em Portugal. Foram recolhidas entre março de 2021 e maio de 2021, uma amostra de 109 respostas, analisadas por regressão linear.

Resultados – Os resultados demostram que o nível de implementação e adoção de tecnologias digitais, ambos, têm impacto positivo no desempenho da inovação das PMEs do setor da indústria transformadora.

Implicações – Os resultados obtidos contribuem para aprofundar o tópico da transformação digital e do desempenho da inovação no contexto das PMEs. As conclusões do estudo podem ser utilizadas por gestores que procuram melhorar o desempenho da inovação, um processo essencial para atingir vantagem competitiva e para a sobrevivência das empresas, por meio de implicações práticas da transformação digital.

Originalidade/valor – Este estudo complementa a literatura ao combinar a transformação digital com o desempenho da inovação no contexto das PMEs, conceitos cujas relações entre si são pouco exploradas na literatura. Foca-se também em Portugal, um país que não recebe atenção significativa dos investigadores, sendo este, tanto quanto é do nosso conhecimento, o primeiro estudo a analisar o impacto da transformação digital no desempenho da inovação das PMEs portuguesas.

Palavras-chave: Transformação digital; Tecnologias digitais; Desempenho da inovação; PME; Portugal

JEL Codes: L60; O30; O33

Table of Contents

Index of Figures

Index of Tables

1. Introduction

Digital transformation has been generally accepted as a factor that impacts businesses in terms of its governance, business models, manufacturing processes, relationships, and performance (Castelo-Branco et al., 2019; Sheng et al., 2019; Matarazzo et al., 2021). The evolvement of digital technologies, as well as its adoption and implementation in the manufacturing sector (known as digital transformation) has often been referred to as Industry 4.0 (I4.0) or the Fourth Industrial Revolution (Raj et al., 2020). This phenomenon represents the interconnection between digital technologies, people, and machines in industry production processes (Kamble et al., 2018).

From the companies' point of view, innovation is identified as a differentiating factor, allowing access to competitive advantage, and contributing to the overall performance of the business (Zimmermann et al., 2020). This advantage is even more important when it comes to small and medium-sized enterprises (SMEs) survival in competitive markets (Garzella et al., 2021). According to the World Bank, SMEs play an extremely important role in job creation and in global economic development and growth, representing about 90% of businesses and more than 50% of employment worldwide (World Bank, 2020).

Researchers have been addressing the main definitions, principles, and technologies in the context of digital transformation (Xu et al., 2018; Koh et al., 2019), as well as the drivers, challenges, barrier, and strategies to the adoption of digital technologies (Stentoft et al., 2020; Raj et al., 2020). Over the last years, a range of studies dealing with the relationship between digital transformation and innovation have emerged (Nambisan et al., 2019), including the impact of digitalization on companies' innovation business models (Bouwman et al., 2018; Müller et al., 2018). However, to the best of our knowledge, the focus has mainly been on large firms (e.g. Björkdahl 2020) and no evidence was found on the impact of digital transformation on innovation performance. Therefore, this research aims to fill this gap by studying the relationship between the adoption of digital technologies and the performance of innovation in SMEs, using the Resource Based View (RBV) as a basis. The main research question that will be addressed is as follows:

RQ: How does the adoption and implementation of digital technologies impact innovation performance?

To accomplish the main purpose of this research, a questionnaire-based survey was developed and applied to SMEs in the manufacturing sector in Portugal.

Besides this introduction, this research is structured as follows: the next chapter presents a brief review of the literature on the main concepts (digital transformation and innovation) and the theoretical framework developed. In chapter 3, a narrative of the methods used to develop the questionnaire and how data was collected is shown. Chapter 4 describes the results and the discussion and finally, chapter 5 presents the conclusions, main implications and recommendations for further research.

2. Literature Review

This chapter presents a brief review of the literature on the main topics. Firstly, we describe the main definitions, principles and technologies of digital transformation. Then, we present an assessment of innovation management and performance, followed by a topic that poses literature on digital transformation and innovation. Subsequently, the resources and technology theories are resumed and finally, the theoretical framework and hypotheses are presented.

2.1 Digital transformation: definitions, principles and technologies

Constant technological developments are impacting the way organizations manage their business (Castelo-Branco et al., 2019). Digital technologies are increasingly being used and applied in the daily routine of organizations, implying changes in their value chain, and adjustments in their structure, processes, products and/or services (González-Varona et al., 2021).

Digital transformation represents the interconnection between digital technologies, people, and machines and, when applied in industry production processes, the concept of Industry 4.0 (I4.0) and of Fourth Industrial Revolution emerges (Raj et al., 2020).

Recently, I4.0 has gained more and more attention from practitioners and academics, however it is difficult to find a clear definition of what I4.0 is (Hermann et al., 2016). The term first appeared in Germany in 2011, as a strategic initiative of German industry, and since then a lot of definitions have emerged. I4.0 is presented as a technological framework that integrates and connects the digital and the real world in manufacturing processes using cyber-physical systems (CPS) (Kamble et al., 2018; Xu et al., 2018). CPS are recognized as the core foundation of I4.0 and it can be defined as engineering systems composed of multiple technological elements such as embedded systems, sensors, hardware and software that allow a deeply interconnection and integration between computation and physical elements in real time (Kamble et al., 2018; Xu et al., 2018).

According to Manocha et al. (2020), I4.0 contributes to a dynamic business environment where some barriers such as geographical barriers are overcome. Other advantages, such as efficiency increases, information sharing along the value chain, cost savings, greater agility and development of new products with more added value for customers, are also pointed to the adoption of I4.0 (Sheng et al., 2019; Manocha et al., 2020; Stentoft et al., 2020).

To obtain these advantages, it is necessary to overcome some barriers during the implementation phase. Stentoft at al. (2020), classified barrier and drivers into three main groups: legislation/standards, strategy, management, and workforce and similarly, Raj et al. (2020), grouped the barriers into prominent, influencing and resulting ones. Lack of standards, lack of clear comprehension about Internet of Things benefits, lack of a digital strategy alongside resource scarcity, too few financial resources and low maturity level of the desired technology, were some of the barriers identified as those that most impact the adoption of I4.0 (Kamble et al., 2018; Raj et al., 2020; Stentoft et al., 2020).

