

MESTRADO
ECONOMIA E GESTÃO DA INOVAÇÃO

Identification of the relevant decision factors of Collaborative Robots adoption in manufacturing organizations in Portugal and Brazil

Guilherme Couto

M

2021



Identification of the relevant decision factors of Collaborative Robots
adoption in manufacturing organizations in Portugal and Brazil

Guilherme Filipe da Silva Couto

Dissertation Plan
Master in Innovation Economics and Management

Supervised by
Professora Doutora Ana Correia Simões
Professor Doutor Paulo Sérgio Amaral de Sousa

September 2021

Biographic Note

Guilherme Filipe da Silva Couto was born on 25th February of 1984, in Vila do Conde, Porto, Portugal. Obtained the bachelor's degree in Economics by FEP - School of Economics from University of Porto in 2010. In the same year, started working at one of the biggest Auction Houses of Portugal. In this present day, works as Content Manager to the same company.

Acknowledgements

I would first like to show my gratitude to my supervising team, composed by Prof. Ana Correia Simões, Paulo Sérgio Amaral de Sousa and Rosário Moreira, for the support, patience, knowledge and pushing me further every week.

A big thank you to my mother for all her teachings and values transmitted. I am what I am because of her.

At last, a special thank you to my life companion, Sónia Sousa, for making this journey with me and for all the sacrifices done.

Abstract

Purpose – The goal of this study is the identification of the relevant decision factors of adopting (or intent of adopting) collaborative robots in manufacturing organizations in two different countries, Portugal and Brazil.

Design/methodology/approach – An on-line survey was distributed among Portuguese and Brazilian manufacturing companies. Samples of 78 and 291 positives answers, respectively, were analyzed with Partial Least Squares - Structural Equation Modelling (PLS-SEM) by using R software.

Findings – Findings show differences in the countries eagerness to realize the adoption process. Brazil seems to be ahead of this effort. Confirmed existence of specific decision factors for each country.

Originality/value – This study fulfills the gap in the literature regarding the scarcity of quantitative analyses on the factors determining the decision (or the intent) to adopt or not collaborative robots, complementing the qualitative point-of-view, enlarges the knowledge available in the technology management field.

Impact – The conclusions of this study will allow managers to focus on specific critical decision factors of Cobot adoption and that information will enable managers and decision makers in manufacturing companies to make better decisions.

Keywords: Collaborative Robots (Cobots) · Technology Adoption · Manufacturing · Operator 4.0

JEL-Codes: M15 · L60 · O33

Table of Contents

Biographic Note.....	i
Acknowledgements	ii
Abstract	iii
1. Introduction.....	1
2. Literature Review	4
2.1. Collaborative Robots.....	4
2.2. Cobot Applications: Advantages & Disadvantages	7
2.3. International Climate: Industry 4.0 and Lean Robotics	11
2.4. Operator 4.0.....	13
2.5. Technology Adoption	14
2.6. Factors Influencing the Decision to Adopt Cobots	18
3. Material and Methods.....	26
3.1. Methodology Selection	26
3.2. Measures definition	27
3.3. Samples	34
4. Results.....	36
4.1. Sample demographics and descriptive statistics.....	36
4.2. Partial Least Squares – Structural Equation Modelling.....	43
4.2.1. Measurements: Reliability and Validity.....	44
4.2.2. Evaluation of the Structural Model.....	53
4.3. Model validation and hypothesis testing	53
5. Discussion of results and implications	57
6. Conclusion	59
References.....	60
Annex 1 - Survey.....	69
Annex 2 - Brazilian Survey on SurveyMonkey	84
Annex 3 - 1st Email.....	93
Annex 4 – 2 nd Email	94
Annex 5 – Sample Demographic	95
Annex 6 – Final Model BR.....	97
Annex 7 – Final Model PT	98

List of Tables and Figures

Table 1- Synthesis of the main features of Collaborative Robots (Cobots)	4
Table 2- Degrees of Interaction between a Cobot and a human worker	5
Table 3- Comparison between Traditional Robots and Collaborative Robots.....	6
Table 4- Pros and cons of humans and robots.....	7
Table 5 - Frequent Applications for Cobots	8
Table 6 - Advantage of Cobots	9
Table 7- Challenges of Industrial Collaborative Robotics.....	11
Table 8 - Table 8: Technologies analyzed by TOE framework.....	16
Table 9- Variables Determining the Rate of Adoption Innovations	17
Table 10 - Organizational Innovativeness	17
Table 11- Factors influencing the intention to adopt AMT	19
Table 12- Advanced Manufacturing Technologies.....	20
Table 13 - Factors most times referred.....	20
Table 14 - Similar Studies about AMT/Industry 4.0 adoption.....	27
Table 15- Structure of the survey	27
Table 16- Cobot Adoption Measures	30
Table 17- Literature inspiration for the survey	33
Table 18- Manufacturing companies' distribution by division in NACE.....	35
Table 19 -Intensity of Cobots Adoption	36
Table 20 - Degree of adoption	37
Table 21- Activity Sector based on NACE	37
Table 22- Company Size	38
Table 23 - Companies Annual Turnover	39
Table 24 - Product Variance	39
Table 25 - Method of Production.....	39
Table 26- Supply Chain Position.....	39
Table 27- Sample descriptive statistics BR.....	41
Table 28 - Sample descriptive statistics PT	43
Table 29 - Validation for Adoption measures BR.....	46
Table 30 - Measures after item removal BR	47
Table 31 - Discriminant Validity for BR	47
Table 32- Validation for Adoption measures PT	49
Table 33 - Measures after item removal PT.....	50
Table 34 - Discriminant Validity for PT.....	50
Table 35 - Cross-Loading Brazilian Samp.....	52
Table 36 - Cross-Loadings Portuguese sample.....	53
Table 37- Validation of the Final PLS-SEM	54
Table 38 - Bootstrap Parameter estimation of the structural model	54
Table 39 - Coefficient of determination of the constructs	54
Table 40 - Validation of the Final PLS-SEM	55
Table 41- Bootstrap Parameter estimation of the structural model	56
Table 42- Coefficient of determination of the constructs	56
Table 43 - Hypothesis Testing	57

List of Figures

Figure 1- Adoption Process	15
Figure 2- Technology, Organization and Environment Framework	16
Figure 3 - Conceptual Framework.....	25

1. Introduction

Every past industrial revolutions were supported and boosted by new technologies that changed the innovation paradigm (Lasi et al., 2014). Technologies like Artificial Intelligence (AI), Internet of Things (IoT), Cyber-Physical Systems (CPS), Big Data and Machine Learning (ML) are discoveries with potential still to be entirely discovered and when combined, can provide exciting new possibilities (Bi et al., 2020). The new paradigm consists in the digitalization of procedures in the real world and integrates it into digital systems (Kagermann et al., 2013; L. Wang et al., 2015).

The most recent revolution, Industry 4.0, connects the “Factory Floor” with the departments up and downstream achieving a more efficient production with less resources wasted (Cohen et al., 2019). In economies with high salaries, the tendency in the pursuit of this internal goal is the automatization of production (Malik & Bilberg, 2017). Basically, it is the real-time connection between product life cycle and supply chain (Dalenogare et al., 2018; Frank et al., 2019; S. Wang et al., 2016b). So unparalleled that it is changing even the way people work (Stock et al., 2018). Three main topics should be emphasized: integration, more production with less waste and new type of work.

One path of automation are the technologies based on Human-Robot Collaboration (HRC) which development considers that a collaboration between a human and a robot is more efficient when they are combined than when separated (Kadir et al., 2018; Simões et al., 2019b; Villani et al., 2018). From one side, the human has creativity and flexibility and on the other side there is the power, accuracy and consistency of the robot (Bernhardt et al., 2007). A promising type of HRC is Collaborative Robot or Cobot, which can be described as robots that can safely interact with a worker in several applications and without any physical or virtual barriers (Bauer et al., 2016). Current developments reveal that companies of different origins and sizes consider Cobots flexible, cost efficient and enabler of more customization (Kadir et al., 2018).

The new industrial revolution is also changing how assembly line workers are seen, contributing to the raise of the concept of Operator 4.0 (Romero et al., 2016). This kind of interaction between human workers and Cobots may assume different degrees which may result in different effects on the human physical and mental state.

In the literature, there exists many studies predominantly on the technical aspects of the technology advocating the many advantages of adopting Cobots (Vojić, 2020), the

technology it should include (Salunkhe et al., 2019), as well as future improvements (Subramaniam et al., 2018). Fewer contributions exist on the compilation of the pros and cons of Cobots, and on the factors relevant to the managers of the companies in the adoption (or the intention to adopt) decision of Cobots in manufacturing organizations.

Cohen et al. (2019) point out there is a gap on the managerial and strategic aspect of the intention to adopt. Simões, Lucas Soares, et al. (2020) presented a qualitative and exploratory study, where they suggested as future research line, the quantification of the importance of decision factors of adopting Cobots for manufacturing company managers. Simões et al. (2019b), an exploratory study about Cobots adoption in manufacturing companies of France and Portugal, adds new factors as drivers as well as presenting safety and workers acceptance as challenges. Sowa et al. (2021) study highlighted how Cobots AI can extend humans' cognition and investigated attitudes towards AI (including generational differences).

Therefore, the purpose of this study is the identification of the relevant decision factors of adopting (or intent of adopting) collaborative robots in manufacturing organizations in two different countries, Portugal and Brazil. Several reasons explain this choice. First, this study is part of a collaboration between FEP – School of Economics from University of Porto, INESC TEC Porto and Fundação Dom Cabral from Brazil. Second, Brazil has in its industrial fabric the sectors where Cobots adoption can be potentially more relevant. Third, location. It is near of one of the biggest centers of technology development and in forth, the history of technology importation.

This study fulfills the gap in the literature regarding the scarcity of quantitative analyses on the factors determining the decision (or the intent) to adopt or not collaborative robots, complementing the qualitative point-of-view, enlarges the knowledge available in the technology management field. Additionally, the results of this study enable managers and decision makers in manufacturing companies to make better decisions.

The dissertation is divided in 6 chapters. After Introduction, Chapter 2 presents the literature review on the main concepts related to the topic, introducing the Cobot technology, their main advantages and disadvantages. After that a reference to the concept of Operator 4.0 is made. Main aspects related to the technology management and the factors to adopt cobots reported in the literature are also presented at the end of this chapter. Chapter 3 presents Material and Methods used to conduct this study. In Chapter 4

the data from the samples is analyzed and confronted to the literature in Chapter 5. In Chapter 6 the main conclusions are resumed and presented.

Keywords: Collaborative Robots (Cobots) · Technology Adoption · Manufacturing · Operator 4.0

JEL-Codes: M15 · L60 · O33

2. Literature Review

The objective of this chapter is to present the main concepts regarding Collaborative Robots, Industry 4.0, Lean Robotics and Operator 4.0, displaying features and relations between them. In the first section, the evolution of the concept of Collaborative Robots is presented, then the advantages and disadvantages in comparison to traditional robots and to humans. In the third section, it is presented how Industry 4.0 programs fosters the adoption of Cobots, the impact of Lean Production principles on robotics and on the fourth section the emergence of a new type of worker is described. In the fifth section, the most suited models of technology adoption are addressed which leads to the factors that influence the decision to adopt Cobots in the sixth section as well as the hypotheses to be verified.

2.1. Collaborative Robots

The concept of Collaborative Robot is not new, and it does not start to appear in the course of the Fourth Industrial Revolution. Collaborative Robots or simply Cobots had several definitions over the last 25 years as can be observed in Table 1. The first definition came from Colgate et al. (1996). In this article the authors defined Cobot as “... robotic device which manipulates objects in collaboration with a human operator.” (p. 433).

Feature	Authors*
Manipulate Objects	1, 5, 6
Collaboration with Human Operator	1, 3, 4, 5, 7, 8, 9,11
Manufacturing Technology	2, 4, 11
Common Workspace	2, 4, 6, 8, 10, 11
Without Safety Fences	2, 3, 4, 6, 8, 10
Lightweight	3
Movable	3
Constrain and guide workers motion	1, 5, 8

Table 1: Synthesis of the main features of Collaborative Robots (Cobots)

Authors: 1 - Colgate et al. (1996); 2 - Simões et al. (2019b); 3 - Bauer et al. (2016); 4 - Kadir et al. (2018); 5 - Malik and Bilberg (2017); 6 - Bi et al. (2020); 7 - Koch et al. (2017); 8 - Vojić (2020); 9 - Galin et al. (2020); 10 - Kadir et al. (2018)

Source: Own Elaboration.

Merging the main definitions presented on Table 1, we can define Cobot as a robot able to work with a human without any virtual or physical barriers and sharing with the human the same workspace. The International Federation of Robotics (IFR) divides robots

in 2 groups (Galin et al., 2020): i) the group for industrial applications; and ii) the group for service applications. Collaborative Robots belong to both but the focus of this study will be industrial applications.

Table 2 identifies the four levels of interaction between a human and a Cobot established by Bauer et al. (2016): Coexistence, Synchronized, Cooperation and Collaboration and its characteristics.

	Cage Free	Human and Robot work at the same time	Same Workspace	Same Component or Product
Cell				
Coexistence	X	X		
Synchronized	X		X	
Cooperation	X	X	X	
Collaboration	X	X	X	X

Table 2: Degrees of Interaction between a Cobot and a human worker

Source: Own Elaboration based on Bauer et al. (2016)

For the best of our knowledge, there is not any manufacturing organization operating in a true collaborative interaction, with the worker sharing the same space and object (Bauer et al., 2016).

The decision of adopting and implementing a Cobot instead of an traditional robot in an industrial context is not an easy one (Fast-Berglund et al., 2016), therefore is important to distinguish the main features and differences between them. Table 3 presents the major differences between industrial traditional robots which focus on speed, repetition and precision and industrial Cobots flexibility and safety.

Traditional Robots	Collaborative Robots
Fixed installation	Flexibly relocated (manually or on mobile robots)
Heavy structure; weights around 250 kg for 3 kg payload	Light-weight structure; weights as little as 11 kg for 3 kg payload
Periodic, repeatable tasks; infrequently changes	Frequent task changes; tasks infrequently repeated
On-line and off-line programming by a robot specialist	On-line instructed by a process expert and supported by off-line methods
Not easy to teach	Easy to teach
Rarely interaction with the human, only	Frequent interaction with the human, even

during programming	force/precision assistance
Human and robot separated through perimeter safeguarding	Workspace sharing with human
Hazards prevented by not allowing access	Safe interaction with human
Profitable only with medium to large lot size	Profitable even at small lot size
Cannot reduce cost and footprint to justify new applications	Reduce cost and footprint to justify new applications
Not requested risk assessment	Requested risk assessment
Usually 6-axis with last three intersecting in wrist	Usually 6 and 7-axis with many offsets
No ability to provide support to the human	Provide power support to the human
Do not provide a virtual surface to constrain and guide human motion	Provide a virtual surface to constrain and guide human motion
Cannot adjust their configurations in real-time to fit with the human physique	Automatically adjust their configurations in real-time to best fit with the human physique and fastening task features
Do not provide an artificial force to the human	Provide an artificial force to the human to perform hazardous activities
Not able to reduce the ergonomic risk of strenuous tasks	Reduce the ergonomic risk of strenuous tasks
Setting up takes days or over weeks	Quick set up (less than a day)
Need for a robotic programmer to be hired which might require additional investment	Easy to program without special skills; anyone who can work on smartphone can use it
Requires large and separate enclosures	Requires less floor space
Small or big and fast	Small, slow and easy to use and easy to move

Table 3: Comparison between Industrial Traditional Robots and Industrial Collaborative Robots

Source: Hentout et al. (2019)

Another important distinction is between robots and humans. Cobots raise operational efficiency because they combine the strong points from human and robots identified in Table 4.

H U M A N	Pros	· Assimilates (new) tasks rapidly and can make judgments · Able to move freely and apply tolerance compensation · Able to sense and locate things · Flexible availability · Can handle complex parts · Able to innovate
	Cons	· Limited quality and process control · Physical and mental performance limits · High cost of training · Requires a jig to position parts accurately

R O B O T	Pros	· Consistent quality thanks to integrated process control · Endurance · Able to take on unreasonable and monotonous tasks · Can handle heavy, hazardous parts
	Cons	· Limited movement · Requires a defined deployment · High cost of implementation, programming and certification · Function-oriented rather than goal-oriented · Fixed costs even if the workload fluctuates

Table 4: Pros and cons of humans and robots

Source: Bauer et al. (2016)

The combination is better than any composed only by robots or just by humans. One can also conclude that robots are more appropriated for repetitive, monotonous, dangerous or physically demanding tasks, while human should be the decision-maker and creativity source (Kadir et al., 2018).

This reasoning also contribute to Cobots becoming the intermediate stage, special for small and medium companies, between a full automated factory and one that depends exclusively on manual labor (Friis & Officer, 2016; Olender & Banas, 2019).

2.2. Cobot Applications: Advantages & Disadvantages

Since 1995, with the first application for material handling, many other applications have become available. The development of Adaptable End Effectors (AEE) devices (Dubey & Crowder, 2002) is a major explanation for this. Robotic Industries Association (2020) defines AEE as “... peripheral devices that attaches to a robot’s wrist, allowing the robot to interact with its task...”.

Lee et al. (2001) study have demonstrated how an additional robot can improve production by reducing time, improving handling of materials and movement speed of workers (Weckenborg et al., 2020). According to IFR Statistical Department (2020), the most relevant sectors for industrial robots are: Automotive Industry, Electrical/Electronics, Metalworking, Machinery Construction and Plastics and Chemical Products. Table 5 presents the most frequent applications for Cobots in manufacturing organizations.

Application	Task
Assembly	Screwdriving Part Insertion
Dispensing	Gluing Sealing Painting
Finishing	Sanding Polishing
Machine Tending	CNC Injection Mold ICT
Material Handling	Packaging/Picking/Placing Palletizing Bin Picking Kitting Metal Casting Plastic Moulding Stamping/Forging/Bending
Material Removal	Grinding Deburring Milling Routing Drilling
Quality Inspection	Testing Inspecting Measuring
Welding	Arc Spot Soldering Laser

Table 5: Frequent Applications for Cobots

Source: Adapted from Universal Robots (2020) and IFR Statistical Department (2020).

The literature is vast regarding the advantages of Cobots. Table 6 gathers, according to several authors, the most commonly advantages referred.

	Authors*
Productivity	1, 4
Ergonomics	1, 4, 5
Monotony	4
Safety	1, 2, 3, 4, 5, 6, 7
Quality Control	1
Flexibility	1, 2, 6, 7
Supervision	1, 2
Reconfigurable	1, 2, 6, 7
Small Floor Space	1
Flexible Investment	1, 3, 4

Cost- Effective	2, 3, 6
High Precision	4
Quick Implementation	2, 6

Table 6: Advantage of Cobots

Authors*: 1 - Malik (2019); 2 - Olender and Banas (2019); 3 - Baptista et al. (2019); 4 - Bauer et al. (2016); 5 - Vojić (2020); 6 - Olender and Banas (2019); 7 - Weckenborg et al. (2020)

Source: Own Elaboration

Other advantages of Cobots:

- New professions – the massification of Cobots in the manufacturing floor will require professionals that have knowledge about workflow design, as well as, pick and deploy of the best Cobot for the specific need (Friis & Officer, 2016).
- The implementation of Cobots allows people to be transferred from manual operations to operations that can add more value. It is still to be proved, notwithstanding, that this transfer means financial rewards to the workers (Friis & Officer, 2016)
- The “Factory of the Future” of Industry 4.0 makes Cobots a tool for putting new products faster on the market, for adjusting production to new variations and small volume productions (Bi et al., 2020; Kadir et al., 2018).
- Protection of the worker from dangerous or repetitive tasks that slowly endangers his physical conditions (Kadir et al., 2018).
- Ability to rapidly substitute accidented or overburden workers
- Low risk investment because of the fast ROI (Return of Investment).
- Allows extra turns on the factory without a huge raise on costs (Kadir et al., 2018).
- In the case of multinational enterprises, the reduction in costs may allow a return of production to the country of origin and that may change the global supply chains.

Also, there are potential challenges on the use of Cobots:

- Cobots not being accepted by the workers (Aaltonen & Salmi, 2019).
- No standards or guidelines from regulators (Bi et al., 2020).
- Generate uncertainty and stress on workers about their jobs (Bauer et al., 2016).
- Low know-how available to operate Cobots (Aaltonen & Salmi, 2019).
- Each application needs certification and it can not be passed (Unger et al., 2018).

- Development of new applications requires high skilled professionals and development time (Ranz et al., 2018).
- Know-how necessary to realize an adoption (designing, choosing and implementing) is concentrated in a few number of enterprises which can lead to a closed sector with low incentive to innovation from the outside (Ionescu & Schlund, 2019).
- Scarcity of documents, case studies and reports about good and bad examples of Cobots adoption (Ionescu & Schlund, 2019).
- Cobots can not adjust outside their programming, so their work needs to be verified by humans (Kadir et al., 2018).
- Implementation problems (Kadir et al., 2018).
- Companies have difficulties to create new tasks and quickly switch Cobots to them (Kadir et al., 2018).
- Expensive (Kadir et al., 2018).
- Change from traditional robots to Cobots is being delayed because of the financial costs associated to the acquisition and implementation of traditional robots (Khalid et al., 2016).

Table 7 presents the major technical challenges for Cobots.

Collaborative Robots Design
- Design of industrial cobots - Development of new sensors and algorithms - Social acceptance - Energy autonomy
Safety and security
From industrial robots towards industrial cobots
Cognitive human-robot interactions
- Perception and interpretation of human behaviors - Classification of human activities

- Voice recognition, comprehension and utilization of natural language - Multi-modal, high-level interaction - Bilateral communication between humans and robots
Collaborative robot programming
- Reprogrammability, scalability and learning ability - Building user-friendly human-robot interfaces - Robotics development frameworks - Real-time constraints
Fault tolerance
Programming by Demonstration
Virtual & augmented reality
Other issues and challenges
Different classes for the identified challenges and open issues of industrial collaborative robotics

Table 7: Challenges of Industrial Collaborative Robotics

Source: Hentout et al. (2019)

An increasing number of companies are becoming aware of Cobots possibilities and because of that are willing to invest. The increase in potential clients, Wright's law, the Learning Curve effect on new products, economies of scale and network are all contributing to the decrease in the base price of Cobots (Bauer et al., 2016; Ionescu & Schlund, 2019).

In conclusion, traditional robots main focus is the automatization of operational tasks at high speed while Cobots focus is the enhancement of the worker capabilities allowing him to be more flexible and productive (Frank et al., 2019).

2.3. International Climate: Industry 4.0 and Lean Robotics

Automation has become more and more important in the last decades (Weckenborg et al., 2020). Industry 4.0 new reality implies reduced "Time to Market", high flexibility, fast decision centers, economic and ecological increase in efficiency, digitalization, remote work, miniaturization (Lasi et al., 2014). To maintain the profit of companies located in the developed countries, the high wages demand high level of automation (Malik & Bilberg,

2017), and at that level, high quantity of production means low variety of products, however, short volumes of customized products have become the market's new tendency (Bi et al., 2020).

While Industry 4.0 is a trend concept in recent years, Lean Production is a mature one (Leyh et al., 2017). The concept of Lean Production states that better results can be obtained by cutting what is in surplus and focus on continuous improvement (Kolberg & Zühlke, 2015).

Studies suggests that more than new technology adoption, a company improvement can be explain by Lean Production principles implementation level because it raises effectiveness and continuous innovation even in low-tech environments (Rossini et al., 2019).

When applied to HRC it means choosing the right tasks for humans and Cobots according to each best characteristic (Malik & Bilberg, 2017). Lean Robotics is a concept developed by Samuel Bouchard, co-founder of Robotiq, that fuses Lean Automation and Cobot Deployment. Its goal is to accelerate the Return of the Investment (ROI) on the acquisition and installation of the Cobot (In Position-Technologies). It has four principles: People before robots, Focus on the robot cell output, Minimize waste, Leverage Management Skills and Learn-By-Doing (Wiley, 2019).

There are several common points as well of opposition between Industry 4.0 and Lean Production models. In common, are the workers at the center, the focus at improvement processes and higher efficiency in operations. By contrast, Industry 4.0 is technology centered while Lean Production models are performance centered (Quenehen et al., 2019). The mainstream view is that Industry 4.0 is considered an improvement at the level of business processes of Lean Management (Nguyen Cong et al., 2020).

In conclusion, Industry 4.0 and Lean Production are symbiotic (G. L. Tortorella & Fettermann, 2018) and the final results are boosted when supported by a previous implementation of Lean Production specially when applied to the manufacturing sector.

2.4. Operator 4.0

According to Weyer et al. (2015), Industry 4.0 is characterized by: i) smart products; ii) smart machines and iii) augmented operators. Nowadays, the major challenges related to the production factor work are: workers resistance to change and the lack of skills needed for the successful adoption of an Industry 4.0 technology (Yunus, 2021).

It is expected with the further implementation of Industry 4.0 the rise of new activities and jobs as well as an increase of its complexity and demanding new skills (Leitão et al., 2020). In the follow-up, Industry 4.0 fostered the rise of a new type of worker designated Operator 4.0 which is characterized by: i) the concern with his physical and mental health leading to less injuries, accidents and absences; ii) the ability to communicate with robots throughout simplistic methods without the need of programming (Pazienza et al., 2019); iii) open to change (Pfeiffer et al., 2019).

Studies are being made to establish a relation between worker's stress levels and the possibility of working with cobots. In the study of Pollak et al. (2020) the results suggest that when working with cobots "... control (the cobots operating mode) play a key role in emotional, cognitive, and physiological reactions during the human-robot collaboration.". Another key aspect of this new concept is the realization that almost every country in the world is facing a demographic crisis characterized by a loss of work force. The governmental solution found was the continuous raise of the retirement age. However, this have the following consequences: i) a workforce physically diminished, ii) lower production levels because of lower response time of the operators, iii) operators with ergonomic problems and resulting costs to the companies, iv) skilled and experienced workforce but demotivated (Bogataj et al., 2019).

The adoption of Cobots may be a solution for this recent tendency by rising the number of workers that can operate it because of the low technical requirements as well as simplicity. Injured workers can be assisted by Cobots while they are recovering with the workers advantage of not losing income and the company not having extra costs with insurances and recruiting a new worker that will require training. Senior workers can also be recovered (Simões et al., 2019b). Their expertise is important and should be praised (Bogataj et al., 2019; Schmidler & Bengler, 2015). Workers with motor impairments assisted by Cobots widen the possibilities of new tasks (Jabre et al., 2002). This is only possible with the developments in AI and a new important tool: conversational agents

(Pazienza et al., 2019) that utilizes Natural Language Processing (NLP-U) so that the Cobot understand its orders and perform what is required (Pazienza et al., 2019).

An important success factor of Industry 4.0 implementation is worker involvement. (Müller, 2019). Studies demonstrate a positive relation between workers involvement and operational performance in Industry 4.0 adoption. (G. Tortorella et al., 2021). Workers Involvement is characterized by the workers ability to make decision calls in solving problems at their level in the company (Welikala And & Sohal, 2008). The rationality is simple. Workers are the ones who have the expertise and know-how to complete the task and because of this, the process of making suggestions and implementing them to improve, is more successful (Thomas et al., 2009). This has two implications: i) Industry 4.0 success is linked to workers enhancing and ii) companies that foment workers involvement should improve operational performance.

2.5. Technology Adoption

Industry 4.0 scope is broader than just manufacturing sector since it involves other sectors like Medical Industry and because of this each adoption process is unique and its specific factors have to be identified (Ghobakhloo, 2020).

Carr Jr (1999) defined Technology Adoption as “... stage of selecting a technology for use by an individual or an organization” and Diffusion as “... stage in which the technology spreads to general use and application...”. Diffusion of new technology is not constant and homogeneous, so it is vital to comprehend the how, why and at which rate the spread in diffusion is expected when facing the adoption (Van den Berg & Van der Lingen, 2019).

Based on Oliveira and Martins (2011), the suitable models of technology adoption (Van den Berg & Van der Lingen, 2019) can be divided according to its focus:

Focused on the organizations: Technology Organization Environment (TOE), Diffusion of Innovations (DOI)

Focused on individual-level: Technology Acceptance Model (TAM), Fit-Viability Model (FVM) and Unified Theory of Acceptance and Use of Technology (UTAUT).

The implementation of new technology varies in time and phase and for that reason it is important to consider the different stages of adoption (Wamba & Queiroz, 2020). According to Figure 1, the decision of adoption occurs at the organizational level, so TOE and DOI will be considered in this study.

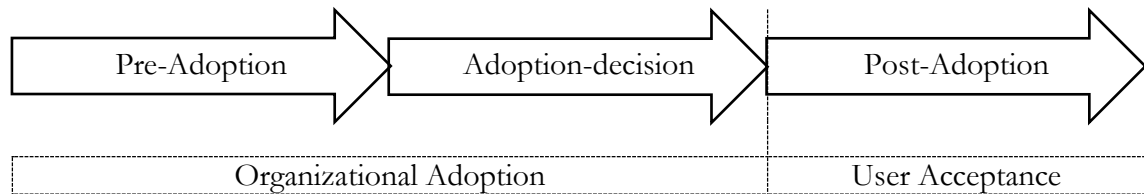


Figure 1: Adoption Process

Source: Adapted from Hameed et al. (2012)

From the literature review made, two conclusions are retrieved: i) an adoption process should be analyzed by a combination of models and not just one (Oliveira & Martins, 2011); ii) TOE framework is considered the model that best explain Technology Adoption (Dincbas et al., 2021).

Table 8 illustrates some of the different technologies analyzed by TOE framework.

Technology	Source
SaaS	Martins et al. (2016)
Business Intelligence System	Puklavec et al. (2018)
Clean Technology	Dincbas et al. (2021)
Social Media	Qalati et al. (2021)
CRM	Cruz-Jesus et al. (2019)
Cloud Computing	McKinnie (2016)
Halal Warehouse	Ngah et al. (2017)
Big Data Analytics	Maroufkhani et al. (2020)
Industry 4.0	Yu and Schweisfurth (2020)
Digital Technologies of Smart Manufacturing	Ghobakhloo and Ching (2019)
Augmented Reality	Masood and Egger (2019)
Biometric	Bello and Olanrewaju (2020)
Digital Manufacturing	Gillani et al. (2020)
Big Data	Bolonne and Wijewardene
Blockchain	Wong et al. (2020)

Information	Nair et al. (2019)
Big Data	Park and Kim (2021)
Logistics Service Providers	Mathauer and Hofmann (2019)

Table 8: Technologies analyzed by TOE framework

Source: Own Elaboration

Table 8 - Table 8: Technologies analyzed by TOE framework

A brief description of these two models is given below.

Technology- Organization-Environment (TOE):

Tornatzky et al. (1990) based on the Contingency Theory of Organizations presented a model of technology adoption by an organization where the contextual determinants are technology, organization and environment. Figure 2 depicts the theory. Technological context refers to both the technology inside organization and the innovations available outside. Organizational context refers to the organization's internal characteristics. Environmental context refers to the platform where the organization exercise its activity.

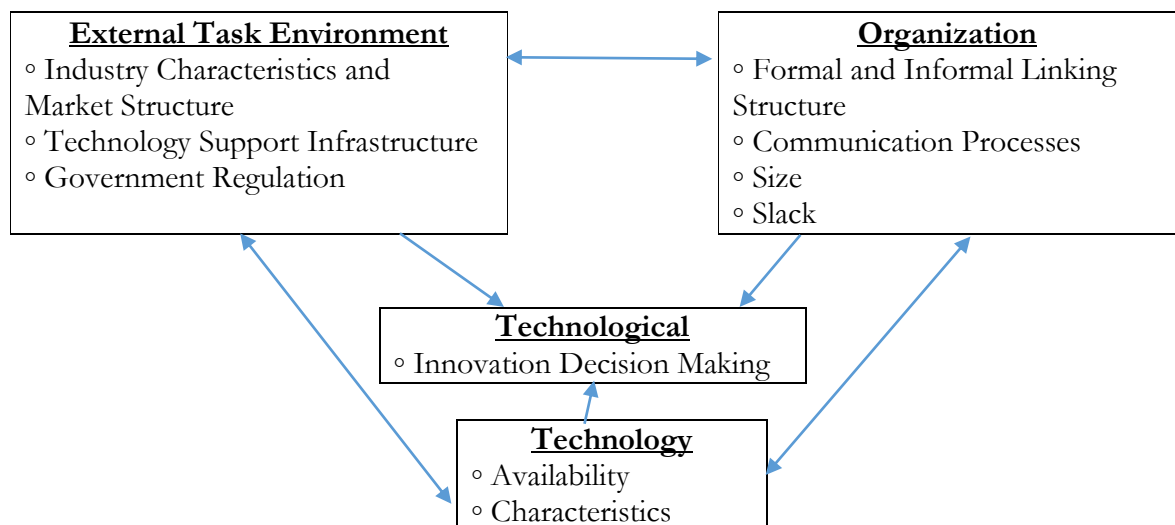


Figure 2: Technology, Organization and Environment Framework

Source: Adapted from Tornatzky et al. (1990)

Diffusion of Innovation (DOI):

Introduced by Rogers (1995), it explains the decision process, the attributes on innovation, and how individuals or organizations adopt innovation. Table 9 illustrates the attributes that influence the rate of adoption which Rogers (1995) defined as "...the relative speed with which an innovation is adopted by members of a social system...".

Relative advantage, compatibility, complexity, trialability, and observability are the attributes that influence the rate of adoption (Rogers, 1995). Table 10 depicts organizational innovativeness. According to Oliveira and Martins (2011) it is influenced by: i) the individual characteristics, in this case, the leaders of an organization; ii) the internal characteristics of the organization and iii) external characteristics of the organization. According to Hameed et al. (2012) this model has two main limitations: i) it mainly focus on the individual's attitude; ii) it does not explain the full adoption process, just pre-adoption and decision stages.

Variables Determining the Rate of Adoption	Dependent Variable that is explained
i) Perceived Attributes of Innovations 1- Relative advantage 2- Compatibility 3- Complexity 4- Trialability 5- Observability ii) Type of Innovation-Decision 1- Optional 2- Collective 3- Authority iii) Communication Channels iv) Nature of the Social System v) Extent of Change Agents Promotion Efforts	Rate of Adoption of Innovations

Table 9: Variables Determining the Rate of Adoption Innovations

Source: Adapted from Rogers (1995)

Individual (Leader) Characteristics	Attitude toward change
Internal Characteristics of organizational structure	Centralization; Complexity; Formalization; Interconnectedness; Organizational slack; Size
External characteristics of the organization	System openness

Table 10: Organizational Innovativeness

Source: Adapted from Oliveira and Martins (2011)

The most common factors that are retrieved from DOI model are Relative Advantage, Compatibility and Complexity (Giovanis et al., 2012). In order to complement the previous models and reinforce the analyze, Institutional Theory was added.

Institutional Theory

Implies that the adoption decision is influenced not only by efficiency reasons but also by social factors, culture and legal aspects. This bounded rationality (Greve & Argote, 2015), provides the structure where the organization has to exist (Scott, 1995). It can give stability or it can also exert pressure on the companies so that they tend to copy their industry leader position on economic and technological themes (Oliveira & Martins, 2011).

2.6. Factors Influencing the Decision to Adopt Cobots

Since Cobots are considered new technology for the majority of the manufacturing companies, and thus, still reaching maturity, several sources were considered to identify the influential factors of adoption. Therefore, in this study, the factors that influence the decision (or the intention) to adopt Advanced Manufacturing Technologies and Key Enabling Technologies of Industry 4.0 were also considered. According to Simões et al. (2018) theoretical framework, the works of Leimeister et al. (2010) and the study of Shahijan et al. (2016) the factors influencing the decision to adopt advanced technologies in manufacturing can be distributed according to internal, technology and external contexts, this validating the choice of TOE framework.. These dimensions should be considered in the search of new factors. Research about Cobots, technology adoption, manufacturing sector and AMT were performed in the platforms of “Web of Science “, “Scopus” and “Google Scholar” in order to identify the most important decision factors to adopt advanced manufacturing technologies. This search resulted in 43 models of adoption considered, 23 of which used TOE framework or combined and in total 302 different decision factors identified. Table 11 present factors from advanced manufacturing technologies adoption retrieved from the literature and referred in Table 12. Table 13 gathers the most referred factor from the search.

Context	Decision Factors	Authors*
Internal	Project champion	1
	Top Management Support	1, 4

	Workers Acceptance	1, 3, 4, 5
	Size	1
	Average age of employees	1, 5
	Value-added perception	1
	Leadership and vision	1
	Involvement	1
	Good managerial relations	1
	IT Professionals	1
	IT Infrastructure	1
	Dedicated time & resources	1
	Resources availability	1
	Workers Protection	3, 4, 5, 6, 8, 9
External	Suppliers	1, 2
	Competitors	1, 2, 3
	Customers	1, 2, 3
	Financing agencies	1
	Governmental agencies	1, 2, 4, 6, 8
	Technological infrastructure	1
Technology	Economic analysis	1, 2, 3, 4, 5
	Degree of innovation	1, 3
	Compatibility	1, 6
	Complexity	1, 8
	Support	1, 5
	Portability	1, 9
	Velocity to perform tasks	1
	Pilot test/trialability	1
	Time till routinization	1
	Flexibility (functions)	1, 3, 7, 9
	Workspace needed	1, 9

Table 11: Factors influencing the intention to adopt AMT

Authors*: 1 - Simões, Soares, et al. (2020); 2 - Simões et al. (2019a); 3 - Simões et al. (2019b); 4 - Bauer et al. (2016); 5 - Aaltonen and Salmi (2019); 6 - Bi et al. (2020); 7 - Lasi et al. (2014); 8 - Ionescu and Schlund (2019); 9 - Malik (2019)

Source: Adapted from (Simões, Lucas Soares, et al., 2020)

Number	Authors	Technology Focused
1	Simões, Lucas Soares, et al. (2020)	Cobots
2	Simões et al. (2019a)	Digitalization Technologies
3	Simões et al. (2019b)	Cobots
4	Bauer et al. (2016)	Lightweight Robots
5	Aaltonen and Salmi (2019)	Cobots
6	Bi et al. (2020)	Cobots
7	Lasi et al. (2014)	Industry 4.0 Technologies
8	Ionescu and Schlund (2019)	Cobots
9	Malik (2019)	Cobots

Table 12: Advanced Manufacturing Technologies

Source: Own Elaboration

Factors	Times Referred
Top Management Support	20
Competitors	15
Compatibility	14
Complexity	13
Relative Advantage	12
Perceived Benefits	11
Perceived Usefulness	10
Size	10
Perceived Ease of Use	9
Technology Competence	8
Customers	6
Pilot Test/ Trialability	5
Resources Availability	5
Governmental Agencies	5
Organizational Readiness	4
Cost Effectiveness	4
Competitive Industry	4
Economic Analysis	4
Support	4
Flexibility	4

Table 13: Factors most times referred

Source: Own Elaboration

Top Management Support, Competitors, Compatibility and Complexity are the most referred factors and are in line with the identified advantages of Cobots referred in section 2.2 of this study. Based in Table 13, the factors were gathered in 10 critical decision factors

which will become the constructs in Chapter 4. We propose the following concepts and contexts from the selected framework.

- Technological Context

Relative Advantage – These are the perceived benefits by the organization from the adoption of the innovation (Rogers, 2010). It can translate into more opportunities, at the product or production method level, in higher productivity, reduction of costs, better reputation, reliability (Masood & Egger, 2019), portability, function flexibility, workspace saved, velocity in performing tasks and faster routinization. Ramamurthy et al. (2008) shows that relative advantage positively impacts the intention of adoption, in their study, of Data Warehouse, and Li et al. (2011) study about online direct sales channels among SMEs demonstrate that the impact also occurs in other phases of diffusion. Therefore, we propose:

H1 (a) Relative advantage has positive impact on the intention to adopt Cobots

H1 (b) Relative advantage has positive impact on the adoption of Cobots

Compatibility – Represent the degree to which the innovation is perceived as a continuation of the companies processes, prior technology (Qalati et al., 2021), culture and values (Masood & Egger, 2019). Martins et al. (2016) suggest a positive relation between compatibility and intention and adoption of SaaS. Therefore, we propose:

H2 (a) Compatibility has positive impact on the intention to adopt Cobots

H2 (b) Compatibility has positive impact on the adoption of Cobots

Simplicity – Degree to which an innovation is perceived as easy to operate (Rogers, 2010). If an innovation is considered complex to operate it is regarded as a disadvantage to the intention and adoption (Beatty et al., 2001). Therefore, we propose:

H3 (a) Simplicity has positive impact on the intention to adopt Cobots

H3 (b) Simplicity has positive impact on the adoption of Cobots

- Organizational Context

Top Management Support – Degree to which an innovation is explicitly supported by the top management and the existence of an active environment of commitment (Wamba & Queiroz, 2020). Studies like Zhu and Kraemer (2005) exert the positive influence of management skills and the importance of good managerial relations especially with the workers (Bello & Olanrewaju, 2020; Wong et al., 2020). Therefore, we propose:

H4 (a) Top Management Support has positive impact on the intention to adopt Cobots

H4 (b) Top Management Support has positive impact on the adoption of Cobots

Technology Competence – Consist in the technological infrastructure as well as the workers with expertise of a company (Martins et al., 2016). Adequate characteristics (technologies, systems, applications, skills) are important to support Technology Competence (Martins et al., 2016) and to impact the intention and adoption of Cobots. Therefore, we propose:

H5 (a) Technology Competence has positive impact on the intention to adopt Cobots

H5 (b) Technology Competence has positive impact on the adoption of Cobots

Resources Availability – Resources are limited (Nguyen & Luu, 2020). The resources can be financial, human or the expertise needed to execute the tasks correctly. The lack of financial resources is identified as a challenge of implementing Industry 4.0 technologies (Karadayi-Usta, 2020). Therefore, we propose:

H6 (a) Resources Availability has positive impact on the intention to adopt Cobots

H6 (b) Resources Availability has positive impact on the adoption of Cobots

Organizational Innovativeness – The degree of openness to innovations and open mind to consider the adoption (Venkatesh & Bala, 2012). It must consider the organizational climate of searching for new ideas, the readiness to adopt and the acceptance level of the company. Therefore, we propose:

H7 (a) Organizational Innovativeness has positive impact on the intention to adopt Cobots

H7 (b) Organizational Innovativeness has positive impact on the adoption of Cobots

Human Resources – Human Resources are able to improve the competitive advantage of a company (Nguyen & Luu, 2020). It is important to consider workers qualifications, workers acceptance of the new technology as well as its involvement in the adoption process. By contradiction, worker resistance leads to high productivity workers leaving the company, overall low productivity and conflict (Masood & Egger, 2019). Therefore, we propose:

H8 (a) Human Resources has positive impact on the intention to adopt Cobots

H8 (a) Human Resources has positive impact on the intention to adopt Cobots

- External Context

Industry Pressure – Degree to which the company feels pressure from its competitors to adopt certain innovation or at least the same technology but not because of logic reasons. This is called the bandwagon effect (Qalati et al., 2021). Another relevant pressure is the one from company clients to adopt certain technology or engage in certain technological lock in. For example, shifting the production process to be able to produce more product variations instead of more quantity. According to Qalati et al. (2021) there is a positive relation between industry pressure and adoption. Therefore, we propose:

H9 (a) Industry Pressure has positive impact on the intention to adopt Cobots

H9 (b) Industry Pressure has positive impact on the adoption of Cobots

External Support – Degree to which external forces (Financial Agencies, Governmental and Regulatory Agencies) support the company's adoption process. If there is a positive external support or if the company is able to try the new technology previously, the company is available to take on more risks in the adoption process (Puklavec et al., 2018). Therefore, we propose:

H10 (a) External Support has positive impact on the intention to adopt Cobots

H10 (b) External Support has positive impact on the adoption of Cobots

- Cobots Diffusion

Intention – Phase of evaluation of the adoption process where the company gathers information about the advantages or disadvantages of the innovation / technology (Zhu et al., 2003). In the words of Puklavec et al. (2018) “...The evaluation stage constitutes the foundation for an efficient adoption.” (p. 243). Therefore, we propose:

H11 – Intention has positive impact on the adoption of Cobots

Adoption – Phase where the company decides to adopt Cobots that better suits its needs (Chong & Chan, 2012) and invest resources to concretize the adoption process (McKinnie, 2016).