In this sense, the implementation of this phenomenon is a complex and time-consuming process that requires effort and persistence from organizations. The literature usually defines six principles to the implementation design: interoperability, virtualization, decentralization, real-time capability, service orientation and modularity (Hermann et al., 2016; Lu, 2017; Oztemel & Gursev, 2018). The ability of two systems to exchange knowledge, data and information with each other is called interoperability (Lu, 2017). Virtualization represents the monitoring of physical processes while decentralization involves changing the decision-making system from central to decentralized, so that decisions can be made at different levels of the value chain and by different participants (Koh et al., 2019). To make better decisions it is important to have real data collection and analysis – real-time capability (Hermann et al., 2016). Also, the devices should fill the needs of users – service orientation – and should have flexible systems, easily adjustable and adaptable to meet requirements – modularity (Hermann et al., 2016; Koh et al., 2019).

Design principles are more easily achieved when digital technologies are adapted to the reality of companies in the manufacturing sector. These are an extremely important pillars in the implementation of I4.0 (Erboz, 2017).

There is no consensus in the literature regarding the main technologies associated with I4.0, however, some of the most mentioned ones and those considered in the study are presented in **Table 1**.

Table 1 – Technologies of Industry 4.0

Technologies	Definition
Big Data Analytics	Analytical tools applied to large, fast, and varied volumes of available information that support decision making, helping them to be better and more informed, allowing improvements in efficiency and cost savings (Gandomi & Haider, 2015; Castelo-Branco et al., 2019; Sheng et al., 2019).

Technologies	Definition
Autonomous Robots	Electromechanical and technological systems developed to act without human intervention, autonomously and/or pre-programmed. These devices can interact and cooperate with humans and machines (Zheng et al., 2019; Alcácer & Cruz-Machado, 2019)
Cloud Computing	Online data computing available on a remote databased that can be consulted at any time, from any place and by many people (Branco et al., 2017). Characterized by high performance and low cost and by high level of information sharing (Zheng et al., 2014).
Simulation	Operation models that simulate certain behaviours based on defined assumptions. In a manufacturing company, this technology allows anticipation of problems and defects as well as cost savings in products development. It also allows the decision making a more informed one (Alcácer & Cruz-Machado, 2019; Erboz 2017).
Internet-of-Things (IoT)	Network of interconnection and information sharing of physical objects, like sensors, smartphones, social networks, etc., through the internet (Xu et al., 2018; Alcácer & Cruz-Machado, 2019). This collaboration enables smart factories and allows the collection of real-time data (Kamble et al., 2018; Koh et al., 2019).
Additive Manufacturing (3D Printing)	Additive manufacturing is characterized by flexible and adaptable systems that allow the production of customized and complex products (Koh et al., 2019). The physical product can come out from 3D Printing, one of the technologies of additive manufacturing (Rüßmann et al., 2015).
Augmented Reality (AG)	AG represents the collaboration between virtual objects and real-world objects (Zheng et al., 2019). Virtual objects include, for example, graphics, sounds and touch feedback (Oztemel & Gursev, 2018). It facilitates human-machine interaction and can be used to assist manufacturing processes, by allowing remote control and visual inspection (Erboz 2017).
Business Intelligence (BI)	BI it includes the collection, integration, analysis and presentation of data obtained from different sources, to help organizations to make more data-driven decisions (Bordeleau et al., 2018; Ghadge et al., 2020).
Cybersecurity	Since machines, processes and activities rely on digital connection, it is important to ensure that it is safe and reliable (Rüßmann et al., 2015). Cybersecurity serves this purpose while trying to prevent the network and the information stored on it from being compromised (Alcácer & Cruz-Machado, 2019).

These technologies collect information that individuals can use to make better and more informed decisions based on the data analysis performed on it. It is expected that making better decisions, the performance of the companies improves, contributing consecutively to economic growth (Frank et al., 2016; Sheng et al., 2019).

2.2 Innovation management and performance

Nowadays organizations need to be dynamic to survive in markets. Due to the constant and rapid changes in the environment involving the organizations, specifically in terms of technologies, customer preferences, and competition, companies need to quickly adapt to them (Danneels, 2002). A process that allows and facilitates this adaptability and renewal is innovation.

Innovation helps organizations to survive and to prosper by creating and increasing value and achieving competitive advantage (Baregheh et al., 2009; Adhikari, 2011). In companies, it can be defined as the implementation of something new or significantly improved to the organization (OECD/Eurostat, 2018). It includes the applicability of new ideas and/or new behaviours that trigger the emergence of new products, new services, new processes, new materials, new devices, and others (Damanpour & Gopalakrishan, 2001; Baregheh et al., 2009). The OECD/Eurostat (2018, p. 20) defines innovation as *"a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)."*

A different way of using and applying the existing resources and knowledge or the implementation of new resources and expanding knowledge or even a mixed of both, generates innovation (Popadiuk & Choo, 2006; Shu et al., 2012).

Over the years, different types of innovation have appeared. Innovation can be classified as incremental, or radical/disruptive (OECD/Eurostat, 2018). Also, the following types were proposed: product, process, organizational and marketing innovation (OECD/Eurostat, 2005; Oke et al., 2007; Ganzer et al., 2017), and more recently two major types of innovation emerged: product and business process innovation (OECD/Eurostat, 2018). Over the years, product innovation and process innovation categories have been widely used and accepted. These are the ones that will be considered throughout this study.

The development of new goods or new services to meet clients and market needs, that are available for use and are different from the ones already exists is called product innovation. Process innovation is defined as the introduction of new or improved elements in the development chain of products, including the core and supporting activities (OECD/Eurostat, 2018). While product innovations are market and customer driven, process innovation it is more efficiency driven (Utterback & Abernathy, 1975).

To go along with the competitiveness and market' dynamism, companies need to measure innovation performance, however, there is no consensus on how to do it (Birchall et al., 2011). The literature identifies innovation performance measures that focus on innovations' inputs, process, outputs, or outcomes (see, e.g., Birchall et al., 2011; Saunila, 2017). According to Saunila (2017), the innovation process is characterized by the transformation of resources provided for innovation (inputs), on its direct result (outputs), which will impact organizations (outcomes). For example, the time and cost of conversion (process) of equipment and knowledge (inputs) into new products (outputs) can have implications on companies' market share and customer satisfaction (outcomes). All of them can be used as innovation performance' measures.

Generally, studies measure innovation performance with focus on outcomes through financial and non-financial metrics (Avlonitis et al., 2001; Shu et al., 2012; Zhang et al., 2019). Examples of financial metrics are sales and profit margins (Svandova & Jirásek, 2019) and non-financial metrics are the number of products developed and the speed and frequency of new product introduction as used by Zhang et al., 2019 to measure product innovation performance.