The selection of TOE framework in combination with DOI and Institutional Theories resulted in three contexts, where the previously most identified factors retrieved from the literature were grouped in 10 critical decision factors that will become the constructs of the PLS-SEM model. Figure 3 is the representation of the framework and research hypothesis of this study.

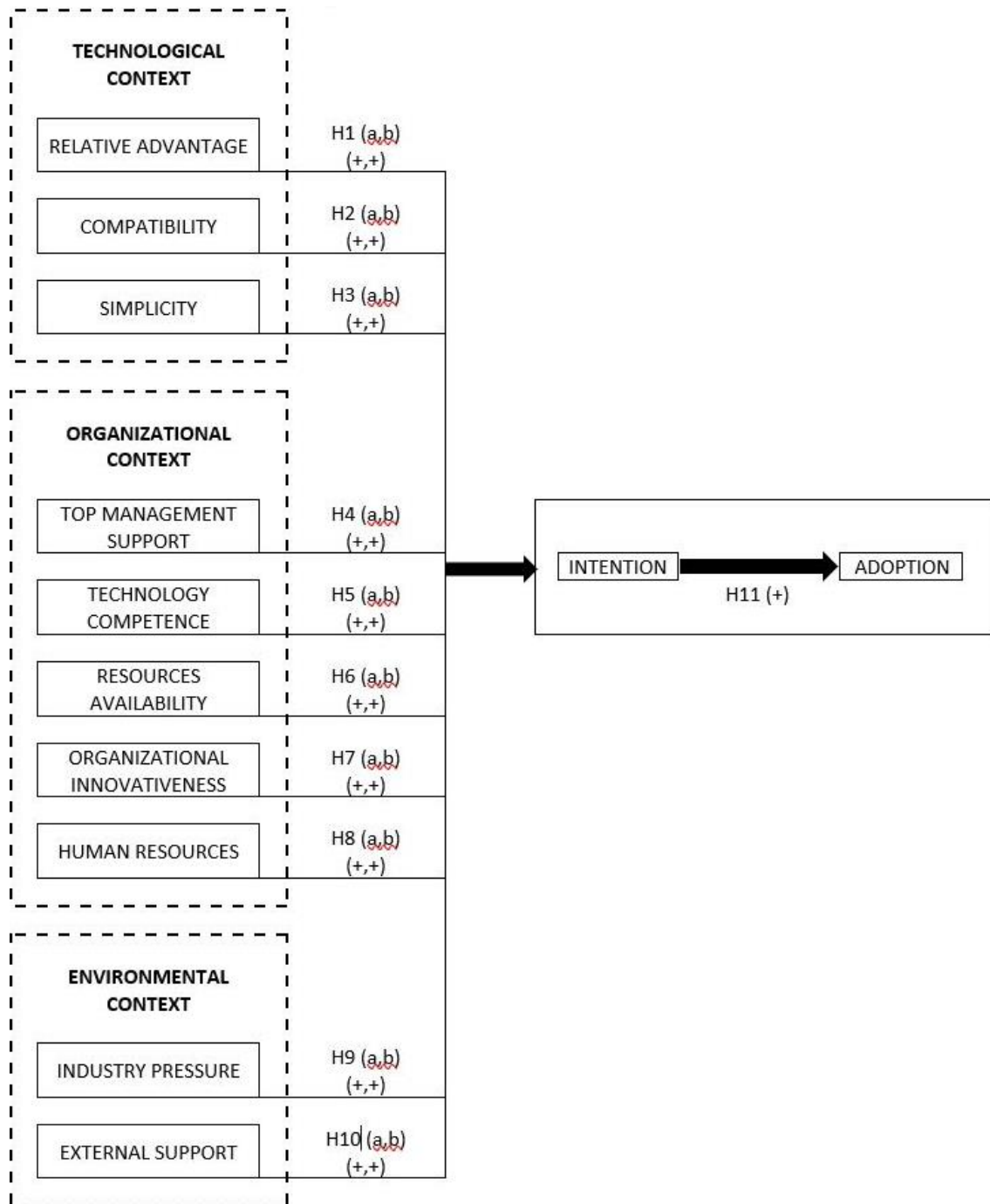


Figure 3: Conceptual Framework
Source: Own Elaboration

3. Material and Methods

The objective of this study is the identification of the relevant decision factors of adopting (or intent of adopting) collaborative robots in manufacturing organizations. In order to accomplish this goal a quantitative research, based on a survey, was performed. This methodological choice was based on three reasons: First, the object of this study is the adoption (or the intention to adopt) of an innovation/new technology and the factors that may or may influence that decision. These factors may have diverse origins and significance. Second, the technology is recent and still developing. Third, the adoption of cobots is a global phenomenon, so the decision factors may not have the same meaning in different countries.

3.1. Methodology Selection

To fulfill the goal of this study a quantitative research method must be applied. Allen (2017) states that “... the purpose of quantitative research is to generate knowledge and create understanding about the social world...”. It emphasizes the frequency of a phenomenon on a particular population (Allen, 2017). To quantify the relevance of the decision factors for managers in the adoption of collaborative robots, two surveys will be applied to manufacturing organizations of the two countries. Bell (2014) justify the use of surveys with the goal of “... obtain information from a representative selection of the population and from that sample will then be able to present the findings as being representative of the population as a whole.”.

The information collected in the surveys are related to knowledge, attitudes, opinions, behaviors or facts concerning the adoption (or the intent to adopt) cobots. Additionally, due to the past pandemic context and the Covid-19 restrictions, electronic surveys were used to collect data.

Since there is a lack of quantitative analysis for the decision factors of cobots adoption, in Table 14 we present similar studies from other Advanced Manufacturing (AMT) and Industry 4.0 technologies, which substantiate the choice of surveys.

Authors	Country	Sample	Response Rate	Sector	Method
Frank et al. (2019)	Brasil	941	9,78%	Manufacturing	Survey
Gangwar and	India	1.000	28,1%	Cloud	Survey

Date (2016)						
Wamba and Queiroz (2020)	India /USA	7.100	35,32% / 6,43%	Computing Blockchain	Survey	
Thakur and Jain (2008)	India	N/A	32 companies	AMT	Survey	
Oettmeier and Hofmann (2017)	Switzerland	934	27,5%	Manufacturing	Survey	
Hofmann and Orr (2005)	Germany	1.000	5%	AMT	Survey	
Patuwo and Hu (1998)	Singapore	1.000	11%	AMT	Survey	

Table 14: Similar Studies about AMT/Industry 4.0 adoption

Source: Own elaboration

3.2. Measures definition

Two surveys were made with the same foundation of questions. The Portuguese survey were divided into 9 sections (survey in Annex 1). Table 15 shows the survey structure, the topics and the number of questions in each section.

Section	Topic	Nr. of question and Description
I	Privacy Agreement	1 Question: checkbox
II	Respondent Knowledge of Cobots Technology	3 Questions: 1 binary + 2 multiple choice
III	Technological Factors	17 Questions: 17 5-point Likert scale
IV	Organizational Factors	19 Questions: 19 5-point Likert scale
V	External Factors	11 Questions: 11 5-point Likert scale
VI	General Information	5 Questions: 1 Short answer + 4 multiple choice
VII	Sector	1 Question: 1 multiple choice
VIII	Company Characterization	6 Questions: 6 multiple choice
IX	Final Message	

Table 15: Structure of the survey

Source: Own Elaboration

The brazilian survey, also designated BR (survey in Annex 2) differs from the portuguese survey version, also designated PT, at question 30 (missing) about the information and experience necessary, the amounts in question 60 about annual turnover and mass

production in question 62. Table 16 indicates the core of measurements of the surveys as well as the codification of the factors. Table 17 presents the sources for the questions retrieved from the literature.

	Question	Item Code
Adoption	1 Do you know Cobots technology?	ADO1
	2 If you're anticipating that your company will adopt Cobots in the future. How soon do you think it will happen?	ADO2
	3 At what stage of Cobots adoption is your organization currently engaged?	ADO3
Relative Advantage	4 Cobots create new opportunities at process level	RA7
	5 Cobots create new opportunities at product development level	RA8
	6 Cobots allows my company to be more productive	RA9
	7 Cobots makes my company gain reputation as an innovator	RA10
	8 Cobots lowers production costs	RA11
	9 Cobots are easy to move and adjust to new layout of the manufacturing process	RA1
	10 Cobots require less area/space to be installed when compared to traditional robots	RA2
	11 Cobots allows the company to perform specific tasks more quickly.	RA3
	12 Cobots reliability at task performance is a requirement to its adoption	RA4
	13 Cobots fast routinization in the manufacturing process is a requirement to its adoption	RA5
	14 Cobots have the ability to rapidly change over products on short notice	RA6
Compatibility	15 Cobots are easy to integrate to the current manufacturing system.	COMP1
	16 Cobots are compliant with the needs of the company	COMP2
	17 Cobots adoption is consistent with the company's beliefs and values	COMP3

	18	There is no health or safety issues concerning the usage of Cobots	COMP4
Simplicity	19	Cobots are very simple to use	SIM1
	20	Cobots require less training and advanced skills of the workers in comparison with traditional robots	SIM2
Top Management Support	21	Top management understands the opportunities provided by Cobots adoption	TMS1
	22	Top management of the company supports Cobots adoption.	TMS2
	23	Cobots have strong advocates in our company	TMS3
	24	Top management actively participates in establishing a vision and formulating strategies for utilizing Cobots	TMS4
	25	Top management inspire/motivates employees to Cobots in their daily work practices	TMS5
Technology	26	My company, as a whole, contains a high level of Cobots technology-related knowledge	TC1
Competence	27	My company has adequate IT infrastructure to implement Cobots	TC2
	28	My company recruits workers with advanced technology skills	TC3
Resources Availability	29	My company allocates adequate financial resource for Cobots adoption.	RESA1
	30	My company has the necessary information and experience for Cobots adoption	RESA2
	31	My company has the necessary human resource for Cobots adoption.	RESA3
Organizational Innovativeness	32	Innovations (including new technologies) are readily accepted in my company	OI1
	33	Management in my company actively seeks innovative ideas at process level	OI2
	34	Management in my company actively seeks innovative ideas at product development level	OI2
	35	My company has a good understanding of how Cobots can be used in our activity sector	OI3
Human Resources	36	The workers that operate Cobots and share workspace with them were/ are / will be included in the decision of adoption	HR1

	37	Workers that/ will operate Cobots, feel safe and trust the technology	HR2
	38	Workers are competent to use new technologies.	HR3
	39	Workers need additional qualification and training to operate Cobots	HR4
Industry	40	If the company does not adopt Cobots it will be disadvantageous in the competition.	IND1
Pressure	41	My company believes that we may lose customers if we do not adopt Cobots	IND2
	42	It is difficult to find the financial resource to invest in Cobots adoption	EX1
	43	The governmental policies encourage my company to adopt Cobots	EX2
External Support	44	The laws and regulations that exist nowadays are suitable to Cobots use	EX3
	45	The region where my company is located has the technological infrastructure needed, especially in data network, to implement Cobots	EX4
	46	Cobots suppliers provide valuable assistance during the adoption stage	EX5
	47	My company could access a trial before making a decision to adopt Cobots	EX6
Intention	48	My company collects information about Cobots with the intention of implementing it.	INT3
	49	My company expects using Cobots	INT1
	50	My company plans to recommend Cobots to other companies	INT2

Table 16: Cobot Adoption Measures

	Item Code	Adaptaded from
1	ADO1	Own Elaboration
2	ADO2	Puklavac, B., Oliveira, T., & Popovič, A. (2018)
3	ADO3	Puklavac, B., Oliveira, T., & Popovič, A. (2018)

4	RA7	Martins, R., Oliveira, T., & Thomas, M. A. (2016) Qalati, S. A., Yuan, L. W., Khan, M. A. S., & Anwar, F. (2021) Maroufkhani, P., Ismail, W. K. W., & Ghobakhloo, M. (2020)
5	RA8	Martins, R., Oliveira, T., & Thomas, M. A. (2016) Qalati, S. A., Yuan, L. W., Khan, M. A. S., & Anwar, F. (2021) Maroufkhani, P., Ismail, W. K. W., & Ghobakhloo, M. (2020)
6	RA9	Martins, R., Oliveira, T., & Thomas, M. A. (2016) Qalati, S. A., Yuan, L. W., Khan, M. A. S., & Anwar, F. (2021)
7	RA10	Dincbas, T., Ergeneli, A., & Yigitbasioglu, H. (2021) Qalati, S. A., Yuan, L. W., Khan, M. A. S., & Anwar, F. (2021)
8	RA11	Maroufkhani, P., Ismail, W. K. W., & Ghobakhloo, M. (2020)
9	RA1	Own Elaboration
10	RA2	Own Elaboration
11	RA3	Martins, R., Oliveira, T., & Thomas, M. A. (2016) Puklavec, B., Oliveira, T., & Popovič, A. (2018) Qalati, S. A., Yuan, L. W., Khan, M. A. S., & Anwar, F. (2021)
12	RA4	Own Elaboration
13	RA5	Own Elaboration
14	RA6	HoangMr, H., Phan, A. C., & Le Thai, P. (2020) Aboelmaged, M. (2018)
15	COMP1	Dincbas, T., Ergeneli, A., & Yigitbasioglu, H. (2021) Maroufkhani, P., Ismail, W. K. W., & Ghobakhloo, M. (2020) Awa, H. O., Ojiabo, O. U., & Orokor, L. E. (2017)
16	COMP2	Dincbas, T., Ergeneli, A., & Yigitbasioglu, H. (2021)
17	COMP3	Qalati, S. A., Yuan, L. W., Khan, M. A. S., & Anwar, F. (2021) Dincbas, T., Ergeneli, A., & Yigitbasioglu, H. (2021) Maroufkhani, P., Ismail, W. K. W., & Ghobakhloo, M. (2020)
18	COMP4	Masood, T., & Egger, J. (2019)
19	SIM1	Palos-Sanchez, PR; Arenas-Marquez, FJ; Aguayo-Camacho, M (2017)
20	SIM2	Awa, H. O., Ojiabo, O. U., & Orokor, L. E. (2017) Martins, R., Oliveira, T., & Thomas, M. A. (2016)
21	TMS1	Palos-Sanchez, PR; Arenas-Marquez, FJ; Aguayo-Camacho, M (2017)

		Dincbas, T., Ergeneli, A., & Yigitbasioglu, H. (2021)
22	TMS2	Dincbas, T., Ergeneli, A., & Yigitbasioglu, H. (2021) Qalati, S. A., Yuan, L. W., Khan, M. A. S., & Anwar, F. (2021) Cruz-Jesus, F., Pinheiro, A., & Oliveira, T. (2019)
23	TMS3	Puklavec, B., Oliveira, T., & Popovič, A. (2018)
24	TMS4	Puklavec, B., Oliveira, T., & Popovič, A. (2018) Martins, R., Oliveira, T., & Thomas, M. A. (2016) Cruz-Jesus, F., Pinheiro, A., & Oliveira, T. (2019)
25	TMS5	Bello, O., & Olanrewaju, O. (2020) Wong, LW; Leong, LY; Hew, JJ; Tan, GWH; Ooi, KB (2020)
26	TC1	Samuel Fosso Wamba & Maciel M. Queiroz (2020) Martins, R., Oliveira, T., & Thomas, M. A. (2016) Pappas, N., Caputo, A., Pellegrini, M. M., Marzi, G., & Michopoulou, E. (2021)
27	TC2	Cruz-Jesus, F., Pinheiro, A., & Oliveira, T. (2019)
28	TC3	Aboelmaged, M. (2018)
29	RESA1	Dincbas, T., Ergeneli, A., & Yigitbasioglu, H. (2021)
30	RESA2	Dincbas, T., Ergeneli, A., & Yigitbasioglu, H. (2021)
31	RESA3	Dincbas, T., Ergeneli, A., & Yigitbasioglu, H. (2021)
32	OI1	McKinnie, M. (2016) Awa, H. O., Ojiabo, O. U., & Orokor, L. E. (2017)
33	OI2	McKinnie, M. (2016)
34	OI2	McKinnie, M. (2016)
35	OI3	Puklavec, B., Oliveira, T., & Popovič, A. (2018)
36	HR1	Own Elaboration
37	HR2	Masood, T., & Egger, J. (2019)
38	HR3	Dincbas, T., Ergeneli, A., & Yigitbasioglu, H. (2021)
39	HR4	Mlekus, L., Paruzel, A., Bentler, D., Jenderny, S., Foullois, M., Bansmann, M., ... & Maier, G. W. (2018)
40	IND1	Dincbas, T., Ergeneli, A., & Yigitbasioglu, H. (2021)
41	IND2	Wong, LW; Leong, LY; Hew, JJ; Tan, GWH; Ooi, KB (2020)
42	EX1	Dincbas, T., Ergeneli, A., & Yigitbasioglu, H. (2021)
43	EX2	Maroufkhani, P., Ismail, W. K. W., & Ghobakhloo, M. (2020)

44	EX3	Dincbas, T., Ergeneli, A., & Yigitbasioglu, H. (2021) Wong, LW; Leong, LY; Hew, JJ; Tan, GWH; Ooi, KB (2020)
45	EX4	Own Elaboration
46	EX5	Masood, T., & Egger, J. (2019) Maroufkhani, P., Ismail, W. K. W., & Ghobakhloo, M. (2020)
47	EX6	Maroufkhani, P., Ismail, W. K. W., & Ghobakhloo, M. (2020)
48	INT3	Martins, R., Oliveira, T., & Thomas, M. A. (2016)
49	INT1	Palos-Sanchez, PR; Arenas-Marquez, FJ; Aguayo-Camacho, M (2017) Wong, LW; Leong, LY; Hew, JJ; Tan, GWH; Ooi, KB (2020) Shieh, LF; Yeh, CC; Lai, MC (2016)
50	INT2	Shieh, LF; Yeh, CC; Lai, MC (2016)

Table 17: Literature inspiration for the survey

Source: Own Elaboration

The survey of Portugal was constructed in the free platform “Google Forms” while the Brazilian survey was made in SurveyMonkey because the service was already active for the institution. For the convenience of who was answering, the survey was kept to the minimal number of questions and focused on questions of 5-point Likert scale in which 1 correspond to “Totally Disagree”, 4 to “Partially Disagree”, 3 to “Indifferent”, 4 to “Partially Agree” and 5 to “Totally Agree”. By opposition, the item HR4 is rated with the inverted scale where 1 is” ‘Totally Agree” and 5 “Totally Disagree”.

Of several statistics methods, like CB-SEM or regression models, Partial Least Squares – Structural Equation Modelling was the chosen method used to estimate the cause-effect between observed and latent variables (Sarstedt et al., 2016) or in other words between constructs and measured variables. This model maximizes the explained variance (R^2) of the endogenous variables so it can indicate the model’s predictive capabilities (Hair et al., 2016). According to Hair et al. (2016), PLS-SEM achieves high statistical power even for medium and low sample sizes ($n=100$) and it is considered the best choice for an exploratory study like the present (Gefen et al., 2011). Additionally, several authors like Wamba and Queiroz (2020), (Martins et al., 2016) (Puklavec et al., 2018) used it to estimate other Industry 4.0 technologies.

3.3. Samples

Since there is very few information about what drives a company to adopt as well as which sectors are most willing to adopt, we extended the targets of the survey to all who knew what Cobots were at manufacturing companies (Simões et al., 2019b). For this purpose, we used the classification established by Instituto Nacional de Estatística (Statistic Portugal Institute) in its “Classificação Portuguesa das Atividades Económicas – Revisão 3” (INE, 2007). By its terms, the manufacturing sector is composed of section C gathering the divisions from 10 to 33. It also states that it represents 59% of GDP.

Using the platform “SABI” the research team gained access to almost the contact mail of the companies divided by the classification. To ensure the best representative sample, only active companies and with financial information in the last 3 years (2020, 2019, 2018) were selected. Like Table 18 show, a total of 17.347 emails were sent to portuguese companies in the first wave (Annex 3). SABI platform contains a contact e-mail of each company, so the receivers could be managers, directors, executives, engineers, administratives, or other. In the situations where failed delivery email occurred, a new search in the company website or social networks was made to update the e-mail address and a new e-mail was sent re-reinforce the first one (Annex 4)

Division	Designation	Companies
10	Food Industry	1.597
11	Beverages Industry	550
12	Tobacco Industry	3
13	Textil Manufacturing	878
14	Clothing Manufacture	1.169
15	Leather Industry	611
16	Wood and cork industries	1.085
17	Paper Industry	219
18	Printing and Reproduction	878
19	Petroleum Products and derivatives	10
20	Chemical Products	361
21	Pharmaceutical Products	64
22	Rubber Products	608
23	Non-metallic mineral products	1.163
24	Metalworking industries	130
25	Metal products manufacturing except machinery and equipments	3.843
26	Computer, Communications and Optical Equipment	131
27	Electric Equipment	311
28	Machinery Equipment	710

29	Automobile Industry	273
30	Other Transport Industry	86
31	Furniture Manufacturing	1.034
32	Other Manufacturing	544
33	Repair, maintenance and intallation of machinery	1.089
Total		17.347

Table 18: Manufacturing companies' distribution by division in NACE¹

Source: Own Elaboration

Regarding Brazil, thanks to the collaboration with FDC – Fundação Dom Cabral, the almost same survey was sent to 6.000 contacts of its internal database mainly to managers, directors, CEOs. The same survey was sent to e-mail contacts in three Brazilian industrial databases i) ABIMAQ – Associação Brasileira da Indústria de Máquinas e Equipamentos, ii) CNI – Confederação Nacional da Indústria and iii) SINDIMAQ – Sindicato Nacional da Indústria de Máquinas.