A combination of measures of performance at different stages of the innovation process is point out as an appropriate measurement (Carayannis & Provance, 2008). When focusing only on inputs, like the research and development expenditure, we can only evaluate the initial phase of the innovation process disregarding, for instance, the final economic impact of innovation on the market (Carayannis & Provance, 2008; Svandova & Jirásek, 2019). Thus, when focusing only on a part of the process and not on the whole process, the value of innovation cannot be properly assessed, and so, multiple metrics at different stages of the innovation process should be applied to accurate measure innovation performance (Svandova & Jirásek, 2019).

2.3 Digital Transformation and Innovation

With a worldwide impact, the evolution of digital technologies is changing the way companies do business (Garzella et al., 2021), requiring a constant need for adaptation to prosper and survive in the digital era (Nambisan et al., 2019). Being innovation recognized as an important aspect for survival (Baregheh et al., 2019), in recent years, the relationship between digital transformation and innovation has gained ground among practitioners and researchers (Nambisan et al., 2019).

Studies approach this relationship from different perspectives. Since the concepts of digital transformation and innovation are very broad, there is a diversity of relationships that can be analysed. **Table 2** summarizes some studies that can be organized according to similar study focus.

The impact on performance was addressed by Scuotto et al. (2017), Trantopoulos et al. (2017), Ferreira et al. (2019), Scuotto et al. (2021). The first two authors stablished a relationship between Information Technology (IT) and innovation performance, while the last two authors studied the impact of innovation and digital capabilities on performance. Mubarak and Petraite (2020) and Ardito et al. (2021) explored the relationship between digital transformation and innovation with focus on the role of technological orientation of companies. Also, Business Model Innovations (BMI) triggered by digital technologies has been studied (Bouwman et al., 2018; Müller et al., 2018; Garzella et al., 2021).

Table 2 – Studies on innovation and digital transformation

Study Focus	Main Conclusions	Authors
The impact of IT on innovation performance	Positive and significant impact of ICTs on innovation performance of SMEs.	Scuotto et al., 2017
	Mainly companies network connectivity infrastructure (variable of IT) leverages the search in external knowledge, to achieve process innovation performance.	Trantopoulos et al., 2017
The impact of innovation and digital capabilities on performance	Innovation capabilities offered by the adoption of digitalization contribute to companies' greater competitiveness.	Ferreira et al., 2019
	Positive impact of individual digital capabilities (with the labour-intensive) on SMEs' innovation performance.	Scuotto et al., 2021
The role of digital orientations on innovation	Open innovation it is impacted positively by digital trust (trust and I4.0 technologies). On this relationship, technological orientation plays a positive moderating role.	Mubarak & Petraite, 2020
	Digital and environmental orientation impact positively product and process innovation performance. Together, have "a negative impact on process innovation performance and is not significant for product innovation performance".	Ardito et al., 2021, p. 44
BMI triggered by digital technologies	Social media and big data drive BMI that impacts positively business performance.	Bouwman et al., 2018
	Industry 4.0 affects business models' value creation, value capture, and value offer.	Müller et al., 2018
	Firms' boundary size promoted by digital technological developments, positively affects BMI. On this relationship, technological and relational management capabilities have a mediating role.	Garzella et al., 2021

2.4 Theoretical Basis

The adoption of digital technologies represents an extremely important pillar in the implementation of I4.0 (Erboz, 2017). To understand the determinants of information technology adoption at firm level, there are two major theories generally accepted in the literature: the technology, organization, and environment (TOE) framework, developed by Tornatzky and Fleischer (1990), and the diffusion on innovation (DOI) developed by Rogers (1995).

TOE framework discusses that the adoption and implementation of IT is influenced by technological context, organizational context, and environmental context (Tornatzky & Fleischer, 1990), whereas DOI framework, argues that individual characteristics of management, internal characteristics of organizational structure, and external characteristics of the organization impact innovativeness (Rogers, 1995).

In this research we will not focus on the determinants of IT adoption, although it is important to state that internal, external, and environmental factors accordingly with TOE and DOI framework, probably impact the adoption and usage of technologies in **Table 1**.

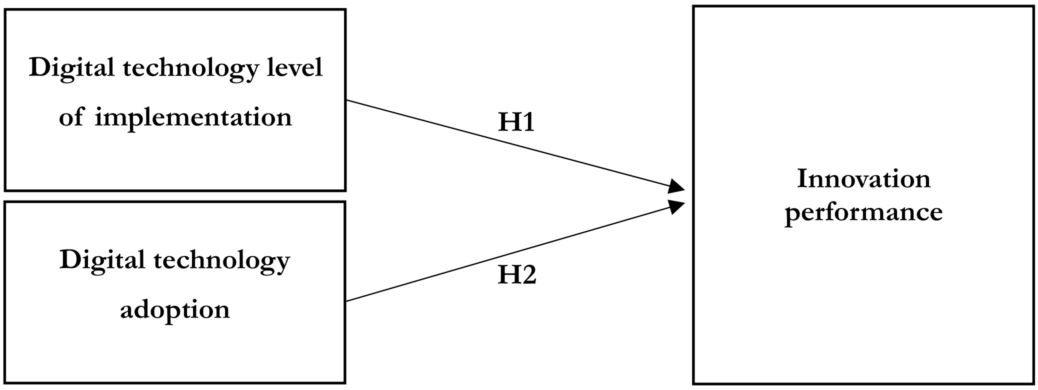
With focus on the impact of digital transformation on innovation performance, this study is developed under the lens of the Resource-based View (RBV), a theoretical foundation widely used and recognized in the literature (see, e.g., Barney, 1991; Verona, 1999; Morash & Lynch, 2002; Chahal et al., 2020; Zimmermann et al., 2020). Barney (1991) developed the RBV model arguing that a firm can achieve sustained competitive advantage through the exploitation of its heterogeneous and immobile resources. He classified resources into physical, human, and organizational capital, including all firm assets, capabilities, organizational processes, knowledge, and others. This model identified four characteristics that resources must possess to achieve organizational sustainable competitive advantage, known as the VRIN characteristics: value, rareness, imperfect imitability, and non-substitutability. According to Barney (1991), resources should allow for increases in efficiency and effectiveness (value), should not be available to other competitors (rareness), not be easily implemented by others (imperfect imitability) and not be able to be replaced by other substitutes (non-substitutability), to generate sustained competitive advantages.

Given the RBV's focus on exploiting resources to achieve competitive advantage and the close relationship between competitive advantage and performance stated in the literature (Peteraf & Barney, 2003), this theory supports the idea that digital transformation impacts innovation performance. Moreover, over the years, innovation has been recognized as a core process for competitive advantage (Lukovszki et al., 2021).

2.5 Theoretical Framework and Hypotheses

The relationship between digital transformation and innovation has been studied through varied approaches (see e.g.: **Table 2**), however, no evidence was found on the impact of digital transformation on innovation performance. In this study, to determine how digital transformation impacts innovation performance, the model presented in **Figure 1** was developed.

Figure 1 – Theoretical framework



Technologies of I4.0 are resources that have been associated to advantages such as the increase of knowledge through the breaking of geographical barriers and the improvement of processes in terms of effectiveness and efficiency (Sheng et al., 2019; Manocha et al., 2020), allowing companies to achieve greater access to opportunities, greater capacity of adaptation and innovation, providing sustainable competitive advantage (Lefebvre & Lefebvre, 1993; Frank et al., 2016; Scuotto et al., 2017; Nambisan et al., 2020; Ardito et al., 2021). Thus, and according to the literature reviewed, we can state that technology impacts innovation. In order to study this impact, two hypotheses were developed under the lens of the RBV.

Digital transformation will be assessed by the level of adoption of the technologies presented in **Table 1** and by its level of implementation in different operational areas; while innovation, will be evaluated through product innovation performance and process innovation performance – the two types of innovation widely used and accepted by researchers. Accordingly, we formulate the following hypotheses:

H1. The level of implementation of digital technologies positively impacts innovation performance

H2: The adoption of digital technologies positively impacts innovation performance

These hypotheses are consistent with Garzella et al. (2021), that state that digital technologies change products and services, and therefore impact innovation product performance and with Zhu and Kraemer (2005) and Scuotto et al. (2017) that highlight ICT as an important resource in improving and developing optimal business processes, thus impacting process innovation performance.

3. Methodology

This chapter starts presenting a brief review of methodological aspects of similar studies and then, a narrative of the methods used to develop the questionnaire and how data was collected.

3.1 Methodological aspects of similar studies

In this section, we underline the methodologies applied in the studies on innovation performance presented in **Table 2**, since they are the closest to the purpose of this study. **Table 3** presents a resume of methodological aspects of these studies, regarding country of study, sample size, industrial sector, firm size, data collection, response rate, key informant, and statistical analysis.

Regarding sampling, we can observe that the largest sample among the studies corresponds to the study developed by Scuotto et al. (2021) as it involves 24 European countries. In terms of firm size, the study developed by Trantopoulos et al. (2017) includes large and small and medium-sized enterprises while the remain studies focus on SMEs exclusively.

As for data collection, we can conclude that all studies collected data through questionnaires. Trantopoulos et al. (2017) and Scuotto et al. (2021) used secondary data of questionnaires developed and applied, in these cases from the Swiss Innovation Survey (SIS) collected by KOF Swiss Economic Institute and from the Eurostat's data set, respectively, while Scuotto et al. (2017) and Ardito et al. (2021) built the questionnaire from literature review. Furthermore, these last two authors identify owners, founders, and managers as the main respondents, while in study developed by Scuotto et al. (2021, p. 386) the questionnaire was answered by "employees operating across all units".

Also, all studies used a different method of statistical analysis. Scuotto et al. (2017) analysed the collected data using Structural Equation Modeling, known as SEM, defending that this statistical tool is appropriate for a larger sample, for exploratory research and that given the fact that the study applies a quantitative method, SEM is appropriate to test theory in the real world. Trantopoulos et al. (2017) choose to apply instrumental-variables (IV) estimators based on the generalized method-of-moments (GMM), based on previous studies that identified endogenous variables as suitable instruments. Ardito et al. (2021, p.49) applied the probit model, given that "the dependent variables are limited dichotomous binary variables” and that the values of Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) were lower than the values of the logit models. Lastly, Scuotto et al. (2021), employed a multiple-regression analysis, a suitable method to test hypotheses on the context of microfoundations.

Table 3 – Methodological aspects of similar studies

Authors	Country of study	Sample Size	Industrial Sector	Firm Size	Data collection	Response rate	Key informant	Statistical analysis
Scuotto et al., 2017	Italy	239	Software, Healthcare, Tourism and Leisure	SMEs	Questionnaire	54,69%	Founder or managing director	Structural Equation Modeling (SEM)
Trantopoulos et al., 2017	Swiss	3.490	Manufacturin g	All	Secondary data from Swiss Innovation Survey	Not applicable	Not mentioned	Instrumental-variables (IV) estimators based on the generalized method-of-moments (GMM)
Ardito et al., 2021	Canada	369	Various industries	SMEs	Questionnaire	9,9%	Business owner-manager	Descriptive Statistics and Test of Hypotheses through Probit Model
Scuotto et al., 2021	European Countries	2.156.360	Labour-intensive	SMEs	Secondary data from Eurostat's dataset	Not applicable	Employees operating across all units	Multiple-regression analysis

3.2 Questionnaire Development

To test the model proposed in this study a questionnaire was developed. Krause et al. (2018) states that when analysing theory with the purpose of study the management of operations, the survey instrument represents proper research. Once developed, the questionnaire was analysed by researchers with experience in innovation and was made available to potential respondents to ensure that it fulfils the purpose for which it was developed. It was initially developed in English and then translated into Portuguese and translated back to English.

Three companies were first contacted to pilot-test the questionnaire and to give opinion in terms of its objectivity. Their feedback resulted in small alterations on the questionnaire that then it was revised by two academic experts.

The reliability and the validity of the questionnaire its supported by the combination of all the reviews mentioned above (Zhao et al., 2007).

The complete questionnaires are presented in **Annexes 1** and **2**.

3.3 Variables Measurement

Digital technologies implementation and adoption was measured based on the models proposed by Lambert and Enz (2017), Druehl et al. (2018) and Stentoft et al. (2020). The respondents were asked to indicate the level of implementation of the digital technologies presented in **Table 1**, classifying them on a seven-point Likert scale (where 1 = the technology is not used in the company at all and 7 = the technology is fully implemented, has proven its contributions and is consolidated in the companies processes and culture). The respondents were also asked to specify the frequency that the company adopts digital technologies in different operational areas (Research & Development, Procurement, Manufacturing, Distribution and Service, support, recovery), classifying them also on a seven-point Likert scale (where 1 = the company never uses the technology and 7 = the company always use the technologies).