Both mails were sent during June and July of 2021. A condition to the survey be considered accepted to the study is the confirmation that the respondent know Cobot technology. This is the first question in the survey. From Brazil, we received 1.289 answers from which 291 answered positively to the question about knowing Cobots technology which correspond to 22,58%. In Portugal, we received 290 answers where 78 were positive which corresponds to 26,90%.

The sample is composed of people in manufacturing companies that know Cobots technology in Portugal and Brazil. The respondents are CEO's, managers, workers, directors. The targets were defined this way because the adoption process affects the company in different ways. The sample is composed by companies in the manufacturing sector without any sector restrictions. This allows us to understand which sectors are more likely to adopt cobots. The size of the company is also an issue taken in consideration. To classify the companies according to their dimension (micro, small and medium) sized companies of the European Commission (2003)². The possibility of doing this do this

¹ Establishment or common chart for the classification of economic activities, to be adopted at the national level, as of January 1, 2008. Beyond statistic objectives, other areas of application, in particular, at the registration of comparable companies and entities, in the elaboration of studies, in tax declarations and in incentives for economic activity.

² Micro enterprise: fewer than 10 employees and an annual turnover (the amount of money taken in a particular period) or balance sheet (a statement of a company's assets and liabilities) below €2 million; Small enterprise: fewer than 50 employees and an annual turnover or balance sheet below €10 million, Medium-sized enterprise: fewer than 250 employees and annual turnover below €50 million or balance sheet below €43 million.

study in two countries reinforces its value and importance for managers all over the world. The collaboration between the FEP, INESC TEC and Fundação Dom Cabral of Brazil was essential for the success of this study.

4. Results

The goal of this section is to present the data gathered from the survey and analyze it using statistical tools to better describe the sample and therefore speculate about the population and test the research hypotheses. To test the proposed research model the statistic software chosen was R software. Purwanto (2021) acknowledges R Software as a competent choice for using PLS-SEM.

4.1. Sample demographics and descriptive statistics

The following section presents some relevant descriptive statistics of the sample. Most of the sample demographics will be in available in (Annex 5). From Table 19, it is possible to conclude that, if the adoption was viable, brazilian managers were more likely to adopt Cobots sooner than the portuguese ones.

Question		BR	%	PT	%
2	Not considering adopting Cobots	7	2,41%	30	38,46%
	In more than 5 years	21	7,22%	7	8,97%
	Between 2 and 5 years	61	20,96%	15	19,23%
	Between 1 and 2 years	92	31,62%	13	16,67%
	In less than 1 year	110	37,80%	13	16,67%

Table 19: Intensity of Cobots Adoption

This is in line with the status of real adoptions of Cobots in Brazil, presented in Table 20, where they are being adopted in a faster rate.

Question		BR	%	PT	%
3	Not considering adopting Cobots	6	2,06%	32	41,03%
	Have evaluated but do not plan to adopt Cobots	0	0,00%	3	3,85%
	Cobot adoption is in evaluation	140	48,11%	34	43,59%
	Currently evaluating (e.g., in a pilot study)	66	22,68%	5	6,41%
	Have already adopted Cobots	79	27,15%	4	5,13%

Table 20: Degree of adoption

Many respondents from Brazil work in the automotive industry. According to the IRF Statistical Department (2020) this is one of the prominent sector of Cobots adoption. From the data of Table 21, we can conclude that in Brazil, the automotive sector is followed by metalworking and other manufacturing and that in Portugal the majority of the respondents work in machinery and metal products sector.

Q.	BR		PT	
57	Setor	Com.	Setor	Com.
	Automobile Industry	101	Metal products manufacturing except machinery and equipments	16
	Other Manufacturing	57	Machinery Equipment	11
	Metalworking industries	27	Food Industry	8
	Machinery Equipment	20	Other Manufacturing	8
	Food Industry	17	Repair, maintenance and intallation of machinery	7
	Beverages Industry	16	Rubber Products	6
	Pharmaceutical Products	15	Textil Manufacturing	4
	Other Transport Industry	14	Printing and Reproduction	3
	Tobacco Industry	7	Metalworking industries	3
	Eletric Equipment	5	Automobile Industry	2

Table 21: Activity Sector based on NACE

Table 22 present the variable Size of the company which as it was expected, is an important divergent factor. Almost all companies in Brazil are considered by the European Commission criteria as big while Portugal is almost evenly distributed in micro, small and medium enterprises.

Question	Size	BR	%	PT	%
58	Micro (<10 workers)	0	0,00%	23	30,77%
	Small (11-50 workers)	1	0,34%	24	28,21%
	Medium (51-250 workers)	9	3,09%	26	33,33%
	Big (>250 workers)	281	96,56%	5	7,69%

Table 22: Company Size

The following tables (23 to 26) further express the differences between the companies of two countries. The first variable is the annual turnover where 89% of the companies have an annual turnover superior to the criteria of the European Commission that classifies a company as big. By opposition, only 5,13% of the respondents choose the option big. The limits in the brazilian survey were converted from euros to reais. Table 24 exemplifies another structural difference in terms of type of production. Multi-products with variants for the brazilian industry and single product variants for the portuguese industry. Table 25 presents the method of production and in Table 26 it is noticeable that the portuguese survey has a fourth option not created when the Brazilian survey was already online. The majority of respondents are OEM / Final product assembly

60	Annual Turnover	%	
BR	Micro <= 12 million reais	1	0,34%
	Small <= 60 million reais	1	0,34%
	Medium <= 300 million reais	30	10,31%
	Big > 300 million reais	259	89,00%
PT	Micro <= 2 million euros	37	47,44%
	Small <= 10 million euros	29	37,18%
	Medium <= 50 million euros	8	10,26%
	Big > 50 million euros	4	5,13%

Table 23: Companies Annual Turnover

Question	Product Variance	BR	%	PT	%
61	Single standard product without variants	2	0,69%	4	47,44%
	Single standard product with variants	6	2,06%	7	37,18%
	Several standard products without variants	2	0,69%	6	10,26%
	Several standard products with variants	281	96,56%	61	5,13%

Table 24: Product Variance

Question	Method of Production	BR	%	PT	%
62	One-of-a-kind production	47	16,15%	22	28,21%
	Small batch production	48	16,49%	22	28,21%
	Batch production	196	67,35%	21	26,92%
	Mass production method of production	-	-	13	16,67%

Table 25: Method of Production

Question	Supply Chain	BR	%	PT	%
63	Raw material supplier	21	7,22%	8	10,26%
	Component's supplier	121	41,58%	21	26,92%
	OEM / Final product assembly	147	50,52%	42	53,85%
	Retailer	2	0,69%	7	8,97%

Table 26: Supply Chain Position

- Regarding the descriptive statistics of the brazilian sample

The mean and the standard deviation of all the variables are presented in Table 27.

	Mean	Standard-Deviation	Min	Max
ADO4	0,2715	0,445488	0	1
RA7	4,419	0,6012981	2	5

RA8	4	0,7745967	2	5
RA9	4,491	0,5468673	2	5
RA10	4,351	0,7101419	2	5
RA11	4,082	0,5571498	1	5
RA1	3,969	0,6713898	1	5
RA2	4,162	0,6362848	2	5
RA3	4,402	0,5870991	1	5
RA4	4,704	0,4719154	3	5
RA5	4,687	0,4861636	2	5
RA6	4,124	0,7084378	3	5
COMP1	3,055	1,015603	1	5
COMP2	3,694	0,8901377	1	5
COMP3	4,402	0,7142847	1	5
COMP4	4,275	0,7239901	1	5
SIM1	3,68	1,205273	1	5
SIM2	3,175	1,034011	1	5
TMS1	3,481	0,7715771	2	5
TMS2	4,254	0,7075507	2	5
TMS3	4,055	0,841018	1	5
TMS4	3,814	0,7191455	1	5
TMS5	3,385	0,6920571	1	5
TC1	3,134	1,082419	1	5
TC2	3,062	0,8999743	1	5
TC3	3,45	1,017142	1	5
RESA1	3,241	1,15842	1	5
RESA3	3,12	1,102959	1	5
OI1	3,375	1,144962	1	5
OI2	4,485	0,7805401	1	5
OI3	4,244	0,7738773	1	5
OI4	3,667	0,976741	1	5
HR1	3,162	1,009283	1	5
HR2	3,361	1,285346	1	5
HR3	2,869	1,330074	1	5

HR4	1,88	0,6664118	1	4
IND1	3,821	1,148774	1	5
IND2	2,88	0,7210872	1	5
EX1	2,674	0,9648767	1	5
EX2	2,464	0,8228863	1	4
EX3	2,134	0,7234334	1	4
EX4	3,392	1,264011	1	5
EX5	3,265	0,7442317	2	5
EX6	3,931	0,8642825	1	5
INT3	4,254	0,7772235	1	5
INT1	4,351	0,7479799	1	5
INT2	4,292	0,7478056	1	5

Table 27: Sample descriptive statistics BR

ADO4 is a binary variable created from ADO3 that measure the adoption phenom. In the brazilian sample when ADO3=5, there is a real concretization of the phenom that is the focus of this study, so ADO4 assumes value=1, 0 if otherwise. This approach was also followed by Tu (2020). In this study, the dependent variable is composed only by one item, manifesting a binary dimension. According to ADO4 values, the Brazilian respondents believe that Cobots are compatible with their companies, beliefs and values, and since more than 96% of the companies are big in size we must conclude that they consider the adoption of Cobots for their type of facilities a need

- Regarding the descriptive statistics of the portuguese sample

The mean and the standard deviation of all the variables are presented in Table 28.

	Mean	Standard-Deviation	Min	Max
ADO2	2,641	1,537196	1	5
ADO3	2,308	1,220046	1	5
RA7	4,141	0,9766675	1	5

RA8	3,487	1,13668	1	5
RA9	4,128	1,154989	1	5
RA10	4,077	1,041593	1	5
RA11	4,051	0,8958408	2	5
RA1	3,705	0,9549458	2	5
RA2	3,91	0,9423085	2	5
RA3	4	0,9116846	1	5
RA4	4,115	0,805513	2	5
RA5	4,038	0,8129201	2	5
RA6	3,769	0,8962125	2	5
COMP1	2,731	1,180723	1	5
COMP2	3,051	1,226307	1	5
COMP3	3,295	1,217929	1	5
COMP4	4,141	0,9359259	1	5
SIM1	3,513	0,8640525	1	5
SIM2	3,538	0,9628463	1	5
TMS1	3,705	1,174502	1	5
TMS2	3,423	1,343761	1	5
TMS3	3,128	1,262434	1	5
TMS4	3,295	1,320261	1	5
TMS5	3	1,319189	1	5
TC1	2,744	1,049872	1	5
TC2	3,077	1,346175	1	5
TC3	3,051	1,126971	1	5
RESA1	3,013	1,284206	1	5
RESA2	2,821	1,13668	1	5
RESA3	2,936	1,085198	1	5
OI1	3,641	1,044147	1	5
OI2	4,026	1,018968	1	5
OI3	4,051	0,9383245	1	5
OI4	3,436	1,134921	1	5
HR1	3,244	0,9423085	1	5
HR2	3,244	0,9284241	1	5

HR3	3,474	0,8933282	2	5
HR4	2,026	0,8823575	1	4
IND1	2,962	1,489725	1	5
IND2	2,141	1,181287	1	5
EX1	2,744	1,098238	1	5
EX2	2,513	1,065925	1	5
EX3	2,949	0,771193	1	5
EX4	3,372	1,174502	1	5
EX5	3,295	0,8391241	1	5
EX6	3,231	1,194392	1	5
INT3	3,038	1,333313	1	5
INT1	3,103	1,49101	1	5
INT2	3,372	1,207218	1	5

Table 28 - Sample descriptive statistics PT

In the Portuguese sample, ADO2 was also created and its purpose is to measure the intensity of the adoption. The effect of Top Management Support is more evident in Brazilian companies, as well as is the pressure to adopt because a direct competitor did it. The Portuguese respondents believed that the workers are more qualified in using new technologies. This question is also the one with the highest standard-deviation which indicate the highest spread of values. There is a tendency to disagree that the regulators' laws are suitable.

The Shapiro-Wilk test for normality was done and for 5% significance level the null hypothesis (data normally distributed) is rejected, therefore the PLS-SEM can be used (Henseler et al., 2009).

4.2. Partial Least Squares – Structural Equation Modelling

Structural Equation Modelling (SEM) has the ability to combine factor analysis and regression simultaneously (McKinnic, 2016). This study used Partial Least Squares (PLS) methods because this method is recommended to exploratory studies, as this study, and

has become the tool that most researchers use in the literature (McKinnie, 2016). According to Hair et al. (2016) reliability and validity of the constructs must be established.

4.2.1. Measurements: Reliability and Validity

Reliability is confirmed by checking the Internal Consistency Reliability and Individual Indicator Reliability. Indicator Reliability consists of the size of the outer loading (Hair et al., 2016). The threshold value is 0,7. Weak indicators with values below 0,4 should be excluded (Hair et al., 2011). Indicators between 0,4 and 0,7 should be excluded if its removal leads to an increase in CR or in the Average Variance Extracted (AVE).

The Internal Consistency Reliability can be verified using Cronbach's alpha (CA) or using Consistency Reliability (CR). According to Hair et al. (2016), the best technical option is Composite Reliability and since this study can be classified as exploratory the limit recommended is 0,6. Validity is confirmed by checking its Convergent Validity and Discriminant Validity (Hair et al., 2016). The criteria of values above 0,5 of AVE means the construct is explaining more than half of the variance of its items and therefore assessing convergent validity. Discriminant validity checks how constructs are really distinct from each other's in capturing phenoms (Hair et al., 2016). It can be checked by 3 ways, the Cross Loadings where an items outer loading related to its construct should be greater than the outer loadings (Hair et al., 2016), the Fornell-Larcker criterion and by checking the Heterotrait-Monotrait Ratio (HTMT) of the correlations. In Hair et al. (2016) definition, it "estimates what the true correlation between two construct should be, if they were perfectly measured. A disattenuated correlation between two constructs close to 1 indicates a lack of discriminant validity."

- Regarding the Brazilian sample

Table 29 represents the validation for Adoption measures in the brazilian sample

	Consistency Reliability		Convergent Validity	
	CA	CR	AVE	Outer Loadings
Criteria	$\geq 0,6$ in exploratory research		$\geq 0,5$	$\geq 0,7$

Constructs	Hair et al. (2016)			(Hair et al., 2011; Sarstedt et al., 2016) Hulland (1999)	
Relative Advantage	0,525*	0,059*	0,125*	RA7	0,513*
				RA8	0,021*
				RA9	0,469*
				RA10	0,257*
				RA11	-0,307*
				RA1	-0,498*
				RA2	0,055*
				RA3	0,416*
				RA4	-0,463*
				RA5	0,31*
				RA6	0,001*
Compatibility	0,621	0,774	0,463*	COMP1	0,651*
				COMP2	0,686*
				COMP3	0,75
				COMP4	0,628*
Simplicity	0,53*	0,81	0,68	SIM1	0,821
				SIM2	0,829
Top Management Support	0,754	0,822	0,507	TMS1	0,25*
				TMS2	0,825
				TMS3	0,839
				TMS4	0,834
				TMS5	0,627*
Technology Competence	0,301*	0,656	0,435*	TC1	0,788
				TC2	0,212*
				TC3	0,798
Resource Availability	0,339*	0,707	0,573	RESA1	0,478*
				RESA3	0,957
Organization Innovativeness	0,483*	0,714	0,41*	OI1	0,295*
				OI2	0,88
				OI3	0,621*
				OI4	0,628*
Human Resources	0,335*	0,406*	0,277*	HR1	-0,075*
				HR2	-0,003*
				HR3	0,736
				HR4	0,75
Industry Pressure	0,503*	0,799	0,665	IND1	0,764
				IND2	0,865
External Support	0,178	0,226	0,254	EX1	-0,5*
				EX2	0,058*
				EX3	-0,271*
				EX4	0,654*
				EX5	0,756
				EX6	0,444*

Intention	0,847	0,907	0,764	INT3	0,895
				INT1	0,894
				INT2	0,832

Table 29: Validation for Adoption measures BR

*Do not achieve criteria suggested by the authors, AVE = Average Variance Extracted

Regarding the weak indicators, they were removed and the model re-estimated until all indicators were above the threshold of 0,7. In that sense the following items were removed in sequence: RA6, HR2, HR1, RA2, RA8, EX2, TC2, RA11, RA10, TMS1, OI1, EX3, RA5. After this point the remaining indicators had loadings between 0,4 and 0,7 therefore, they were analyze for its impact on CR and AVE. An increase of any on them after the temporary removal would implicate exclusion. The items excluded were EX6, EX1, RESA1, RA7, RA9, RA3, TMS5, COMP4, OI3 and COMP1. On the Brazilian sample, the exclusion of RESA1 means the construct just has one more item and since the sample is higher than 50, the removal of the construct accordingly to Diamantopoulos et al. (2012). Table 30 represents the measures after the items removal.

	CR	AVE	Outer Loadings	
Relative Advantage	0.809	0.708	RA1	0.819
			RA4	0.863
Compatibility	0.777	0.635	COMP2	0.779
			COMP3	0.814
Simplicity	0.810	0.680	SIM1	0.821
			SIM2	0.829
Top Management Support	0.881	0.712	TMS2	0.849
			TMS3	0.873
			TMS4	0.808
Technology Competence	0.785	0.646	TC1	0.791
			TC3	0.816
Organization Innovativeness	0.780	0.642	OI2	0.874
			OI4	0.721
Human Resources	0.728	0.573	HR3	0.784
			HR4	0.728
Industry Pressure	0.799	0.666	IND1	0.764

External Suport	0.765	0.622	IND2	0.864
			EX4	0.865
			EX5	0.703
Intention	0.906	0.764	INT3	0.892
			INT1	0.899
			INT2	0.828

Table 30: Measures after item removal BR

However, HTMT criteria was not established. Using Hair et al. (2016) strategy to decrease HTMT by eliminating items that have low correlations with other items measuring the same construct. The solution was found by the removal of IND, COMP, EX, HR and TC. This leads to the results in table 31 which are all below the reference value of 0.9.

	(1)	(2)	(3)	(4)	(5)	(6)
Relative Advantage (1)	-					
Simplicity (2)	0.630	-				
Top Management Support (3)	0.216	0.317	-			
Organization Innovativeness (4)	0.293	0.632	0.815	-		
Intention (5)	0.104	0.291	0.656	0.624	-	
Adoption (6)	0.364	0.539	0.157	0.130	0.044	-

Table 31 – Discriminant Validity for BR

- Regarding the portuguese sample

Table 32 represents the validation for Adoption measures in the portuguese sample

	Consistency Reliability		Convergent Validity	
	CA	CR	AVE	Outer Loadings
Criteria	$\geq 0,6$ in exploratory research		$\geq 0,5$	$\geq 0,7$
Constructs	Hair et al. (2016)		(Hair et al., 2011; Sarstedt et al., 2016) (Hulland, 1999)	
Relative Advantage	0,856	0,883	0,413*	RA7 0,624* RA8 0,396*

Compatibility	0,768	0,852	0,599	RA9	0,729
				RA10	0,649*
				RA11	0,774
				RA1	0,598*
				RA2	0,693*
				RA3	0,487*
				RA4	0,72
				RA5	0,652*
				RA6	0,652*
				COMP1	0,802
				COMP2	0,886
				COMP3	0,832
				COMP4	0,524*
Simplicity	0,553*	0,781	0,652	SIM1	0,965
				SIM2	0,611*
Top Management Support	0,936	0,951	0,796	TMS1	0,823
				TMS2	0,9
				TMS3	0,895
				TMS4	0,929
				TMS5	0,911
Technology Competence	0,723	0,838	0,636	TC1	0,721
				TC2	0,896
				TC3	0,764
Resource Availability	0,832	0,9	0,75	RESA1	0,812
				RESA2	0,867
				RESA3	0,915
Organization Innovativeness	0,827	0,879	0,645	OI1	0,798
				OI2	0,867
				OI3	0,716
				OI4	0,825
Human Resources	0,489*	0,642	0,44*	HR1	0,851
				HR2	0,887
				HR3	0,46*
				HR4	-0,195*
Industry Pressure	0,727	0,874	0,777	IND1	0,937
				IND2	0,822
External Support	0,761	0,829	0,449*	EX1	0,633*
				EX2	0,742
				EX3	0,679*
				EX4	0,583*
				EX5	0,674*
				EX6	0,698*
Intention	0,839	0,904	0,76	INT3	0,931
				INT1	0,94
				INT2	0,728

Table 32: Validation for Adoption measures PT

*Do not achieve criteria suggested by the authors, AVE = Average Variance Extracted

Regarding the weak indicators, they were removed and the model re-estimated until all indicators were above the threshold of 0,7. In that sense the following items were removed in sequence: HR4 and RA8. After this point the remaining indicators had loadings between 0,4 and 0,7 therefore, they were analyzed for its impact on CR and AVE. An increase on any of them after the temporary removal would implicate exclusion. The items excluded were HR3, RA3, COMP4, EX4, RA1, SIM2, EX1, RA7, RA6, RA2, EX3 and EX2. The exclusion of SIM2, implies the removal of the construct according to Diamantopoulos et al. (2012) since the sample is higher than 50 and the construct only has one more item. Table 33 represents the measures after the items removal.

	CR	AVE	Outer Loadings	
Relative Advantage	0.873	0.581	RA9	0.805
			RA10	0.762
			RA11	0.721
			RA4	0.808
			RA5	0.708
Compatibility	0.891	0.732	COMP1	0.822
			COMP2	0.912
			COMP3	0.830
Top Management Support	0.951	0.796	TMS1	0.823
			TMS2	0.900
			TMS3	0.895
			TMS4	0.929
			TMS5	0.911
Technology Competence	0.838	0.636	TC1	0.721
			TC2	0.896
			TC3	0.764
Resource Availability	0.9	0.75	RESA1	0.812
			RESA2	0.867
			RESA3	0.915

Organization Innovativeness	0.879	0.645	OI1	0.798
			OI2	0.867
			OI3	0.716
			OI4	0.825
Human Resources	0.893	0.807	HR1	0.885
			HR2	0.911
Industry Pressure	0.874	0.777	IND1	0.937
			IND2	0.822
External Suport	0.798	0.665	EX5	0.773
			EX6	0.855
Intention	0.904	0.760	INT3	0.932
			INT1	0.940
			INT2	0.726

Table 33: Measures after item removal PT

However, HTMT' criteria was not established. Using Hair et al. (2016) strategy to decrease HTMT' by eliminating items that have low correlations with other items measuring the same construct. The solution was found by the removal of the item RA5, and the constructs TMS, COMP, RESA, TC and ADO2. This leads to the results in table 34 which are all below the reference value of 0,9.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Relative Advantage (1)	-						
Resource Availability (2)	0.132	-					
Organization Innovativeness (3)	0.231	0.475	-				
Human Resources (4)	0.417	0.502	0.633	-			
Industry Pressure (5)	0.551	0.278	0.261	0.433	-		
Intention (6)	0.646	0.64	0.633	0.656	0.664	-	
Adoption (7)	0.465	0.402	0.455	0.489	0.571	0.831	-

Table 34 – Discriminant Validity for PT

Table 35 and 36 present the Cross-Loadings for the brazilian sample and the portuguese sample respectively.

	RA	COMP	SIM	TMS	TC	RESA	OI	HR	IND	EX	INT
RA7	0,513	0,249	0,060	0,135	0,201	0,028	0,224	0,090	-0,018	0,027	0,156
RA8	0,021	0,111	0,112	0,056	0,047	-0,010	0,060	0,001	-0,077	-0,299	-0,018
RA9	0,469	0,279	0,049	-0,044	0,151	0,123	0,068	0,038	0,000	-0,019	0,148
RA10	0,257	0,127	-0,125	0,297	0,093	0,005	0,236	-0,090	0,041	0,043	0,095
RA11	-0,307	0,086	-0,277	0,119	-0,235	-0,176	0,037	-0,257	0,446	-0,191	0,164
RA1	-0,498	-0,319	-0,264	0,001	-0,479	-0,195	-0,146	-0,242	0,193	-0,301	-0,084
RA2	0,055	-0,344	0,361	-0,303	-0,158	-0,008	-0,378	0,238	-0,316	0,022	-0,278
RA3	0,416	0,300	0,192	0,254	0,240	-0,266	0,118	-0,034	0,010	0,051	0,316
RA4	-0,463	-0,034	-0,331	0,103	-0,220	-0,056	0,129	-0,207	0,160	-0,339	-0,044
RA5	0,310	0,242	-0,179	0,291	0,051	-0,037	0,212	-0,146	0,125	0,066	0,278
RA6	0,001	0,110	0,120	-0,098	-0,022	0,082	-0,019	0,055	-0,179	-0,341	0,009
COMP1	0,369	0,651	0,207	0,254	0,436	-0,120	0,199	0,008	0,017	-0,069	0,345
COMP2	0,270	0,686	-0,248	0,452	0,204	-0,108	0,330	-0,144	0,351	0,153	0,505
COMP3	0,344	0,750	0,009	0,406	0,389	0,152	0,343	-0,056	0,072	0,093	0,483
COMP4	0,206	0,628	0,024	0,117	0,342	0,237	0,348	0,044	0,032	-0,171	0,315
SIM1	0,265	-0,102	0,821	-0,111	0,229	0,132	-0,157	0,372	-0,391	0,202	-0,170
SIM2	0,243	0,048	0,829	-0,262	0,259	0,145	-0,140	0,379	-0,393	0,235	-0,159
TMS1	-0,112	0,189	0,020	0,250	-0,025	-0,132	0,054	-0,159	0,157	-0,043	-0,022
TMS2	0,189	0,558	-0,250	0,825	0,373	-0,140	0,605	-0,290	0,336	0,154	0,485
TMS3	0,258	0,427	-0,058	0,839	0,299	-0,452	0,299	-0,258	0,203	0,177	0,541
TMS4	0,087	0,266	-0,216	0,834	0,221	-0,403	0,407	-0,423	0,227	0,057	0,367
TMS5	-0,157	0,199	-0,257	0,627	-0,004	-0,234	0,148	-0,447	0,389	-0,215	0,197
TC1	0,455	0,340	0,371	0,297	0,788	-0,002	0,255	0,153	-0,177	0,324	0,245
TC2	0,050	-0,077	0,265	-0,149	0,212	0,278	-0,178	0,168	-0,246	0,144	-0,147
TC3	0,361	0,480	0,053	0,262	0,798	0,222	0,423	0,157	0,000	0,100	0,271
RESA1	-0,301	-0,246	-0,207	-0,315	-0,334	0,478	-0,213	0,062	-0,020	-0,110	-0,267
RESA3	0,213	0,141	0,256	-0,342	0,314	0,957	0,071	0,482	-0,285	0,212	-0,114
OI1	0,299	0,144	0,296	0,163	0,276	-0,049	0,295	0,106	-0,206	0,321	0,081
OI2	0,215	0,376	-0,190	0,473	0,338	-0,002	0,880	-0,123	0,134	0,136	0,367
OI3	0,105	0,302	-0,019	0,187	0,345	0,149	0,621	0,034	-0,024	-0,127	0,092
OI4	-0,012	0,301	-0,309	0,272	0,100	-0,042	0,628	-0,141	0,303	-0,092	0,270
HR1	0,257	0,352	0,060	0,237	0,355	0,014	0,198	-0,075	0,179	0,069	0,158
HR2	0,093	0,380	-0,092	0,114	0,195	0,066	0,282	-0,003	0,212	-0,042	0,211
HR3	0,188	0,068	0,283	-0,140	0,230	0,312	0,042	0,736	-0,170	0,224	-0,105
HR4	0,173	-0,044	0,383	-0,448	0,179	0,383	-0,108	0,750	-0,401	0,087	-0,151
IND1	-0,056	0,212	-0,332	0,296	-0,006	-0,191	0,174	-0,297	0,764	0,233	0,372
IND2	-0,282	0,119	-0,435	0,271	-0,206	-0,233	0,091	-0,389	0,865	-0,355	0,144
EX1	-0,075	0,031	-0,011	0,047	0,073	-0,002	-0,002	0,026	0,006	-0,500	-0,061
EX2	0,023	0,169	-0,155	0,145	0,175	-0,024	0,187	-0,002	0,141	0,058	0,246
EX3	0,140	0,185	0,103	-0,019	0,238	-0,067	0,016	0,018	0,040	-0,271	0,092
EX4	0,228	-0,042	0,394	-0,066	0,245	0,290	-0,065	0,296	-0,333	0,654	-0,060

EX5	0,357	0,157	0,255	0,288	0,380	-0,058	0,233	0,113	-0,014	0,756	0,139
EX6	-0,055	-0,018	-0,217	-0,004	-0,047	0,087	0,020	0,026	0,253	0,444	0,203
INT3	0,253	0,584	-0,189	0,513	0,300	-0,166	0,379	-0,194	0,253	0,156	0,895
INT1	0,240	0,594	-0,202	0,529	0,272	-0,115	0,349	-0,204	0,267	0,070	0,894
INT2	0,235	0,437	-0,121	0,334	0,171	-0,208	0,239	-0,171	0,263	0,072	0,832

Table 35: Cross-Loading Brazilian Sample

	RA	COMP	SIM	TMS	TC	RESA	OI	HR	IND	EX	INT
RA7	0,624	0,270	0,179	0,299	0,147	0,115	0,260	0,237	0,236	0,206	0,344
RA8	0,396	0,122	0,179	0,076	0,006	0,096	0,123	0,196	0,049	0,113	0,112
RA9	0,729	0,517	0,088	0,511	-0,040	-0,076	0,010	0,318	0,434	0,277	0,423
RA10	0,649	0,354	0,061	0,422	0,001	-0,038	0,160	0,238	0,288	0,221	0,332
RA11	0,774	0,457	0,376	0,347	0,143	0,091	0,232	0,285	0,311	0,341	0,464
RA1	0,598	0,391	0,380	0,404	0,218	0,290	0,207	0,297	0,245	0,260	0,409
RA2	0,693	0,440	0,379	0,362	0,211	0,253	0,244	0,388	0,195	0,408	0,397
RA3	0,487	0,380	0,228	0,289	-0,090	0,010	0,178	0,294	0,186	0,225	0,195
RA4	0,720	0,438	-0,008	0,400	-0,013	-0,018	0,137	0,296	0,314	0,245	0,359
RA5	0,652	0,442	0,143	0,319	-0,004	-0,017	-0,013	0,199	0,334	0,135	0,328
RA6	0,652	0,476	0,518	0,425	0,130	0,194	0,318	0,465	0,266	0,323	0,398
COMP1	0,364	0,802	0,462	0,538	0,399	0,396	0,262	0,445	0,473	0,613	0,598
COMP2	0,580	0,886	0,349	0,729	0,319	0,327	0,279	0,456	0,591	0,544	0,739
COMP3	0,538	0,832	0,337	0,742	0,449	0,439	0,322	0,509	0,433	0,511	0,783
COMP4	0,453	0,524	0,500	0,427	0,322	0,181	0,301	0,320	0,119	0,340	0,413
SIM1	0,273	0,490	0,965	0,380	0,482	0,392	0,411	0,418	0,153	0,449	0,459
SIM2	0,415	0,273	0,611	0,201	0,135	0,135	0,249	0,254	0,108	0,251	0,239
TMS1	0,595	0,643	0,277	0,823	0,304	0,224	0,546	0,482	0,352	0,378	0,694
TMS2	0,567	0,713	0,268	0,900	0,406	0,394	0,582	0,528	0,459	0,461	0,710
TMS3	0,436	0,700	0,312	0,895	0,511	0,502	0,493	0,395	0,447	0,517	0,742
TMS4	0,473	0,793	0,446	0,929	0,528	0,512	0,588	0,513	0,499	0,587	0,831
TMS5	0,491	0,747	0,386	0,911	0,582	0,468	0,531	0,478	0,506	0,548	0,795
TC1	0,005	0,290	0,379	0,364	0,721	0,432	0,526	0,300	0,167	0,331	0,408
TC2	0,214	0,539	0,371	0,523	0,896	0,757	0,415	0,411	0,325	0,533	0,603
TC3	-0,030	0,208	0,345	0,321	0,764	0,595	0,517	0,356	0,191	0,301	0,323
RESA1	0,142	0,347	0,243	0,398	0,599	0,812	0,436	0,353	0,164	0,529	0,472
RESA2	0,025	0,377	0,366	0,393	0,673	0,867	0,386	0,371	0,234	0,412	0,431
RESA3	0,147	0,437	0,366	0,443	0,718	0,915	0,435	0,438	0,223	0,475	0,493
OI1	0,124	0,215	0,314	0,470	0,505	0,327	0,798	0,372	0,179	0,278	0,364
OI2	0,291	0,262	0,367	0,527	0,437	0,348	0,867	0,463	0,157	0,363	0,455
OI3	0,211	0,108	0,194	0,356	0,257	0,266	0,716	0,344	0,039	0,248	0,214
OI4	0,198	0,453	0,400	0,552	0,559	0,527	0,825	0,515	0,282	0,557	0,554
HR1	0,271	0,468	0,342	0,493	0,377	0,494	0,509	0,851	0,267	0,556	0,404
HR2	0,449	0,551	0,370	0,498	0,350	0,300	0,436	0,887	0,348	0,472	0,473
HR3	0,062	0,074	0,370	0,100	0,435	0,402	0,376	0,460	0,120	0,199	0,134
HR4	-0,385	-0,183	-0,015	-0,089	-0,024	0,103	-0,011	-0,195	-0,104	-0,046	-0,161
IND1	0,442	0,601	0,234	0,522	0,359	0,277	0,211	0,370	0,937	0,374	0,626

IND2	0,284	0,326	-0,002	0,347	0,128	0,109	0,207	0,230	0,822	0,272	0,363
EX1	0,090	0,284	0,277	0,241	0,273	0,438	0,279	0,196	0,069	0,633	0,301
EX2	0,300	0,410	0,359	0,385	0,204	0,249	0,334	0,322	0,246	0,742	0,403
EX3	0,445	0,467	0,288	0,400	0,215	0,256	0,274	0,406	0,369	0,679	0,396
EX4	0,171	0,334	0,192	0,277	0,431	0,443	0,320	0,230	0,032	0,583	0,296
EX5	0,211	0,492	0,441	0,338	0,436	0,431	0,262	0,506	0,199	0,674	0,491
EX6	0,334	0,536	0,255	0,519	0,444	0,395	0,446	0,464	0,436	0,698	0,589
INT3	0,448	0,747	0,356	0,786	0,555	0,520	0,569	0,439	0,561	0,601	0,931
INT1	0,529	0,816	0,367	0,832	0,582	0,487	0,476	0,467	0,622	0,569	0,940
INT2	0,514	0,635	0,546	0,568	0,379	0,399	0,339	0,407	0,302	0,543	0,728

Table 36: Cross-Loadings Portuguese sample

4.2.2. Evaluation of the Structural Model

Hair et al. (2016) states that after reliability and validity are confirmed the next step is the analysis of the structural model.

4.3. Model validation and hypothesis testing

By implementing the validity and reliability criteria, the structural model was fine-tuned and estimated with the retained constructs and items. In this last stage analysis, the assumed relationship between the variables was estimated.

- Relating to the brazilian sample

Table 37 represents the Validation of the final PLS structural model, Table 38 the bootstrap parameter estimation of the structural and table 39 the coefficients of determination of constructs as well as the paths coefficients.

	CR	AVE	Outer loadings	
Relative Advantage	0.829	0.708	RA1	0.820
			RA4	0.862
Simplicity	0.810	0.682	SIM1	0.821
			SIM2	0.828
Top Management Support	0.881	0.712	TMS2	0.849
			TMS3	0.873
			TMS4	0.808
Organization	0.781	0.642	OI2	0.872

Innovativeness			OI4	0.724
			INT3	0.898
Intention	0.906	0.7622	INT1	0.901
			INT2	0.817

Table 37: Validation of the Final PLS-SEM

	Original Est.	Bootstrap Mean	Bootstrap SD	Confidence Interval 95%
RA -> INT'	-0.130*	-0.134	0.060	[-0.254; -0.020]
RA -> ADO	-0.150*	-0.153	0.063	[-0.276; -0.031]
SIM -> INT'	-0.114*	-0.115	0.052	[-0.216; -0.014]
SIM -> ADO	0.378***	0.378	0.049	[0.278; 0.472]
TMS -> INT'	0.475***	0.475	0.069	[0.332; 0.603]
TMS -> ADO	-0.185***	-0.188	0.066	[-0.323; -0.060]
OI -> INT'	0.137**	0.142	0.047	[0.050; 0.234]
OI -> ADO	0.256***	0.257	0.053	[0.154; 0.363]
INT -> ADO	0.142*	0.141	0.068	[0.010; 0.277]

Table 38 – Bootstrap Parameter estimation of the structural model

Note: * $p < 0.05$; ** $p < 0.1$; *** $p < 0.01$

As it is visible, the constructs are statistically significant as the confidence interval in any case does not contain the value 0.

	Intention	Adoption
R^2	0.356	0.240
$R^2_{Adj.}$	0.347	0.227
RA	-0.130	-0.132
SIM	-0.114	0.394
TMS	0.475	-0.252
OI	0.137	0.236
INT'		0.142

Table 39 – Coefficient of determination of the constructs

The findings show support hypotheses (H1a, H1b, H3a, H3b, H4a, H4b, H7a, H7b and H11). The effects are all statistically significant (5%) since the confidence intervals do not contain zero although not all the paths have the expected sign. The complete structural model with path coefficients and the coefficient of determination (R^2) can be found in Annex 6

- Regarding the portuguese sample,

Table 40 represents the Validation of the final PLS structural model, Table 41 the bootstrap parameter estimation of the structural and table 42 the coefficients of determination of constructs as well as the paths coefficients.

	CR	AVE	Outer Loadings	
Relative Advantage	0,865	0,617	RA9	0,816
			RA10	0,791
			RA11	0,767
			RA4	0,767
Resource Availability	0,942	0,89	RESA2	0,935
			RESA3	0,932
Organization Innovativeness	0,879	0,646	OI1	0,801
			OI2	0,867
			OI3	0,718
			OI4	0,823
Human Resources	0,893	0,806	HR1	0,883
			HR2	0,912
Industry Pressure	0,873	0,775	IND1	0,941
			IND2	0,816
Intention	0,858	0,752	INT3	0,917
			INT2	0,814

Table 40: Validation of the Final PLS-SEM

	Original Est.	Bootstrap Mean	Bootstrap SD	Confidence Interval 95%
RA -> INT	0,352***	0,346	0,099	[0,148; 0,533]
RA -> ADO	0,242	0,244	0,097	[0,051; 0,434]

RESA -> INT	0,336***	0,328	0,084	[0,150; 0,486]
RESA -> ADO	0,195	0,19	0,104	[-0,015; 0,393]
OI -> INT	0,284**	0,297	0,09	[0,114; 0,469]
OI -> ADO	0,247	0,257	0,103	[0,051; 0,453]
HR -> INT	-0,002	-0,003	0,095	[-0,190; 0,185]
HR -> ADO	0,039	0,039	0,102	[-0,165; 0,234]
IND -> INT	0,223**	0,223	0,088	[0,054; 0,398]
IND -> ADO	0,292*	0,294	0,106	[0,080; 0,492]
INT -> ADO	0,495***	0,494	0,123	[0,253; 0,734]

Table 41 – Bootstrap Parameter estimation of the structural model

Note: *p < 0.05; ** p < 0.1; *** p < 0.01

As it is visible, the constructs are statistically significant as the confidence interval in any case does not contain the value 0.

	Intention	Adoption
R ²	0.607	0.551
R ² _{Adj.}	0.580	0.513
RA	0.352	0.068
RESA	0.336	0.028
OI	0.284	0.106
HR	-0.002	0.040
IND	0.223	0.181
INT		0.495

Table 42 - Coefficient of determination of the constructs

The findings show support hypotheses (H1a, H6a, H7a, H7b, H9a, H9b and H11). The effects are all statistically significant (5%) since the confidence intervals do not contain zero although not all the paths have the expected sign. The complete structural model with path coefficients and the coefficient of determination (R²) can be found in Annex 7.

		Signal	Sample BR	Signal	Sample PT
H1	a) RA	-	SUPPORTED	+	SUPPORTED
	b)	-	SUPPORTED	+	NOT SUPPORTED

H2	a)	COMP	NON-SIGNIFICANT	NON-SIGNIFICANT
	b)		NON-SIGNIFICANT	NON-SIGNIFICANT
H3	a)	SIM	- SUPPORTED	NON-SIGNIFICANT
	b)		+ SUPPORTED	NON-SIGNIFICANT
H4	a)	TMS	+ SUPPORTED	NON-SIGNIFICANT
	b)		- SUPPORTED	NON-SIGNIFICANT
H5	a)	TC	NON-SIGNIFICANT	NON-SIGNIFICANT
	b)		NON-SIGNIFICANT	NON-SIGNIFICANT
H6	a)	RESA	NON-SIGNIFICANT	+ SUPPORTED
	b)		NON-SIGNIFICANT	+ NOT SUPPORTED
H7	a)	OI	+ SUPPORTED	+ SUPPORTED
	b)		+ SUPPORTED	+ NOT SUPPORTED
H8	a)	HR	NON-SIGNIFICANT	- NOT SUPPORTED
	b)		NON-SIGNIFICANT	+ NOT SUPPORTED
H9	a)	IND	NON-SIGNIFICANT	+ SUPPORTED
	b)		NON-SIGNIFICANT	+ SUPPORTED
H10	a)	EX	NON-SIGNIFICANT	NON-SIGNIFICANT
	b)		NON-SIGNIFICANT	NON-SIGNIFICANT
H11		INT	+ SUPPORTED	+ SUPPORTED

Table 43 – Hypothesis Testing

5. Discussion of results and implications

According to Cruz-Jesus et al. (2019), the factors more frequently referred to in the literature, as being the critical ones used in TOE framework, are Technology Competence, Top Management Support and Competitive Pressure. However, the construct Technology Competence did not appear in any of the two final models after PLS-SEM estimation, Top Management Support only appeared in the Brasil model and with an unexpected signal at the adoption phase and Industry Pressure only appeared on the adoption model for Portugal.

The studies of (Fosso Wamba et al., 2016; Martins et al., 2016; Ramanathan et al., 2017) demonstrate that Relative Advantage is a crucial factor that influences technology adoption. In the work of Wamba and Queiroz (2020), this factor had only influence in the Intention and Adoption but not for the routinization stage for India and USA. The results of the present study go in in an opposite direction, since a negative signal was shown for the two stages. A possible explanation could be the fact that only recently Brazil created legislation to allow the implementation of Cobots. This could change or overshadow the perception of the relative advantages of the technology, for example, favoring the adoption of traditional robots.

Top Management Support effects instability is well reported in the literature. There is a study identifying its effects in all stages of the adoption process (Fosso Wamba et al., 2016) and others (Junior et al., 2019) report this effect to first stage.

The non-presence of the construct Technology Competence goes in opposition to the studies of (Chong & Chan, 2012; Junior et al., 2019; Martins et al., 2016; Venkatesh & Bala, 2012).