Innovation performance was measured following the multi-item scales developed by Shu et al. (2012). Seven statements regarding product and process innovation were presented to respondents so that they indicate the level of agreement with those, ranking it on a seven-point Likert scale with 1 = strongly disagree and 7 = strongly agree.

The constructs used in the study are presented in **Table 4**.

Table 4 – Variables and measures

Construct	Items	Source
Digital technology level of implementation (DT_Impl) (Please indicate the level that your company adopts/ implements the following digital technologies, using the scale below as a basis)	Big Data Analytics	Based on Lambert & Enz, 2017; Stentoft et al., 2020
	Autonomous Robots	
	Cloud Computing	
	Simulation	
	Internet-of-Things (IoT)	
	Additive Manufacturing (3D Printing)	
	Augmented Reality	
	Business Intelligence	
	Cybersecurity	
Digital technology adoption (DT_Ado) (Please indicate the frequency your company applies the before mentioned digital technologies in the following areas)	Research & Development	Based on Lambert & Enz, 2017; Druehl et al., 2018; Stentoft et al., 2020
	Procurement	
	Manufacturing	
	Distribution	
	Service, support, recovery	
Innovation performance (InovPerf) (Please indicate below the extent to which you agree or disagree with the following statements)	The number of new products/services introduced in the past three years by our company increased steadily. (IP_1)	Based on Shu et al., 2012
	Our company continuously improves the quality of its products. (IP_2)	
	Our company continuously introduces new products and develops new markets. (IP_3)	
	Our company cares a great deal about the new technology breakthroughs. (IP_4)	
	Our company is a pioneer in developing new markets. (IP_5)	
	Our company has frequently improved manufacturing or operational processes. (IP_6)	
	Our company has endeavoured to economize resource consumption. (IP_7)	

3.4 Sample and Data Collection

The sample comprised Portuguese SMEs within the manufacturing sector. SMEs play an important role in job creation (accounting for 77,4% of employment) and in economic growth (accounting for 68,3% value added) in Portugal, representing, 99.9% of total enterprises (European Commission, 2019). Not representing one of the most regular countries in studies of digital transformation and innovation, Portuguese SMEs were analysed in this study. These firms were collected from the SABI[1] database.

The manufacturing sector was defined according to the statistical classification of economic activities in the European Community (NACE[2] Rev. 2) and the final sample incorporates companies from various sectors, such as automotive and parts, construction and materials, food and beverages, industrial materials, machinery and plant construction and textiles and apparel. To comprised information on SMEs, defined by the European Commission (2003, p. 4) as "enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million.", we filter the population of Portuguese manufacturing firms by selecting those with employees' number less than 250 and with an annual turnover below EUR 50 million.

The questionnaire was made available in the Qualtrics online platform and an email was sent to key respondents which included the most fit person to answer the questions. In companies where it was not possible to obtain the email of that person, the questionnaire was sent to the company's general email. The email composed by a brief explanation of the purpose of the study, a note about anonymity and the link to the questionnaire, was sent to 1.000 SMES.

From March 2021 to May 2021, the 1.000 SMEs were contact more than once to increase the number of responses obtained. We collected 109 responses, having a return rate of 11%. Although the difficulties imposed to companies during the COVID-19[3] pandemic was a barrier to collect data, this response rate is considered adequate. In **Table 5** specific characteristics of the sample in terms of sector of activity, companies' foundation year, number of employees and annual turnover, are presented.

Table 5 - Sample composition

	Sample	**Sample (%)**
Sector of activity		
Food and beverages	24	22,02
Textiles and apparel	16	14,69

[1] SABI is the acronym for "Sistema de Análise de Balanços Ibéricos", a database that contains business information on Portuguese and Spanish companies
[2] NACE is the acronym for "Nomenclature statistique des activités économiques dans la Communauté européenne".
[3] Coronavirus disease 2019

	Sample	Sample (%)
Construction and materials	12	11,01
Automotive and parts	11	10,09
Industrial metals	7	6,42
Machinery and plant construction	6	5,50
Chemical	3	2,75
Electronic and electrical equipment	3	2,75
Household goods and personal care	2	1,83
Oil and gas	2	1,83
Pharmaceuticals and biotechnology	2	1,83
Other	21	19,28
Companies' foundation year		
Before 1970s	20	18,35
1971 to 1980	20	18,35
1981 to 1990	18	16,51
1991 to 2000	25	22,94
2001 to 2010	18	16,51
2011 to 2019	8	7,34
Number of employees		
Less than 10	5	4,59
10 to 49	58	53,21
50 to 250	46	42,20
Annual turnover (EUR)		
< 1Million	16	14,68
1Million < 2Million	16	14,68
2Million < 10Million	48	44,03
10Million < 50Million	29	26,61

4. Results and Discussion

This chapter presents the analysis of the data collected. First, it starts with the validity and reliability assessment of the structural model, followed by the presentation and discussion of the results.

4.1 Results

To understand the impact of digital transformation on innovation performance, we employed linear regression with SPSS v27, where the independent variable for H1 is the level of implementation of digital technologies (DT_Impl) and for H2 is the adoption of digital technologies (DT_Ado), and for both hypotheses the dependent variable is innovation performance (InovPerf).

Before testing the hypothesis formulated above, the goodness of fit of the structural model was assessed with SPSS AMOS v27 (see **Annex 3**). By analysing the $\chi 2$, IFI, CFI and RMSEA[4] we can see that the results support the validity of the structural model hypothesized (see **Table 6**).

To assess the validity of the constructs, some indicators were measured according with the threshold values set by Hair et al. (2010). The three results of Average Value Extracted (AVE) presented in **Table 7**, are higher than the recommended value of 0.5, meaning that, each latent variable have convergent validity. In turn, the same table also presents the values of Composite reliability (CR) which indicates the internal consistency and reliability of the constructs used. MaxR(H) values were also observed greater than the values of CR which indicates good construct validity. Also, the square roots of the AVE values, presented along the diagonal in bold, are higher than the correlation between the other variables, contributing to the validity of the constructs.