Simplicity, as the opposite of “Complexity”, has no effect on Intention stage in Brazil which goes in line with the evidence found in (Y.-M. Wang et al., 2010) where complexity appears only as an inhibitor at the intention phase and no effects on the others ((Martins et al., 2016).

Industry pressure, exerted by competitors or customers was identified as a crucial factor in the Portuguese model which is compatible with the results of Cruz-Jesus et al. (2019) where the factor has effects in all stages.

Human Resources was absent from the Brazilian model but it appears in the Portuguese model but only for the adoption phase. This result contradicts the studies of (Nwaiwu et al., 2020) where Human Resource is a factor for the implementation of Industry 4.0 in Czech SME manufacturing sector.

Organization Innovativeness appears on both models as a critical factor for Intention and Adoption which is supported by the studies of (McKinnie, 2016).

Regarding the low value of R^2 of the Brazilian model it can be explained by the still exploratory nature of it, by the complexity of the phenom and the field of science of the topic (Hair et al., 2011).

6. Conclusion

This collaboration resulted in a rewarding investigation. Although with an extensive literature review and a broad sense of congruence between authors, the adoption process, specially of an early technology like Cobots is still a complex phenom, like is shown in the unpredictability of factors removed or relations between variables and stages of adoption not being the ones expected.

Based on the data from two very different countries, this study identified the more advanced and dynamic Cobots adoption process of Brazil as well as a bigger eagerness in terms of intention. A possible explanation can come from the internal characteristics of the country and with effects stronger than technological or organizational factors. This topic demands further investigation and should be a research question. The presence of the automobile industry and many companies classified as big can be the motor and center of the adoption movement in the country. A higher importance to the Resource Availability factor present in the Portuguese model could also be a consequence of the dependency between the adoption process and where it occurs. This is present in the below the mean values of the question related to resources availability.

However, the advantages of Cobots go beyond the mere economic ones. It is a technology that is changing how small and medium manufacturing companies work and compete in the market allowing fast, flexible, precious production with cost savings. It is also changing how workers are considered. In industrialized countries the retirement age is progressively increasing and consequently more workers must perform tasks while seeing their physical capabilities diminish. With Cobots adoption companies can prevent future lesions both mentally and physically.

Cobots potential is changing the global supply chain by altering the cost matrix. National and local companies become more attractive to do business with. And all of this is just the beginning.

References

- Aaltonen, I., & Salmi, T. (2019). Experiences and expectations of collaborative robots in industry and academia: barriers and development needs. *Procedia Manufacturing*, 38, 1151-1158. doi: <https://doi.org/10.1016/j.promfg.2020.01.204>
- Allen, M. (2017). *The SAGE encyclopedia of communication research methods* (Vol. 1-4): Sage Publications.
- Association, R. I. (2020). What is an End Effector and How do you Use One? Retrieved from https://www.robotics.org/content-detail.cfm/Industrial-Robotics-News/What-is-an-End-Effector-and-How-Do-You-Use-One/content_id/9134
- Baptista, J. S., Arezes, P. M., Barroso, M. P., Carneiro, P., Cordeiro, P., Costa, N., . . . Perestrelo, G. (2019). *Occupational and Environmental Safety and Health*: Springer.
- Bauer, W., Bender, M., Braun, M., Rally, P., & Scholtz, O. (2016). *Lightweight robots in manual assembly—best to start simply*. Stuttgart: Fraunhofer-Institut für Arbeitswirtschaft und Organisation IAO.
- Beatty, R. C., Shim, J. P., & Jones, M. C. (2001). Factors influencing corporate web site adoption: a time-based assessment. *Information & management*, 38(6), 337-354. doi: [https://doi.org/10.1016/S0378-7206\(00\)00064-1](https://doi.org/10.1016/S0378-7206(00)00064-1)
- Bell, J. (2014). *Doing Your Research Project: A guide for first-time researchers*: McGraw-Hill Education (UK).
- Bello, O., & Olanrewaju, O. (2020). Factors influencing biometric technology adoption: Empirical evidence from Nigeria. *African Journal of Science, Technology, Innovation and Development*, 1-13. doi:<https://doi.org/10.1080/20421338.2020.1837415>
- Bernhardt, R., Surdilovic, D., Katschinski, V., & Schröer, K. (2007). Flexible assembly systems through workplace-sharing and time-sharing human-machine cooperation—pisa. *IFAC Proceedings Volumes*, 40(3), 247-251. doi: <https://doi.org/10.3182/20070523-3-ES-4908.00041>
- Bi, Z., Luo, M., Miao, Z., Zhang, B., Zhang, W., & Wang, L. (2020). Safety assurance mechanisms of collaborative robotic systems in manufacturing. *Robotics and Computer-Integrated Manufacturing*, 67, 102022. doi: <https://doi.org/10.1016/j.rcim.2020.102022>
- Bogataj, D., Battini, D., Calzavara, M., & Persona, A. (2019). The ageing workforce challenge: Investments in collaborative robots or contribution to pension schemes, from the multi-echelon perspective. *International journal of production economics*, 210, 97-106. doi: <https://doi.org/10.1016/j.ijpe.2018.12.016>
- Bolonne, H., & Wijewardene, P. Critical Factors Affecting the Intention to Adopt Big Data Analytics in Apparel Sector, Sri Lanka.
- Carr Jr, V. (1999). Technology adoption and diffusion. *The Learning Center for Interactive Technology*. Retrieved from <http://tlc.nlm.nih.gov/resources/publications/sourcebook/adoptiondiffusion.html>.
- Chong, A. Y.-L., & Chan, F. T. S. (2012). Structural equation modeling for multi-stage analysis on Radio Frequency Identification (RFID) diffusion in the health care industry. *Expert Systems with Applications*, 39(10), 8645-8654. doi: <https://doi.org/10.1016/j.eswa.2012.01.201>
- Cohen, Y., Shoval, S., & Faccio, M. (2019). Strategic View on Cobot Deployment in Assembly 4.0 Systems. *IFAC-PapersOnLine*, 52(13), 1519-1524. doi: <https://doi.org/10.1016/j.ifacol.2019.11.415>

- Colgate, J. E., Edward, J., Peshkin, M. A., & Wannasuphoprasit, W. (1996). Cobots: Robots for collaboration with human operators. *Proceedings of the ASME Dynamic Systems and Control Division*, 58, 433-440.
- Commission, E. U. (2003). Commission recommendation of 6 May 2003 concerning the definition of micro, small and medium-sized enterprises. *official Journal of the European union*, 46(L124), 36-41. Retrieved from http://publications.europa.eu/resource/ellar/1bd0c013-0ba3-4549-b879-0ed797389fa1.0005.02/DOC_2
- Cruz-Jesus, F., Pinheiro, A., & Oliveira, T. (2019). Understanding CRM adoption stages: empirical analysis building on the TOE framework. *Computers in Industry*, 109, 1-13. doi: <https://doi.org/10.1016/j.compind.2019.03.007>
- Dalenogare, L. S., Benitez, G. B., Ayala, N. F., & Frank, A. G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International journal of production economics*, 204, 383-394. doi: <https://doi.org/10.1016/j.ijpe.2018.08.019>
- Department, I. S. (2020). World Robotics 2020 - Industrial Robots. In.
- Diamantopoulos, A., Sarstedt, M., Fuchs, C., Wilczynski, P., & Kaiser, S. (2012). Guidelines for choosing between multi-item and single-item scales for construct measurement: a predictive validity perspective. *Journal of the Academy of Marketing Science*, 40(3), 434-449. doi: <https://doi.org/10.1371/journal.pone.0234143>
- Dincbas, T., Ergeneli, A., & Yigitbasioglu, H. (2021). Clean technology adoption in the context of climate change: Application in the mineral products industry. *Technology in Society*, 64, 101478. doi: <https://doi.org/10.1016/j.techsoc.2020.101478>
- Dubey, V. N., & Crowder, R. M. (2002). *A finger mechanism for adaptive end effectors*. Paper presented at the International Design Engineering Technical Conferences and Computers and Information in Engineering Conference.
- Fast-Berglund, Å., Palmkvist, F., Nyqvist, P., Ekered, S., & Åkerman, M. (2016). Evaluating cobots for final assembly. *Procedia CIRP*, 44, 175-180. doi: <https://doi.org/10.1016/j.procir.2016.02.114>
- Fosso Wamba, S., Gunasekaran, A., Bhattacharya, M., & Dubey, R. (2016). Determinants of RFID adoption intention by SMEs: an empirical investigation. *Production Planning & Control*, 27(12), 979-990. doi:10.1080/09537287.2016.1167981
- Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International journal of production economics*, 210, 15-26. doi: <https://doi.org/10.1016/j.ijpe.2019.01.004>
- Friis, D., & Officer, C. C. (2016). Cobots Expand Automation Opportunities. *Editorial Notes, IFR, Editorial World Robotics Industrial Robots*.
- Galin, R., Meshcheryakov, R., Kamesheva, S., & Samoshina, A. (2020). *Cobots and the benefits of their implementation in intelligent manufacturing*. Paper presented at the IOP Conference Series: Materials Science and Engineering.
- Gangwar, H., & Date, H. (2016). Critical factors of cloud computing adoption in organizations: An empirical study. *Global Business Review*, 17(4), 886-904. doi: <https://doi.org/10.1177/0972150916645692>
- Gefen, D., Rigdon, E., & Straub, D. (2011). Editor's comments: an update and extension to SEM guidelines for administrative and social science review. *MIS Q*, 35, iii-xiv. doi: <https://doi.org/10.2307/23044042>
- Ghobakhloo, M. (2020). Determinants of information and digital technology implementation for smart manufacturing. *International Journal of Production Research*, 58(8), 2384-2405. doi:<https://doi.org/10.1080/00207543.2019.1630775>

- Ghobakhloo, M., & Ching, N. T. (2019). Adoption of digital technologies of smart manufacturing in SMEs. *Journal of Industrial Information Integration*, 16, 100107. doi: <https://doi.org/10.1016/j.jii.2019.100107>
- Gillani, F., Chatha, K. A., Sadiq Jajja, M. S., & Farooq, S. (2020). Implementation of digital manufacturing technologies: Antecedents and consequences. *International journal of production economics*, 229, 107748. doi: <https://doi.org/10.1016/j.ijpe.2020.107748>
- Giovanis, A. N., Binioris, S., & Polychronopoulos, G. (2012). An extension of TAM model with IDT and security/privacy risk in the adoption of internet banking services in Greece. *EuroMed Journal of Business*, 7(1), 24-53. doi: <https://doi.org/10.1108/14502191211225365>
- Greve, H. R., & Argote, L. (2015). Behavioral Theories of Organization. *International Encyclopedia of the Social & Behavioral Sciences*. 2nd edn. Orlando, FL, USA, 481-486.
- Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2016). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)* (Second ed.): Sage.
- Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a Silver Bullet. *Journal of Marketing Theory and Practice*, 19(2), 139-152. doi: <https://doi.org/10.2753/MTP1069-6679190202>
- Hameed, M. A., Counsell, S., & Swift, S. (2012). A conceptual model for the process of IT innovation adoption in organizations. *Journal of Engineering and Technology Management*, 29(3), 358-390. doi: <https://doi.org/10.1016/j.jengtecman.2012.03.007>
- Henseler, J., Ringle, C. M., & Sinkovics, R. R. (2009). The use of partial least squares path modeling in international marketing. In R. R. Sinkovics & P. N. Ghauri (Eds.), *New Challenges to International Marketing* (Vol. 20, pp. 277-319): Emerald Group Publishing Limited.
- Hentout, A., Aouache, M., Maoudj, A., & Akli, I. (2019). Human–robot interaction in industrial collaborative robotics: a literature review of the decade 2008–2017. *Advanced Robotics*, 33(15-16), 764-799. doi: <https://doi.org/10.1080/01691864.2019.1636714>
- Hofmann, C., & Orr, S. (2005). Advanced manufacturing technology adoption—the German experience. *Technovation*, 25(7), 711-724. doi: <https://doi.org/10.1016/j.technovation.2003.12.002>
- Hulland, J. (1999). Use of partial least squares (PLS) in strategic management research: a review of four recent studies. *Strategic Management Journal*, 20(2), 195-204. doi: [https://doi.org/10.1002/\(SICI\)1097-0266\(199902\)20:2<195::AID-SMJ13>3.0.CO;2-7](https://doi.org/10.1002/(SICI)1097-0266(199902)20:2<195::AID-SMJ13>3.0.CO;2-7)
- Ionescu, T. B., & Schlund, S. (2019). A Participatory Programming Model for Democratizing Cobot Technology in Public and Industrial Fablabs. *Procedia CIRP*, 81, 93-98. doi: <https://doi.org/10.1016/j.procir.2019.03.017>
- Jabre, L., McGrew, R., Gillespie, R. B., & Goleski, P. (2002). An assistive cobot for aid in self care activities. *IFAC Proceedings Volumes*, 35(2), 511-516. doi: [https://doi.org/10.1016/S1474-6670\(17\)33991-5](https://doi.org/10.1016/S1474-6670(17)33991-5)
- Junior, C. H., Oliveira, T., & Yanaze, M. (2019). The adoption stages (Evaluation, Adoption, and Routinisation) of ERP systems with business analytics functionality in the context of farms. *Computers and Electronics in Agriculture*, 156, 334-348. doi: <https://doi.org/10.1016/j.compag.2018.11.028>
- Kadir, B. A., Broberg, O., & Souza da Conceição, C. (2018). *Designing human-robot collaborations in industry 4.0: explorative case studies*. Paper presented at the DS 92: Proceedings of the DESIGN 2018 15th International Design Conference.
- Kagermann, H., Hellbig, J., Hellinger, A., & Wahlster, W. (2013). *Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0 Working Group*: Forschungsunion.

- Karadayi-Usta, S. (2020). An Interpretive Structural Analysis for Industry 4.0 Adoption Challenges. *IEEE Transactions on Engineering Management*, 67(3), 973-978. doi: <https://doi.org/10.1109/TEM.2018.2890443>
- Khalid, A., Kirisci, P., Ghrairi, Z., Thoben, K.-D., & Pannek, J. (2016). A methodology to develop collaborative robotic cyber physical systems for production environments. *Logistics Research*, 9(1), 23. doi: <https://doi.org/10.1007/s12159-016-0151-x>
- Koch, P. J., van Amstel, M. K., Dębska, P., Thormann, M. A., Tetzlaff, A. J., Bøgh, S., & Chrysostomou, D. (2017). A skill-based robot co-worker for industrial maintenance tasks. *Procedia Manufacturing*, 11, 83-90. doi: <https://doi.org/10.1016/j.promfg.2017.07.141>
- Kolberg, D., & Zühlke, D. (2015). Lean automation enabled by industry 4.0 technologies. *IFAC-PapersOnLine*, 48(3), 1870-1875. doi: <https://doi.org/10.1016/j.ifacol.2015.06.359>
- Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. *Business & information systems engineering*, 6(4), 239-242. doi: <https://doi.org/10.1007/s12599-014-0334-4>
- Lee, T. O., Kim, Y., & Kim, Y. K. (2001). Two-sided assembly line balancing to maximize work relatedness and slackness. *Computers & Industrial Engineering*, 40(3), 273-292. doi: [https://doi.org/10.1016/S0360-8352\(01\)00029-8](https://doi.org/10.1016/S0360-8352(01)00029-8)
- Leimeister, S., Böhm, M., Riedl, C., & Krcmar, H. (2010). The business perspective of cloud computing: actors, roles and value networks. *ECIS 2010 Proceedings*. 56. doi: <https://aisel.aisnet.org/ecis2010/56>
- Leitão, P., Geraldes, C. A. S., Fernandes, F. P., & Badikyan, H. (2020, 10-12 June 2020). *Analysis of the Workforce Skills for the Factories of the Future*. Paper presented at the 2020 IEEE Conference on Industrial Cyberphysical Systems (ICPS).
- Leyh, C., Martin, S., & Schäffer, T. (2017, 3-6 Sept. 2017). *Industry 4.0 and Lean Production — A matching relationship? An analysis of selected Industry 4.0 models*. Paper presented at the 2017 Federated Conference on Computer Science and Information Systems (FedCSIS).
- Li, X., Troutt, M. D., Brandyberry, A., & Wang, T. (2011). Decision factors for the adoption and continued use of online direct sales channels among SMEs. *Journal of the Association for Information Systems*, 12(1), 4. doi: <https://doi.org/10.17705/1jais.00255>
- Malik, A. A. (2019). Application guidelines for collaborative robots. *Syddansk Universitet*.
- Malik, A. A., & Bilberg, A. (2017). *Framework to implement collaborative robots in manual assembly: a lean automation approach*. Paper presented at the Proceedings of the 28th DAAAM International Symposium, B. Katalinic (Ed.), Published by DAAAM International, ISSN.
- Maroufkhani, P., Wan Ismail, W. K., & Ghobakhloo, M. (2020). Big data analytics adoption model for small and medium enterprises. *Journal of Science and Technology Policy Management*, 11(4), 483-513. doi: <https://doi.org/10.1108/JSTPM-02-2020-0018>
- Martins, R., Oliveira, T., & Thomas, M. A. (2016). An empirical analysis to assess the determinants of SaaS diffusion in firms. *Computers in Human Behavior*, 62, 19-33. doi: <https://doi.org/10.1016/j.chb.2016.03.049>
- Masood, T., & Egger, J. (2019). Augmented reality in support of Industry 4.0—Implementation challenges and success factors. *Robotics and Computer-Integrated Manufacturing*, 58, 181-195. doi: <https://doi.org/10.1016/j.rcim.2019.02.003>
- Mathauer, M., & Hofmann, E. (2019). Technology adoption by logistics service providers. *International Journal of Physical Distribution & Logistics Management*, 49(4), 416-434. doi: <https://doi.org/10.1108/IJPDLM-02-2019-0064>

- McKinnie, M. (2016). *Cloud computing: TOE adoption factors by service model in manufacturing*. (doctoral thesis). Georgia State University, Atlanta, Retrieved from http://scholarworks.gsu.edu/bus_admin_diss/68
- Müller, J. M. (2019). Assessing the barriers to Industry 4.0 implementation from a workers' perspective. *IFAC-PapersOnLine*, 52(13), 2189-2194. doi: <https://doi.org/10.1016/j.ifacol.2019.11.530>
- Nair, J., Chellasamy, A., & Singh, B. N. B. (2019). Readiness factors for information technology adoption in SMEs: testing an exploratory model in an Indian context. *Journal of Asia Business Studies*, 13(4), 694-718. doi: <https://doi.org/10.1108/JABS-09-2018-0254>
- Ngah, A. H., Zainuddin, Y., & Thurasamy, R. (2017). Applying the TOE framework in the Halal warehouse adoption study. *Journal of Islamic Accounting and Business Research*, 8(2), 161-181. doi: <https://doi.org/10.1108/JIABR-04-2014-0014>
- Nguyen Cong, T., Thai Thi Kim, O., Tran, D. T., Dinh Van, T., & Thai Van, H. (2020). INDUSTRY 4.0, LEAN MANAGEMENT AND ORGANIZATIONAL SUPPORT: A CASE OF SUPPLY CHAIN OPERATIONS. *Polish Journal of Management Studies*, 22(1), 583-594. doi: <https://dx.doi.org/10.17512/pjms.2020.22.1.37>
- Nguyen, X. T., & Luu, Q. K. (2020). Factors affecting adoption of industry 4.0 by small-and medium-sized enterprises: A case in Ho Chi Minh city, Vietnam. *The Journal of Asian Finance, Economics, and Business*, 7(6), 255-264. doi: <https://doi.org/10.13106/jafeb.2020.vol7.no6.255>
- Nwaiwu, F., Duduci, M., Chromjakova, F., & Otekhile, C.-A. F. (2020). Industry 4.0 concepts within the Czech SME manufacturing sector: an empirical assessment of critical success factors. *Business: Theory and Practice*, 21(1), 58-70. doi:<https://doi.org/10.3846/btp.2020.10712>
- Oettmeier, K., & Hofmann, E. (2017). Additive manufacturing technology adoption: an empirical analysis of general and supply chain-related determinants. *Journal of Business Economics*, 87(1), 97-124. doi: <https://doi.org/10.1007/s11573-016-0806-8>
- Olender, M., & Banas, W. (2019). COBOTS—FUTURE IN PRODUCTION. *International Journal of Modern Manufacturing Technologies*, XI(3), 103-109.
- Oliveira, T., & Martins, M. F. (2011). Literature review of information technology adoption models at firm level. *The Electronic Journal Information Systems Evaluation*, Vol. 14 No. 1, 110-121.
- Park, J.-H., & Kim, Y. B. (2021). Factors Activating Big Data Adoption by Korean Firms. *Journal of Computer Information Systems*, 61(3), 285-293. doi: <https://doi.org/10.1080/08874417.2019.1631133>
- Patuwo, B. E., & Hu, M. Y. (1998). The human factor in advanced manufacturing technology adoption : An empirical analysis. *International Journal of Operations & Production Management*, 18(1), 87-106. doi: <https://doi.org/10.1108/01443579810192925>
- Pazienza, A., Macchiarulo, N., Vitulano, F., Fiorentini, A., Cammisa, M., Rigutini, L., . . . Trevisi, A. (2019). *A Novel Integrated Industrial Approach with Cobots in the Age of Industry 4.0 through Conversational Interaction and Computer Vision*. Paper presented at the CLiC-it.
- Pfeiffer, S., Lee, H., & Held, M. (2019). Doing Industry 4.0: participatory design on the shop floor in the view of engineering employees. *Cuadernos de Relaciones Laborales*, 37(1), 293-311.
- Pollak, A., Paliga, M., Pulopulos, M. M., Kozusznik, B., & Kozusznik, M. W. (2020). Stress in manual and autonomous modes of collaboration with a cobot. *Computers in Human Behavior*, 112, 106469. doi: <https://doi.org/10.1016/j.chb.2020.106469>
- Puklavec, B., Oliveira, T., & Popovič, A. (2018). Understanding the determinants of business intelligence system adoption stages: An empirical study of SMEs. *Industrial*