Table 6 - Goodness of fit for the structural model

Goodness of fit measures	Recommended values	Results
$\chi 2$ / df	≤ 3.00	1.557
IFI	≥ 0.90	0.907
CFI	≥ 0.90	0.903
RMSEA	≤ 0.060	0.060

[4] Chi-square, Incremental Fit Index, Tucker-Lewis Index, Comparative Fit Index, Root Mean Square Error of Approximation (Hu & Bentler, 1995).

Table 7 – Descriptive statistics

Variable	CR	AVE	MaxR (H)	DT_ Impl	DT_ Ado	Inov Perf	Mean	Std. Deviation	Variance
DT_Impl	0.860	0.509	0.872	**0.778**			2.3904	1.22181	1.493
DT_Ado	0.885	0.606	0.887	0.599	**0.713**		4.4532	1.88358	3.548
InovPerf	0.826	0.551	0.858	0.603	0.551	**0.742**	5.3263	0.95161	0.906

Recommended values: CR ≥ 0.700; AVE ≥ 0.500; MaxR(H) ≥ 0.800 (Hair et al., 2010)

The results from linear regression analysis presented in **Table 8** supports both hypotheses. The data confirm that the level of implementation of digital technologies have a positive impact on innovation performance ($\beta = 0.492$; $p < 0.001$), supporting **H1**, and that the adoption of digital technologies have a positive impact on innovation performance ($\beta = 0.464$; $p < 0.001$), supporting **H2**.

Table 8 - Linear regression statistics

Variable	R squared	Adjusted R squared	β	Significance
DT_Impl	0.242	0.235	0.492	< 0.001
DT_Ado	0.216	0.208	0.464	< 0.001

4.2 Discussion

The analysis of data through linear regression supported H1 and H2 formulated. The results confirm that the level of implementation and the adoption of digital technologies, both positively impact innovation performance on SMEs in the manufacturing sector, in Portugal.

Identified as being innovative and important to economic growth (Bougrain & Haudeville, 2002), SMEs have limited resources (Lukovszki et al., 2021) and a proper use of it under the lens of RBV will help companies in achieving competitive advantage (Barney, 1991). Recognized as a core process for competitive advantage (Lukovszki et al., 2021), innovation is impacted by the interconnection between digital technologies, machines and people (considered company' resources), given the associated advantages such as efficiency increases, cost savings, overcome of geographical barriers allowing the expansion of knowledge, and the development of new products with more added value for customers (Sheng et al., 2019; Manocha et al., 2020; Stentoft et al., 2020). Thus, and in line with the results, digital transformation affects innovation performance positively, evaluated in this research, through product and process innovation performance, together. The impact on product innovation translates into new goods and new services (OECD/Eurostat, 2018; Garzella et al., 2021), while the impact on process innovation denotes new or improved elements in the development chain of products (Zhu and Kraemer, 2005; Scuotto et al., 2017; OECD/Eurostat, 2018).

The positive impact of digital transformation on innovation performance is consistent with previous studies in this field (Scuotto et al., 2017; Nambisan et al., 2020; Ardito et al., 2021). The results are in line with the findings of Scuotto et al. (2017), Nambisan et al. (2020) and Ardito et al. (2021) that demonstrate a positive relationship between the use of digital technologies and digital orientation strategy, and innovation performance. In turn, our research builds on and extend prior work, following suggestions for further research presented, namely by considering the impact of technologies on different organizational processes (Scuotto et al., 2017) and by including a more complete measure of innovation than a simple binary encoding (Ardito et al., 2021).

Regarding digital technologies' implementation and adoption variables, some observations can be made. By the average analysis of these variables (presented in **Table 7**), we can see that the implementation of the I4.0 digital technologies (DT_Impl) is still at an initial stage, and that in terms of the adoption of digital technologies on the areas of research & development, procurement, manufacturing, distributing and service, support, recovery, (DT_Ado) the average answer is sometimes (once a month). These observations are in line with Xu et al. (2018, p. 2952) *"Industry 4.0 technologies and applications are still in their infancy",* and according with TOE and DOI framework, that could be explained by the impact of internal, external, and environmental factors in adoption and usage of digital technologies. Also, when looking at the technologies individually, cloud computing and cybersecurity represent the technologies with higher level of implementation, whereas augmented reality and autonomous robots represent the ones with the lowest level of implementation. Additionally, the areas with more frequency of technology utilization are manufacturing and procurement, while service, support, recovery, represents the area with the least use of technologies.

In terms of innovation performance, the results show that more than 50% of the interviewers agreed with all the statements, demonstrating the company's commitment to innovation. Specifically, the focus of the companies in this study, in terms of innovation, is to improve the quality of its products and to economize resource consumption.

5. Conclusions

Aiming to contribute to a better understanding of the relationship between digital transformation and innovation performance and to the decision-making process of managers who seek to improve business performance by means of the assessment, discussion and presentation of the practical implications of digital transformation on innovation performance, the findings of this study offer theoretical and practical implications.

The emergence of digital transformation is a recent phenomenon that has gained attention from practitioners and academics. In particular, the impact of digital transformation on companies' performance has been studied (e.g. Dalenogare et al., 2018; Haseeb et al., 2019), however, innovation performance is not representative (Nambisan et al., 2019) and there is a major focus on large companies (e.g. Björkdahl 2020). This study fills this gap, contributing to the topic of digital transformation and innovation performance in the context of SMEs, recognized as a "largely unexplored topic" by Ferreira et al. (2019, p.584) and as a "under-researched phenomenon" by Ardito et al. (2021, p.52).

This paper also offers managerial implications. Under the lens of RBV, that focus on exploiting resources to achieve competitive advantage (Barney, 1991), this study indicates that companies will benefit from a positively impact on innovation performance given the adoption and implementation of Industry 4.0 technologies in the companies' operations. According to this, managers may use these findings in decision-making when seeking to improve innovation, recognized as a core process for competitive advantage and for survival (Baregheh et al., 2009; Adhikari, 2011). Our results indicate that higher investment in digital technologies result in improvements on innovation performance. As so, managers may seek to adopt digital technologies to attain the underlying advantages to improve product and process innovation performance. Moreover, the study helps managers make strategic decisions in terms of new product/service offerings, improvements on product quality, manufacturing and operational processes, and resource consumption savings, through digital transformation.

This study has some limitations that future research can take into consideration to overcome them. First, Industry 4.0 technologies and applications are still recent and so the impact may not be feasible at short term (Dalenogare et al., 2018; Xu et al., 2018). Second, our study it was applied to a tiny population, that limits the generalizability of results and so, we propose that future research consider a variety of countries to make cross-country comparisons to overcome this barrier.

Finally, future research may consider the impact of each technology individually, the impact by sector of activity and the impact on product and process innovation performance, separately. The impact of each technology will allow companies to understand which technology has the greatest impact on innovation performance while the impact by sector of activity, will help companies to realize if the sector in which they operate is characteristic of a greater or lesser impact of adoption and implementation of technologies on innovation performance. Also, the separation between product and process innovation performance it is suggested given that their demand different strategic orientations, different actions and it may not be possible for companies, to pursuit both types of innovation together and therefore to achieve better levels of innovation performance on both.

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Annex 1 – Questionnaire translated

PARTE A – TECNOLOGIAS DIGITAIS

1. Por favor indique qual o nível em que a sua empresa se encontra relativamente à adoção/implementação das seguintes tecnologias digitais, usando esta escala como base:
1 = Não é utilizada – a tecnologia não é utilizada na empresa
2 = Nível inicial – a adoção/implementação está num nível inicial (ad hoc, "caótico", emergente, falta de entendimento)
3 = Repetível – a tecnologia está suficientemente documentada (existe uma metodologia estabelecida para a implementação; a implementação da tecnologia tem sido controlada e coordenada, mas ainda é reativa, sendo a sua contribuição para a empresa, quanto à otimização/melhoria dos processos, muito pequena)
4 = Definida – a tecnologia está implementada, mas as suas contribuições, sendo maiores que no nível anterior, são ainda muito limitadas (a implementação da tecnologia está padronizada e documentada, sendo proativa)
5 = Gerida – a tecnologia está implementada, com mais contribuições que no nível anterior, mas ainda algo limitadas (foram estabelecidas métricas de qualidade, e a tecnologia é confiável)
6 = Otimizada – a tecnologia está totalmente implementada e contribui para a otimização/melhoria de processos (melhoria contínua)
7 = Consolidada – a tecnologia está totalmente implementada, provou as suas contribuições e está consolidada nos processos e cultura da empresa (partilha de conhecimento e informação)

	1 – Não é utilizada	2 - Nível inicial	3 - Repetível	4 - Definida	5 - Gerida	6 - Otimizada	7 - Consolidada
Big Data Analytics							
Robôs Autônomos							
Tecnologia Cloud							
Simulação							
Internet das Coisas (Internet-of-Things IoT)							
Additive Manufacturing (Impressão 3D)							
Realidade aumentada							
Business Intelligence							
Cibersegurança							

1.1. Existem outras tecnologias que gostaria de mencionar? Por favor, escreva-as no espaço abaixo indicado:

____

1.2. Indique, por favor, a frequência com que a sua empresa aplica as tecnologias digitais mencionadas anteriormente, nas seguintes áreas:

	Nunca	Muito raramente (uma vez a cada 3 meses)	Raramente (uma vez a cada 2 meses)	Às vezes (uma vez por mês)	Frequente mente (uma vez por semana)	Muito frequentemente (dia sim, dia não)	Sempre (todos os dias)
Investigação & Desenvolvimento							
Compras							

Produção							
Distribuição							
Serviço, suporte, recolha/recuperação							

PARTE B – PERFORMANCE

2. Por favor indique abaixo até que ponto concorda ou discorda com as seguintes afirmações:

	Discordo totalmente	Discordo	Discordo parcialmente	Nem concordo, nem discordo	Concordo parcialmente	Concordo	Concordo totalmente
O número de novos produtos/serviços introduzidos pela nossa empresa nos últimos três anos aumentou de forma constante.							
A nossa empresa melhora continuamente a qualidade dos seus produtos.							
A nossa empresa introduz continuamente novos produtos e explora novos mercados.							
A nossa empresa preocupa-se bastante com os novos avanços tecnológicos.							
A nossa empresa é pioneira na exploração de novos mercados.							
A nossa empresa melhora frequentemente os seus processos operacionais e de fabrico.							
A nossa empresa empenha-se em economizar no consumo de recursos.							

PARTE C – CLASSIFICAÇÃO PMEs

As perguntas a seguir serão utilizadas exclusivamente com o propósito de categorizar as PMEs para fins de análise estatística de dados.

3. Qual dos seguintes setores melhor descreve as atividades da sua empresa?

- Aerospacial
- Automóvel e peças
- Químico

- Construção e materiais
- Eletricidade
- Equipamentos eletrónicos e elétricos
- Alimentos e bebidas
- Silvicultura e papel
- Bens domésticos e cuidados pessoais
- Metais industriais
- Maquinaria e construção de instalações
- Equipamento médico
- Mineração
- Óleo e gás
- Farmacêutica e biotecnologia
- Hardware e equipamentos de tecnologia
- Têxteis e vestuário
- Outro. Por favor, indique abaixo qual:

____

4. Quando foi fundada a empresa (ano)?

____

5. Quadro de funcionários

O critério do número de funcionários abrange funcionários em tempo integral, parcial, temporário e sazonal e inclui o seguinte:

- funcionários;

- pessoas que trabalham para a empresa, que foram destacadas para esta e são consideradas trabalhadoras nos termos da legislação nacional (isto também pode incluir trabalhadores temporários ou os chamados estagiários);

- proprietários-gestores;

- sócios que exerçam uma atividade regular na empresa e que dela tirem vantagens financeiras.

- Menos de 10 pessoas
- 10 a 49 pessoas
- 50 a 250 pessoas

6. Volume de negócios anual

O volume de negócios anual é determinado calculando o rendimento que uma empresa recebeu durante o ano em questão com a venda de produtos e prestação de serviços abrangidos pelas atividades normais da empresa, após dedução de quaisquer descontos. O volume de negócios não deve incluir Imposto sobre o Valor Acrescentado (IVA) ou outros impostos indiretos.