- Management & Data Systems*, 118(1), 236-261. doi: <https://doi.org/10.1108/IMDS-05-2017-0170>
- Purwanto, A. (2021). Partial Least Squares Structural Equation Modeling (PLS-SEM) Analysis for Social and Management Research: A Literature Review. *Journal of Industrial Engineering & Management Research*, 2(4), 114-123. doi: <https://doi.org/10.7777/jiemar.v2i4>
- Qalati, S. A., Yuan, L. W., Khan, M. A. S., & Anwar, F. (2021). A mediated model on the adoption of social media and SMEs' performance in developing countries. *Technology in Society*, 64, 101513. doi: <https://doi.org/10.1016/j.techsoc.2020.101513>
- Quenehen, A., Pocachard, J., & Klement, N. (2019). Process optimisation using collaborative robots - comparative case study. *IFAC-PapersOnLine*, 52(13), 60-65. doi: <https://doi.org/10.1016/j.ifacol.2019.11.131>
- Ramamurthy, K., Sen, A., & Sinha, A. P. (2008). An empirical investigation of the key determinants of data warehouse adoption. *Decision Support Systems*, 44(4), 817-841. doi: <https://doi.org/10.1016/j.dss.2007.10.006>
- Ramanathan, R., Philpott, E., Duan, Y., & Cao, G. (2017). Adoption of business analytics and impact on performance: a qualitative study in retail. *Production Planning & Control*, 28(11-12), 985-998. doi:10.1080/09537287.2017.1336800
- Ranz, F., Komenda, T., Reisinger, G., Hold, P., Hummel, V., & Sihn, W. (2018). A morphology of human robot collaboration systems for industrial assembly. *Procedia CIRP*, 72, 99-104. doi: <https://doi.org/10.1016/j.procir.2018.03.011>
- Robots, U. (2020). COLLABORATIVE ROBOT APPLICATIONS Retrieved from <https://www.universal-robots.com/applications/>
- Rogers, E. M. (1995). *Diffusion of innovations*: Simon and Schuster.
- Rogers, E. M. (2010). *Diffusion of innovations*: Simon and Schuster.
- Romero, D., Stahre, J., Wuest, T., Noran, O., Bernus, P., Fast-Berglund, Å., & Gorecky, D. (2016). *Towards an operator 4.0 typology: a human-centric perspective on the fourth industrial revolution technologies*. Paper presented at the proceedings of the international conference on computers and industrial engineering (CIE46), Tianjin, China.
- Rossini, M., Costa, F., Staudacher, A. P., & Tortorella, G. (2019). Industry 4.0 and Lean Production: an empirical study. *IFAC-PapersOnLine*, 52(13), 42-47. doi: <https://doi.org/10.1016/j.ifacol.2019.11.122>
- Salunkhe, O., Stensöta, O., Åkerman, M., Berglund, Å. F., & Alveflo, P.-A. (2019). Assembly 4.0: Wheel Hub Nut Assembly Using a Cobot. *IFAC-PapersOnLine*, 52(13), 1632-1637. doi: <https://doi.org/10.1016/j.ifacol.2019.11.434>
- Sarstedt, M., Hair, J. F., Ringle, C. M., Thiele, K. O., & Gudergan, S. P. (2016). Estimation issues with PLS and CBSEM: Where the bias lies! *Journal of Business Research*, 69(10), 3998-4010. doi: <https://doi.org/10.1016/j.jbusres.2016.06.007>
- Schmidtler, J., & Bengler, K. (2015). Fast or accurate?—Performance measurements for physical human-robot collaborations. *Procedia Manufacturing*, 3, 1387-1394. doi: <https://doi.org/10.1016/j.promfg.2015.07.298>
- Scott, R. W. (1995). *The institutional construction of organizations: International and longitudinal studies*: SAGE Publications, Incorporated.
- Shahijan, M. K., Rezaei, S., & Amin, M. (2016). International students' course satisfaction and continuance behavioral intention in higher education setting: an empirical assessment in Malaysia. *Asia Pacific Education Review*, 17(1), 41-62. doi: <https://doi.org/10.1007/s12564-015-9410-9>
- Simões, A. C., Barros, A. C., & Soares, A. L. (2018). *Conceptual framework for the identification of influential contexts of the adoption decision*. Paper presented at the 2018 IEEE 16th International Conference on Industrial Informatics (INDIN).

- Simões, A. C., Lucas Soares, A., & Barros, A. C. (2020). Factors influencing the intention of managers to adopt collaborative robots (cobots) in manufacturing organizations. *Journal of Engineering and Technology Management*, 57, 101574. doi:<https://doi.org/10.1016/j.jengtecman.2020.101574>
- Simões, A. C., Oliveira, L., Rodrigues, J. C., Simas, O., Dalmarco, G., & Barros, A. C. (2019a). *Environmental factors influencing the adoption of digitalization technologies in automotive supply chains*. Paper presented at the 2019 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC).
- Simões, A. C., Soares, A. L., & Barros, A. C. (2019b). Drivers Impacting Cobots Adoption in Manufacturing Context: A Qualitative Study. In *Advances in Manufacturing II* (pp. 203-212): Springer.
- Simões, A. C., Soares, A. L., & Barros, A. C. (2020). Factors influencing the intention of managers to adopt collaborative robots (cobots) in manufacturing organizations. *Journal of Engineering and Technology Management*, 57, 101574.
- Sowa, K., Przegalinska, A., & Ciechanowski, L. (2021). Cobots in knowledge work: Human – AI collaboration in managerial professions. *Journal of Business Research*, 125, 135-142. doi:<https://doi.org/10.1016/j.jbusres.2020.11.038>
- Stock, T., Obenaus, M., Kunz, S., & Kohl, H. (2018). Industry 4.0 as enabler for a sustainable development: A qualitative assessment of its ecological and social potential. *Process Safety and Environmental Protection*, 118, 254-267. doi: <https://doi.org/10.1016/j.psep.2018.06.026>
- Subramaniam, S., Aggarwal, P., Dasgupta, G. B., & Paradkar, A. (2018). *Cobots-a cognitive multi-bot conversational framework for technical support*. Paper presented at the Proceedings of the 17th International Conference on Autonomous Agents and MultiAgent Systems.
- Technologies, I.-P. Lean Robotics. Retrieved from <https://iptech1.com/lean-robotics/>
- Thakur, L. S., & Jain, V. K. (2008). Advanced manufacturing techniques and information technology adoption in India: A current perspective and some comparisons. *The International Journal of Advanced Manufacturing Technology*, 36(5-6), 618. doi: <https://doi.org/10.1007/s00170-006-0852-4>
- Thomas, G. F., Zolin, R., & Hartman, J. L. (2009). The central role of communication in developing trust and its effect on employee involvement. *The Journal of Business Communication* (1973), 46(3), 287-310. doi: <https://doi.org/10.1177/0021943609333522>
- Tornatzky, L. G., Fleischer, M., & Chakrabarti, A. K. (1990). *Processes of technological innovation*: Lexington books.
- Tortorella, G., Miorando, R., Caiado, R., Nascimento, D., & Portioli Staudacher, A. (2021). The mediating effect of employees' involvement on the relationship between Industry 4.0 and operational performance improvement. *Total Quality Management & Business Excellence*, 32(1-2), 119-133. doi: <https://doi.org/10.1080/14783363.2018.1532789>
- Tortorella, G. L., & Fettermann, D. (2018). Implementation of Industry 4.0 and lean production in Brazilian manufacturing companies. *International Journal of Production Research*, 56(8), 2975-2987. doi: <https://doi.org/10.1080/00207543.2017.1391420>
- Tu, H.-M. (2020). Does active leisure participation promote psychological capital through peer support in economically disadvantaged children? *PLOS ONE*, 15(6), e0234143. doi: <https://doi.org/10.1371/journal.pone.0234143>
- Unger, H., Markert, T., & Müller, E. (2018). Evaluation of use cases of autonomous mobile robots in factory environments. *Procedia Manufacturing*, 17, 254-261. doi: <https://doi.org/10.1016/j.promfg.2018.10.044>

- Van den Berg, J., & Van der Lingen, E. (2019). An empirical study of the factors affecting the adoption of mobile enterprise applications. *South African Journal of Industrial Engineering*, 30(1), 124-146. doi: <https://doi.org/10.7166/30-1-1992>
- Venkatesh, V., & Bala, H. (2012). Adoption and Impacts of Interorganizational Business Process Standards: Role of Partnering Synergy. *Information Systems Research*, 23(4), 1131-1157. doi: <https://doi.org/10.1287/isre.1110.0404>
- Villani, V., Pini, F., Leali, F., & Secchi, C. (2018). Survey on human–robot collaboration in industrial settings: Safety, intuitive interfaces and applications. *Mechatronics*, 55, 248-266. doi: <https://doi.org/10.1016/j.mechatronics.2018.02.009>
- Vojić, S. (2020). Applications of collaborative industrial robots. *Machines. Technologies. Materials.*, 14(3), 96-99.
- Wamba, S. F., & Queiroz, M. M. (2020). Industry 4.0 and the supply chain digitalisation: a blockchain diffusion perspective. *Production Planning & Control*, 1-18. doi: <https://doi.org/10.1080/09537287.2020.1810756>
- Wang, L., Törngren, M., & Onori, M. (2015). Current status and advancement of cyber-physical systems in manufacturing. *Journal of Manufacturing Systems*, 37, 517-527. doi: <https://doi.org/10.1016/j.jmsy.2015.04.008>
- Wang, S., Wan, J., Li, D., & Zhang, C. (2016b). Implementing smart factory of industrie 4.0: an outlook. *International journal of distributed sensor networks*, 12(1), 3159805. doi: <https://doi.org/10.1155/2016/3159805>
- Wang, Y.-M., Wang, Y.-S., & Yang, Y.-F. (2010). Understanding the determinants of RFID adoption in the manufacturing industry. *Technological Forecasting and Social Change*, 77(5), 803-815. doi: <https://doi.org/10.1016/j.techfore.2010.03.006>
- Weckenborg, C., Kieckhäfer, K., Müller, C., Grunewald, M., & Spengler, T. S. (2020). Balancing of assembly lines with collaborative robots. *Business Research*, 13(1), 93-132. doi: <https://doi.org/10.1007/s40685-019-0101-y>
- Welikala And, D., & Sohal, A. S. (2008). Total Quality Management and employees' involvement: A case study of an Australian organisation. *Total Quality Management & Business Excellence*, 19(6), 627-642. doi: <https://doi.org/10.1080/14783360802024440>
- Weyer, S., Schmitt, M., Ohmer, M., & Gorecky, D. (2015). Towards Industry 4.0 - Standardization as the crucial challenge for highly modular, multi-vendor production systems. *IFAC-PapersOnLine*, 48(3), 579-584. doi: <https://doi.org/10.1016/j.ifacol.2015.06.143>
- Wiley, B. (2019). Effective Cobot Implementation Using 4 Principles of Lean Robotics. Retrieved from <https://www.wileymetal.com/effective-cobot-implementation-using-4-principles-of-lean-robotics/>
- Wong, L.-W., Leong, L.-Y., Hew, J.-J., Tan, G. W.-H., & Ooi, K.-B. (2020). Time to seize the digital evolution: Adoption of blockchain in operations and supply chain management among Malaysian SMEs. *International Journal of Information Management*, 52, 101997. doi: <https://doi.org/10.1016/j.ijinfomgt.2019.08.005>
- Yu, F., & Schweisfurth, T. (2020). Industry 4.0 technology implementation in SMEs – A survey in the Danish-German border region. *International Journal of Innovation Studies*, 4(3), 76-84. doi: <https://doi.org/10.1016/j.ijis.2020.05.001>
- Yunus, E. N. (2021). The mark of industry 4.0: how managers respond to key revolutionary changes. *International Journal of Productivity and Performance Management*, 70(5), 1213-1231. doi: <https://doi.org/10.1108/IJPPM-12-2019-0590>
- Zhu, K., Kraemer, K., & Xu, S. (2003). Electronic business adoption by European firms: a cross-country assessment of the facilitators and inhibitors. *European Journal of Information Systems*, 12(4), 251-268. doi: <https://doi.org/10.1057/palgrave.ejis.3000475>

Zhu, K., & Kraemer, K. L. (2005). Post-Adoption Variations in Usage and Value of E-Business by Organizations: Cross-Country Evidence from the Retail Industry. *Information Systems Research*, 16(1), 61-84. doi: <https://doi.org10.1287/isre.1050.0045>

Annex 1 - Survey

Identificação dos Fatores de Decisão Relevantes para a Adoção de Robôs Colaborativos em Empresas Industriais

Faculdade de Economia da Universidade do Porto

O presente estudo enquadra-se no âmbito de uma investigação em curso do Mestrado em Economia e Gestão da Inovação da Faculdade de Economia da Universidade do Porto e pretende identificar os fatores de decisão relevantes para os agentes, na intenção de adotar, ou na adoção, de robôs colaborativos em empresas industriais.

Se concordar participar ser-lhe-á pedido que responda a um questionário, maioritariamente constituído por perguntas de escolha múltipla, avaliadas numa escala de Likert (1 a 5) sobre os fatores de decisão. Poderá abandonar o preenchimento do questionário em qualquer momento.

O tempo estimado para responder a este questionário é de cerca de 8 minutos.

As suas respostas serão tratadas de forma anónima, confidencial e agregada. Os dados recolhidos neste questionário servem exclusivamente para fins de investigação.

Se tiver alguma dúvida ou queira esclarecer qualquer questão acerca deste estudo, pode contactar a equipa de investigação através do e-mail up200200062@g.uporto.pt

O esclarecimento de quaisquer dúvidas relacionadas com proteção de dados pode ser feito para o DPO da U.Porto através do e-mail dpo@reit.up.pt

Agradecemos o seu tempo e disponibilidade em participar neste estudo.

☐ Declaro que li as informações sobre o presente estudo, tomei conhecimento dos objetivos da investigação e aceito responder ao inquérito da forma mais sincera possível.

Robôs colaborativos ou Cobots, podem ser descritos como robôs que podem interagir com segurança com um trabalhador em diversas aplicações e sem quaisquer barreiras físicas ou virtuais.

1 - Conhece a tecnologia Cobots?

Sim ☐

Não* ☐

*No caso de a resposta ser negativa o questionário salta para a última secção com a mensagem de agradecimento e termina

2 - Se antecipa que a sua empresa adote Cobots no futuro, qual o horizonte temporal previsto para tal acontecer?

Não está nos planos adotar ☐

Mais do que 5 anos ☐

Entre 2 e 5 anos ☐

Entre 1 e 2 anos ☐

Em menos de 1 ano ☐

3 - A sua empresa está em que etapa no processo de adoção de Cobots?

- Não está nos planos da minha empresa adotar Cobots •
- Após avaliação não tencionamos adotar Cobots na minha empresa •
- A adoção de Cobots está em avaliação •
- Está a decorrer um piloto (teste) de Cobot(s) na minha empresa •
- Já temos Cobot(s) em pleno funcionamento na nossa empresa •

Com base no conceito de Cobot, expresse o seu grau de concordância com as afirmações abaixo numa escala de 1 (discordo totalmente), 2 (discordo parcialmente), 3 (indiferente), 4 (concordo parcialmente) e 5 (concordo totalmente).

4 - Os Cobots criam novas oportunidades ao nível do processo

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

5 - Os Cobots criam novas oportunidades ao nível do desenvolvimento do produto

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

6 - Os Cobots permitem melhorar a produtividade da minha empresa

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

7 – A adoção de Cobots contribui para melhorar a imagem da minha empresa como mais inovadora

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

8 – Os Cobots reduzem os custos da produção

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

9 – Os Cobots são fáceis de mover de local, ajustando-se facilmente a novos layouts do processo produtivo

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

10 – Os Cobots requerem pouca área/espço para serem instalados quando comparados com outros robôs tradicionais

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

11 – Os Cobots permitem realizar tarefas específicas rapidamente

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

12 – A fiabilidade no desempenho das tarefas por parte dos Cobots é um requisito para a sua adoção

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

13 – A possibilidade de rápida rotinização dos Cobots no processo produtivo é um requisito para a sua adoção

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

14 – Os Cobots permitem uma rápida adaptação à customização/personalização de ordens de fabrico

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

15 – A integração de Cobots no atual processo produtivo da minha empresa é fácil

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

16 – A utilização de Cobots satisfaz as necessidades da minha empresa

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

17 – A adoção de Cobots vai de encontro à cultura e princípios da minha empresa

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

18 – A utilização de Cobots não traz problemas de saúde e segurança para os operadores

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

19 – No geral, os Cobots são simples de usar

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

20 – Os Cobots requerem menos treino e competências especializadas por parte dos trabalhadores que os operam em comparação com os robôs tradicionais

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

21 – A gestão de topo da minha empresa reconhece as vantagens da adoção de Cobots

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

22 – A gestão de topo da minha empresa apoia a adoção de Cobots

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

23 – Os Cobots têm fortes apoiantes/adeptos na minha empresa

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

24 – A gestão de topo da minha empresa participa ativamente no estabelecimento da visão e formulação de estratégias de utilização de Cobots

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

25 – A gestão de topo da minha empresa inspira/motiva os trabalhadores a utilizarem Cobots no seu trabalho

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

26 – A minha empresa, como um todo, dispõe de um bom nível de conhecimento sobre Cobots

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

27 – Na minha empresa existe infraestrutura IT necessária para implementar Cobots

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

28 – A minha empresa recruta trabalhadores com competências tecnológicas avançadas

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

29 – A minha empresa possui os recursos financeiros suficientes para a adoção de Cobots

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

30 – Na minha empresa, os quadros técnicos têm a experiência e a informação necessária para a implementação de Cobots

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

31 – A minha empresa tem os recursos humanos necessários para a adoção de Cobots

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

32 – As inovações (incluindo as novas tecnologias) são prontamente aceites na minha empresa

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

33 – A gestão na minha empresa procura ativamente ideias inovadoras ao nível do processo

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

34 – A gestão na minha empresa procura ativamente ideias inovadoras ao nível do desenvolvimento do produto

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

35 – A minha empresa tem bom entendimento de como os Cobots podem ser utilizados no sector de atividade onde se insere

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

36 – Os trabalhadores que operam os Cobots e partilham o espaço de trabalho com eles foram/estão/serão envolvidos no processo de decisão de adoção

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

37 – Os trabalhadores que operam/irão operar com Cobots e partilham o espaço de trabalho com eles sentem-se seguros e confiam na tecnologia

•	•	•	•	•
---	---	---	---	---

1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

38 – Os trabalhadores são competentes na utilização de novas tecnologias

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

39 – Os trabalhadores têm necessidade de qualificações adicionais para trabalhar com Cobots

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

40 – Caso a minha empresa não adote Cobots estará em desvantagem face aos meus concorrentes

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

41 – A minha empresa poderá perder clientes caso não adote Cobots

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

42 – Os recursos financeiros para o investimento e a adoção de Cobots são fáceis de obter

•	•	•	•	•
---	---	---	---	---

1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

43 – O Governo incentiva a adoção de Cobots

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

44 – As medidas regulamentares de utilização de Cobots são adequadas

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

45 – A região onde está instalada a minha empresa tem a infraestrutura tecnológica, particularmente de rede de dados necessária que permite a implementação de Cobots

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

46 – Os fornecedores de Cobots providenciam uma valiosa assistência durante o processo de adoção

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

47 – A minha empresa pode testar a utilização de Cobots antes de tomar a decisão de os adoptar

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

48 – A minha empresa recolhe informações sobre Cobots com a intenção de os implementar

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

49 – A minha empresa tenciona utilizar Cobots

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

50 – Planeio recomendar a adoção de Cobots a outras empresas

•	•	•	•	•
1	2	3	4	5
Discordo Totalmente	Discordo Parcialmente	Indiferente	Concordo Parcialmente	Concordo Totalmente

51 – Idade?

Idade ____

52 – Com qual dos géneros se identifica?

Feminino •

Masculino •

Prefiro não dizer •

Outro •

53 – Formação?

Ensino Básico •

Ensino Secundário •

Licenciatura •

Mestrado •

Doutoramento •

Outro •

54 – Área de Formação?

Economia / Gestão •

Engenharia •

Ciências •

Outra (qual?) •

55 – Função?

Membro do Conselho de Administração / Gerente •

CEO / CIO / Diretor Geral •

Responsável de Departamento / Área / Secção •

Outra •

56 - Número de anos na função atual?

Número de anos na função atual _____

57 – Sector de Atividade com base no CAE

10 - Indústrias alimentares •

11 - Indústria das bebidas •

12 - Indústria do tabaco •

13 - Fabricação de têxteis •

- 14 - Indústria do vestuário •
- 15 - Indústria do couro e dos produtos do couro •
- 16 - Indústrias da madeira e da cortiça e suas obras, excepto mobiliário; fabricação de obras de cestaria e de espartaria •
- 17 - Fabricação de pasta, de papel, cartão e seus artigos
- 18 - Impressão e reprodução de suportes gravados •
- 19 - Fabricação de coque, de produtos petrolíferos refinados e de aglomerados de combustíveis

- 20 - Fabricação de produtos químicos e de fibras sintéticas ou artificiais, excepto produtos farmacêuticos •
- 21 - Fabricação de produtos farmacêuticos de base e de preparações farmacêuticas •
- 22 - Fabricação de artigos de borracha e de matérias plásticas •
- 23 - Fabricação de outros produtos minerais não metálicos
- 24 - Indústrias metalúrgicas de base •
- 25 - Fabricação de produtos metálicos, excepto máquinas e equipamentos •
- 26 - Fabricação de equipamentos informáticos, equipamentos para comunicações e produtos eletrónicos e ópticos •
- 27 - Fabricação de equipamento elétrico
- 28 - Fabricação de máquinas e equipamentos, n.e.
- 29 - Fabricação de veículos automóveis, reboques, semirreboques e componentes para veículos automóveis •
- 30 - fabricação de outro equipamento de transporte •
- 31 - Fabricação de mobiliário e de colchões
- 32 - Outras indústrias transformadoras
- 33 - Reparação, manutenção e instalação de máquinas e equipamentos •

58 – Classificação da sua empresa quanto ao número de trabalhadores

•	•	•	•
Micro	Pequena	Média	Grande
<= 10	11 - 50	51-250	>250

59 – Indique em que faixa etária se situa a idade média dos trabalhadores que operam/poderão vir a operar com os Cobots na sua empresa

•	•	•	•	•	•
< 25	26 - 35	36 – 45	46 – 55	56 – 65	>65

60 – Volume de Negócios no ano de 2020?