- Menos de 1 milhão de Euros
- De 1 milhão de Euros a 2 milhões de Euros
- De 2 milhões de Euros a 10 milhões de Euros
- Mais de 10 milhões de Euros e menos de 50 milhões de Euros

Annex 2 – Questionnaire

PART A – DIGITAL TECHNOLOGIES

1. Please indicate the level that your company adopts/implements the following digital technologies, using the scale below as a basis:

1 = Not used at all – The technology is not used in the company at all
2 = Initial level – the adoption/implementation is at an initial stage (ad hoc, "chaotic", emerging, lack of understanding)
3 = Repeatable – the technology is documented sufficiently (there is an established methodology to implementation, the technology implementation has being controlled and coordinated, reactive)
4 = Defined – the technology is implemented but its contributions are still very limited (standardized and documented, proactive)
5 = Managed – the technology is implemented but its contributions are limited (quality metrics have been established, the technology is reliable)
6 = Optimized – the technology is fully implemented and contributes to processes optimization/improvement (continuous improvement)
7 = Consolidated – the technology is fully implemented, has proven its contributions and is consolidated in the companies processes and culture (share of knowledge and information)

	1 - Not used at all	2 - Initial level	3 - Repeatable	4 - Defined	5 - Managed	6 - Optimized	7 - Consolidated
Big Data Analytics							
Autonomous Robots							
Cloud Computing							
Simulation							
Internet-of-Things (IoT)							
Additive Manufacturing (3D Printing)							
Augmented Reality (AG)							
Business Intelligence (BI)							
Cybersecurity							

1.1. Are there any other technologies you would like to mention? Please write them below:

____

1.2. Please indicate the frequency your company applies the before mentioned digital technologies in the following areas:

	Never	Very rarely (once every 3 months)	Rarely (once every 2 months)	Sometimes (once a month)	Frequently (once a week)	Very frequently (every other day)	Always (every day)
Research & Development							
Procurement							
Manufacturing							
Distribution							
Service, support,							

recovery							

PART B – PERFORMANCE

2. Please indicate below the extent to which you agree or disagree with the following statements:

	Strongly disagree	Disagree	Somewhat disagree	Neither agree not disagree	Somewhat agree	Agree	Strongly agree
The number of new products/services introduced in the past three years by our company increased steadily.							
Our company continuously improves the quality of its products.							
Our company continuously introduces new products and develops new markets.							
Our company cares a great deal about the new technology breakthroughs.							
Our company is a pioneer in developing new markets.							
Our company has frequently improved manufacturing or operational processes.							
Our company has endeavoured to economize resource consumption.							

PART C – SMEs CLASSIFICATION

The following questions will be used solely for the purpose of categorizing SMEs for the purpose of statistical data analysis.

3. Which of the following sectors best describes your company's activities?

- Aerospace
- Automotive and parts
- Chemical
- Construction and materials
- Electricity
- Electronic and electrical equipment
- Food and beverages
- Forestry and paper
- Household goods and personal care

- Industrial metals
- Machinery and plant construction
- Medical equipment
- Mining
- Oil and gas
- Pharmaceuticals and biotechnology
- Technology hardware and equipment
- Textiles and apparel
- Other. Please indicate below which one:

____

4. When was the company founded (year)?

____

5. Staff headcount

The staff headcount criterion covers full-time, part-time, temporary and seasonal staff and includes the following:
- employees;
- persons working for the enterprise who have been seconded to it and are considered to be employees under national law (this can also include temporary or so-called interim employees);
- owner-managers;
- partners engaged in a regular activity in the enterprise and deriving financial advantages from the enterprise.

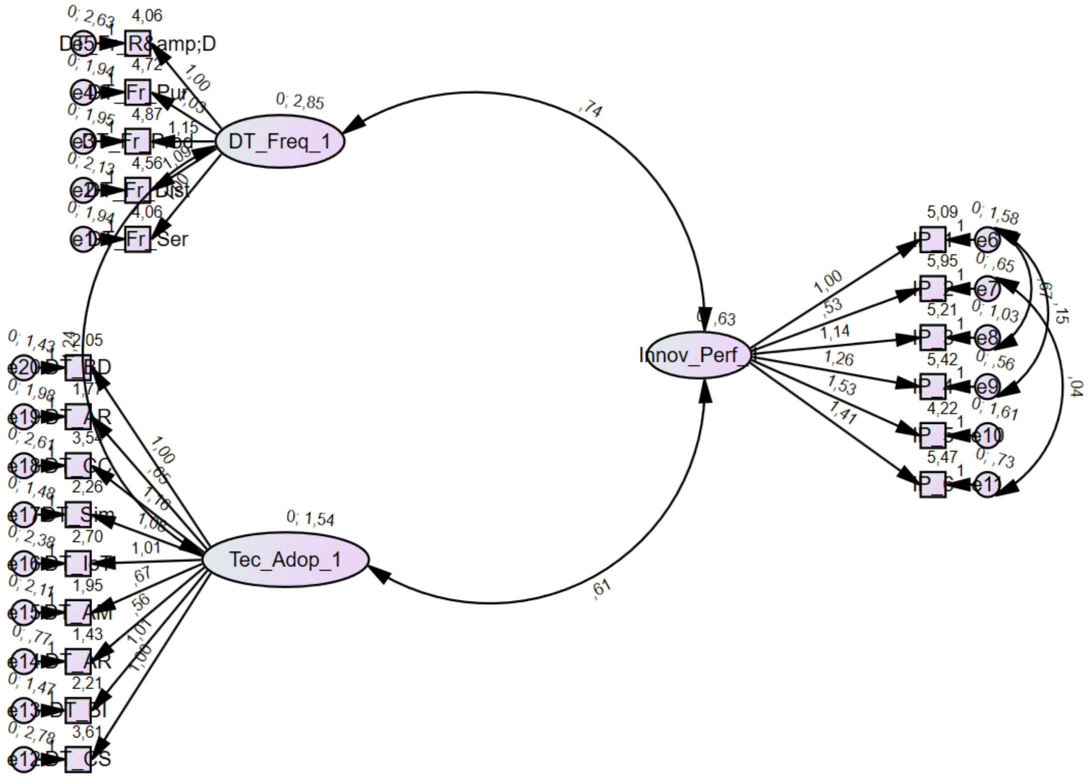
- Fewer than 10 persons
- 10 to 49 persons
- 50 to 250 persons

6. Annual turnover

Annual turnover is determined by calculating the income that an enterprise received during the year in question from the sale of products and provision of services falling within the company's ordinary activities, after deducting any rebates. Turnover should not include value added tax (VAT) or other indirect taxes.

- Less than EUR 1 million
- EUR 1 million to EUR 2 million
- EUR 2 million to EUR 10 million
- More than EUR 10 million and less than EUR 50 million

Annex 3 – Structural model



5

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[5] "DT_Freq_1" represents the variable DT_Ado, "Tec_Adop_1" represents DT_Impl and "Innov_Perf_" represents InovPerf.