- Micro - Menor ou igual a 2 milhões de euros •
- Pequena - Menor ou igual a 10 milhões de euros •

Média - Menor ou igual a 50 milhões de euros •

Grande - Mais de 50 milhões de euros •

61 - Nível de Flexibilidade ao nível do produto ?

Produto único sem variantes •

Produto único com variantes •

Vários produtos sem variantes •

Vários produtos com variantes •

62 – Tipo de Processo produtivo?

Produção Única (por projeto)	☐
Produção por pequenos lotes	☐
Produção por lotes	☐
Produção em massa	☐

63 – Posição da empresa na cadeia de abastecimento?

Fornecedor de matérias-primas ☐

Fornecedor de componentes ☐

OEM/ Produção (ou montagem) do produto final ☐

Distribuidor/retalhista ☐

Mensagem final:

Muito obrigado pela sua participação.

No caso de desejar receber o sumário com os resultados desta investigação indique por favor o seu email na caixa abaixo.

--

Annex 2 - Brazilian Survey on SurveyMonkey

Em um estudo científico cooperativo, estabelecido entre a Fundação Dom Cabral (FDC), Universidade Federal de Minas Gerais (UFMG) e pesquisadores da Universidade do Porto (Portugal), esta pesquisa tem como objetivo identificar os fatores de decisão relevantes para adoção de robôs colaborativos em empresas industriais.

Se concordar participar ser-lhe-á pedido que responda a um questionário, maioritariamente constituído por perguntas de escolha múltipla, avaliadas numa escala de Likert (1 a 5) sobre os fatores de decisão. Poderá abandonar o preenchimento do questionário em qualquer momento.

O tempo estimado para responder a este questionário é de cerca de 5 minutos.

As suas respostas serão tratadas de forma anónima, confidencial e agregada. Os dados recolhidos neste questionário servem exclusivamente para fins de investigação.

Se tiver alguma dúvida ou queira esclarecer qualquer questão acerca deste estudo, pode contactar paulorenato@fdc.org.br

Agradecemos o seu tempo e disponibilidade em participar neste estudo.

1. Declaro que li as informações sobre o presente estudo, tomei conhecimento dos objetivos da investigação e aceito responder ao inquérito da forma mais sincera possível.

- ☐ Sim
☐ Não

2. Robôs colaborativos ou Cobots, podem ser descritos como robôs que podem interagir com segurança com um trabalhador em diversas aplicações e sem quaisquer barreiras físicas ou virtuais.

Conhece a tecnologia Cobots?

- ☐ Sim
☐ Não

3. A minha pretende adotar Cobots no futuro, qual o tempo previsto para acontecer?

- ☐ Em menos de 1 ano
- ☐ Entre 1 e 2 anos
- ☐ Entre 2 e 5 anos
- ☐ Mais do que 5 anos
- ☐ Não está nos planos adotar

4. A minha empresa está em qual etapa no processo de adoção de Cobots?

- ☐ Não está nos planos da minha empresa adotar Cobots
- ☐ A adoção de Cobots está em avaliação
- ☐ Está a decorrer um piloto (teste) de Cobot(s) na minha empresa
- ☐ Já temos Cobot(s) em pleno funcionamento na nossa empresa
- ☐ Após avaliação não pretendemos adotar Cobots na minha empresa

5. Com base no conceito de Cobot, expresse o seu grau de concordância com as afirmações abaixo numa escala de 1 (discordo totalmente), 2 (discordo parcialmente), 3 (indiferente), 4 (concordo parcialmente) e 5 (concordo totalmente).

	1 (Discordo totalmente)	2 (Discordo)	3 (Não concordo nem discordo)	4 (Concordo em parte)	5 (Concordo totalmente)
4 - Os Cobots criam novas oportunidades ao nível do processo	☐	☐	☐	☐	☐
5 - Os Cobots criam novas oportunidades ao nível do desenvolvimento do produto	☐	☐	☐	☐	☐
6 - Os Cobots permitem melhorar a produtividade da minha empresa	☐	☐	☐	☐	☐
7 - A adoção de Cobots contribui para melhorar a imagem da minha empresa como mais inovadora	☐	☐	☐	☐	☐
8 - Os Cobots reduzem os custos da produção	☐	☐	☐	☐	☐
9 - Os Cobots são fáceis de mover de local, ajustando-se facilmente a novos layouts do processo produtivo	☐	☐	☐	☐	☐
10 - Os Cobots requerem pouca área/espço para serem instalados quando comparados com outros robôs tradicionais	☐	☐	☐	☐	☐
11 - Os Cobots permitem realizar tarefas específicas rapidamente	☐	☐	☐	☐	☐
12 - A confiabilidade no desempenho das tarefas por parte dos Cobots é um requisito para a sua adoção	☐	☐	☐	☐	☐
13 - A possibilidade de rápida rotinização dos Cobots no processo produtivo é um requisito para a sua adoção	☐	☐	☐	☐	☐
14 - Os Cobots permitem uma rápida adaptação à customização/personalização de ordens de fabricação	☐	☐	☐	☐	☐

	1 (Discordo totalmente)	2 (Discordo)	3 (Não concordo nem discordo)	4 (Concordo em parte)	5 (Concordo totalmente)
15 – A integração de Cobots no atual processo produtivo da minha empresa é fácil	☐	☐	☐	☐	☐
16 – A utilização de Cobots satisfaz as necessidades da minha empresa	☐	☐	☐	☐	☐
17 – A adoção de Cobots vai de encontro à cultura e princípios da minha empresa	☐	☐	☐	☐	☐
18 – A utilização de Cobots não traz problemas de saúde e segurança para os operadores	☐	☐	☐	☐	☐
19 – No geral, os Cobots são simples de usar	☐	☐	☐	☐	☐
20 – Os Cobots requerem menos treino e competências especializadas por parte dos operadores que o usam em comparação com os robôs tradicionais	☐	☐	☐	☐	☐
21 – A alta gestão da minha empresa reconhece as vantagens da adoção de Cobots	☐	☐	☐	☐	☐
22 – A alta administração da minha empresa apóia a adoção de Cobots	☐	☐	☐	☐	☐
23 – Os Cobots têm fortes apoiadores/adeptos na minha empresa	☐	☐	☐	☐	☐
24 – A alta gestão da minha empresa participa ativamente no estabelecimento da visão e formulação de estratégias de utilização de Cobots	☐	☐	☐	☐	☐
25 – A alta gestão da minha empresa inspira/motiva os trabalhadores a utilizarem Cobots no seu trabalho	☐	☐	☐	☐	☐
26 – A minha empresa, como um todo, dispõe de um bom nível de conhecimento sobre Cobots	☐	☐	☐	☐	☐

	1 (Discordo totalmente)	2 (Discordo)	3 (Não concordo nem discordo)	4 (Concordo em parte)	5 (Concordo totalmente)
27 – Na minha empresa existe infraestrutura TI necessária para implementar Cobots	☐	☐	☐	☐	☐
28 – A minha empresa recruta trabalhadores com competências tecnológicas avançadas	☐	☐	☐	☐	☐
29 – A minha empresa possui os recursos financeiros suficientes para a adoção de Cobots	☐	☐	☐	☐	☐
31 – A minha empresa tem os recursos humanos necessários para a adoção de Cobots	☐	☐	☐	☐	☐
32 – As inovações (incluindo as novas tecnologias) são prontamente aceitas na minha empresa	☐	☐	☐	☐	☐
33 – A gestão na minha empresa procura ativamente ideias inovadoras ao nível do processo	☐	☐	☐	☐	☐
34 – A gestão na minha empresa procura ativamente ideias inovadoras ao nível do desenvolvimento do produto	☐	☐	☐	☐	☐
35 – A minha empresa tem bom entendimento de como os Cobots podem ser utilizados no setor de atividade onde se insere	☐	☐	☐	☐	☐
36 – Os trabalhadores que operam os Cobots e partilham o espaço de trabalho com eles foram/estão/serão envolvidos no processo de decisão de adoção	☐	☐	☐	☐	☐
37 – Os trabalhadores que operam/irão operar com Cobots e partilham o espaço de trabalho com eles sentem-se seguros e confiam na tecnologia	☐	☐	☐	☐	☐

	1 (Discordo totalmente)	2 (Discordo)	3 (Não concordo nem discordo)	4 (Concordo em parte)	5 (Concordo totalmente)
38 – Os trabalhadores são competentes na utilização de novas tecnologias	☐	☐	☐	☐	☐
39 – Os trabalhadores têm necessidade de qualificações adicionais para trabalhar com Cobots	☐	☐	☐	☐	☐
40 – Caso a minha empresa não adote Cobots estará em desvantagem face aos meus concorrentes	☐	☐	☐	☐	☐
41 – A minha empresa poderá perder clientes caso não adote Cobots	☐	☐	☐	☐	☐
42 – Os recursos financeiros para o investimento e a adoção de Cobots são fáceis de obter	☐	☐	☐	☐	☐
43 – O Governo incentiva a adoção de Cobots	☐	☐	☐	☐	☐
44 – As medidas regulamentares de utilização de Cobots são adequadas	☐	☐	☐	☐	☐
45 – A região onde está instalada a minha empresa tem a infraestrutura tecnológica, particularmente de rede de dados necessária que permite a implementação de Cobots	☐	☐	☐	☐	☐
46 – Os fornecedores de Cobots providenciam uma valiosa assistência durante o processo de adoção	☐	☐	☐	☐	☐
47 – A minha empresa pode testar a utilização de Cobots antes de tomar a decisão de os adotar	☐	☐	☐	☐	☐
48 – A minha empresa recolhe informações sobre Cobots com a intenção de implementar	☐	☐	☐	☐	☐
49 – A minha empresa pretende utilizar Cobots	☐	☐	☐	☐	☐
50 – Planejo recomendar a adoção de Cobots a outras empresas	☐	☐	☐	☐	☐

Perfil

6. Idade?

7. Com qual dos gêneros se identifica?

- ☐ Masculino
- ☐ Feminino
- ☐ Prefiro não dizer
- ☐ Outro

8. Formação?

- ☐ Ensino Básico
- ☐ Ensino Secundário
- ☐ Superior
- ☐ Outro
- ☐ Mestrado
- ☐ Doutoramento

9. Área de formação

- ☐ Economia / Gestão
- ☐ Engenharia
- ☐ Ciências
- ☐ Outro (qual?)

10. Função?

- ☐ Membro do Conselho de Administração / Gerente
- ☐ CEO / CIO / Diretor Geral
- ☐ Responsável de Departamento / Área / Secção
- ☐ Outra

11. Número de anos na função atual?

12. Sector de Atividade com base no CAE

- | | |
|---|---|
| ☐ 10 - Indústrias alimentares | ☐ 22 - Fabricação de artigos de borracha e de matérias plásticas |
| ☐ 11 - Indústria das bebidas | ☐ 23 - Fabricação de outros produtos minerais não metálicos |
| ☐ 12 - Indústria do tabaco | ☐ 24 - Indústrias metalúrgicas de base |
| ☐ 13 - Fabricação de têxteis | ☐ 25 - Fabricação de produtos metálicos, excepto máquinas e equipamentos |
| ☐ 14 - Indústria do vestuário | ☐ 26 - Fabricação de equipamentos informáticos, equipamentos para comunicações e produtos eletrónicos e ópticos |
| ☐ 15 - Indústria do couro e dos produtos do couro | ☐ 27 - Fabricação de equipamento elétrico |
| ☐ 16 - Indústrias da madeira e da cortiça e suas obras, excepto mobiliário; fabricação de obras de cestaria e de espartaria | ☐ 28 - Fabricação de máquinas e equipamentos, n.e. |
| ☐ 17 - Fabricação de pasta, de papel, cartão e seus artigos | ☐ 29 - Fabricação de veículos automóveis, reboques, semirreboques e componentes para veículos automóveis |
| ☐ 18 - Impressão e reprodução de suportes gravados | ☐ 30 - fabricação de outro equipamento de transporte |
| ☐ 19 - Fabricação de coque, de produtos petrolíferos refinados e de aglomerados de combustíveis | ☐ 31 - Fabricação de mobiliário e de colchões |
| ☐ 20 - Fabricação de produtos químicos e de fibras sintéticas ou artificiais, excepto produtos farmacêuticos | ☐ 32 - Outras indústrias transformadoras |
| ☐ 21 - Fabricação de produtos farmacêuticos de base e de preparações farmacêuticas | ☐ 33 - Reparação, manutenção e instalação de máquinas e equipamentos |

13. Classificação da sua empresa quanto ao número de trabalhadores

- ☐ Micro <=10
- ☐ Pequena 11-50
- ☐ Média 51-250
- ☐ Grande >250

14. Indique em que faixa etária se situa a idade média dos trabalhadores que operam/poderão vir a operar com os Cobots na sua empresa

- | | |
|-----------------------------|-----------------------------|
| ☐ <25 | ☐ 46-55 |
| ☐ 26-35 | ☐ 56-65 |
| ☐ 36-45 | ☐ >65 |

15. Volume de Negócios no ano de 2020?

- ☐ Micro - Menor ou igual a 12 milhões
- ☐ Pequena - Menor ou igual a 60 milhões
- ☐ Média - Menor ou igual a 300 milhões
- ☐ Grande - Mais de 300 milhões

16. Nível de Flexibilidade ao nível do produto ?

- ☐ Produto único sem variantes
- ☐ Produto único com variantes
- ☐ Vários produtos sem variantes
- ☐ Vários produtos com variantes

17. Tipo de Processo produtivo?

- ☐ Produção Única (por projeto)
- ☐ Produção por pequenos lotes
- ☐ Produção por lotes

18. Posição da empresa na cadeia de abastecimento?

- ☐ Fornecedor de matérias-primas
- ☐ Fornecedor de componentes
- ☐ OEM/ Produção (ou montagem) do produto final
- ☐ Distribuidor/retalhista

Annex 3 - 1st Email

Assunto: Estudo Robôs Colaborativos | FEP · INESC TEC · Fundação D. Cabral

Exmos(as) Senhores(as),

Vimos pedir a sua participação numa investigação em curso do Mestrado em Economia e Gestão da Inovação da FEP em colaboração com o INESC TEC e a Fundação D. Cabral (9.ª Melhor Escola De Negócios Do Mundo Pelo Ranking do Financial Times). Este estudo pretende identificar os fatores de decisão relevantes na intenção de adotar, ou na adoção, de robôs colaborativos em empresas industriais sediadas em Portugal e no Brasil.

Pedimos-lhe então, o favor de preencher o questionário abaixo, maioritariamente constituído por perguntas de escolha múltipla, o qual demora cerca de 8 minutos a ser preenchido.

https://docs.google.com/forms/d/e/1FAIpQLSeCNZZRbGZwUHpuKhwCb8B9sib_SmJBTFw2O-lk1I-KHLmWmA/viewform?usp=sf_link

Agradecemos, desde já, a sua disponibilidade e participação neste estudo, a qual garantirá o seu sucesso.

Com os melhores cumprimentos,

Guilherme Couto (FEP), Ana Simões (INESC TEC), Paulo Sousa (FEP), Rosário Moreira (FEP & INESC TEC), Paulo Renato de Sousa (Fundação D. Cabral), Noel Torres Júnior (Universidade Federal de Minas Gerais) e Marcelo Bronzo (Universidade Federal de Minas Gerais)

Annex 4 – 2nd Email

Assunto: Estudo Robôs Colaborativos | FEP · INESC TEC · Fundação D. Cabral

Exmos(as) Senhores(as),

Reiteramos o pedido da sua participação numa investigação em curso do Mestrado em Economia e Gestão da Inovação da FEP em colaboração com o INESC TEC e a Fundação D. Cabral (9.^a Melhor Escola De Negócios Do Mundo Pelo Ranking do Financial Times). Este estudo pretende identificar os fatores de decisão relevantes na intenção de adotar, ou na adoção, de robôs colaborativos em empresas industriais sediadas em Portugal e no Brasil.

Pedimos-lhe então, o favor de preencher o questionário abaixo, maioritariamente constituído por perguntas de escolha múltipla, o qual demora cerca de 8 minutos a ser preenchido.

https://docs.google.com/forms/d/e/1FAIpQLSeCNZZRbGZwUHpuKhwCb8B9sib_SmJBTFw2O-lk1I-KHLmWmA/viewform?usp=sf_link

A todos os que já colaboraram e preencheram o questionário, o nosso muito obrigado.

Agradecemos, desde já, a sua atenção e disponibilidade, as quais garantirão o sucesso da investigação.

Com os melhores cumprimentos,

Guilherme Couto (FEP), Ana Simões (INESC TEC), Paulo Sousa (FEP), Rosário Moreira (FEP & INESC TEC), Paulo Renato de Sousa (Fundação D. Cabral), Noel Torres Júnior (Universidade Federal de Minas Gerais) e Marcelo Bronzo (Universidade Federal de Minas Gerais)

Annex 5 – Sample Demographic

Question	BR	PT
51	44,54296	44,884615

Table: Average Age

Question	Gender	BR	%	PT	%
52	Female	17	5,84%	13	16,67%
	Male	274	94,16%	65	83,33%
	Prefer not to say	0	0,00%	0	0,00%
	Other	0	0,00%	0	0,00%

Table: Gender distribution

Question	Education	BR	%	PT	%
53	Primary School	0	0,00%	0	0,00%
	High School	0	0,00%	9	11,54%
	College	276	94,85%	43	55,13%
	Master	11	3,78%	22	28,21%
	Ph.D.	0	0,00%	0	0,00%
	Other	4	1,37%	4	5,13%

Table: Education level

Question	Field of expertise	BR	%	PT	%
54	Economics	189	64,95%	23	29,49%
	Engineering	93	31,96%	44	56,41%
	Science	4	1,37%	2	2,56%
	Other	5	1,72%	9	11,54%

Table: Field of expertise

Question	Function in company	BR	%	PT	%
55	Member of the Board / Manger	233	64,95%	24	30,77%
	CEO / CIO / Director	22	31,96%	22	28,21%
	Department / Officer	35	1,37%	26	33,33%
	Other	1	1,72%	6	7,69%

Table: Function in company

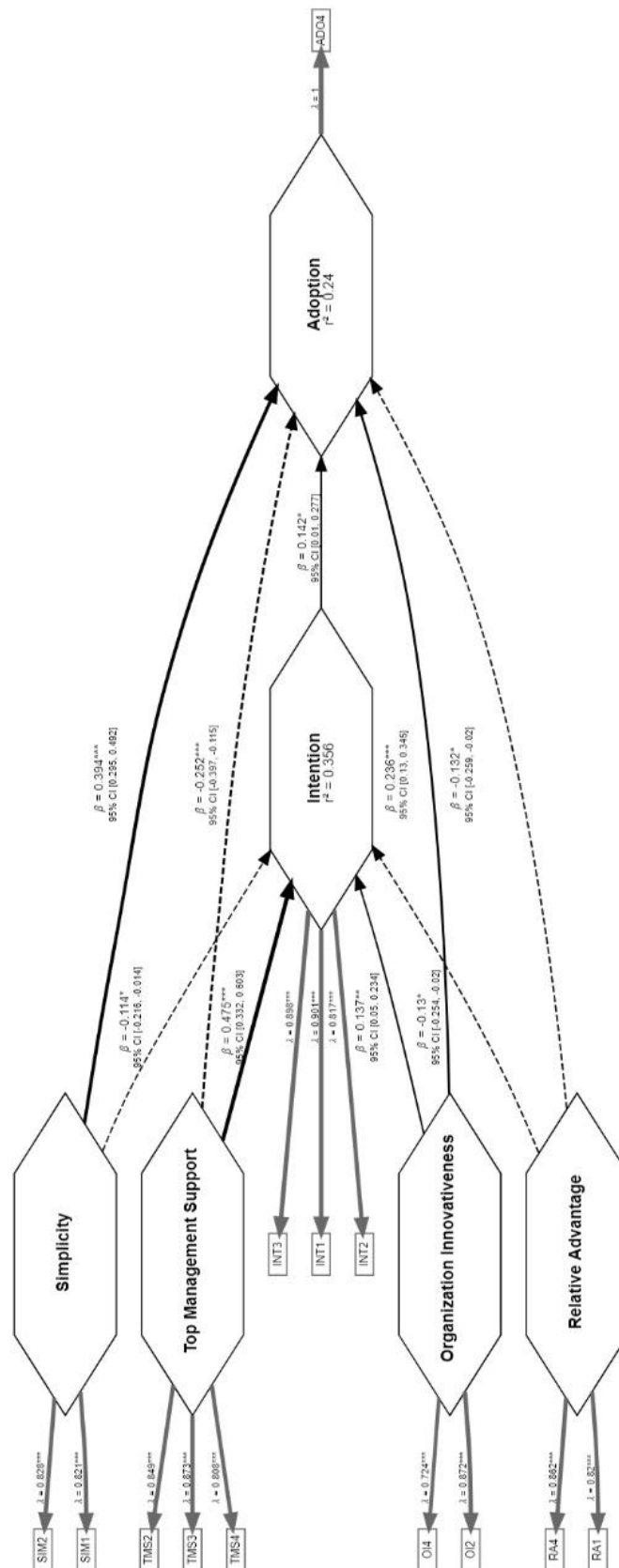
Question	BR	PT
56	10	13

Table: Average Tenure in position

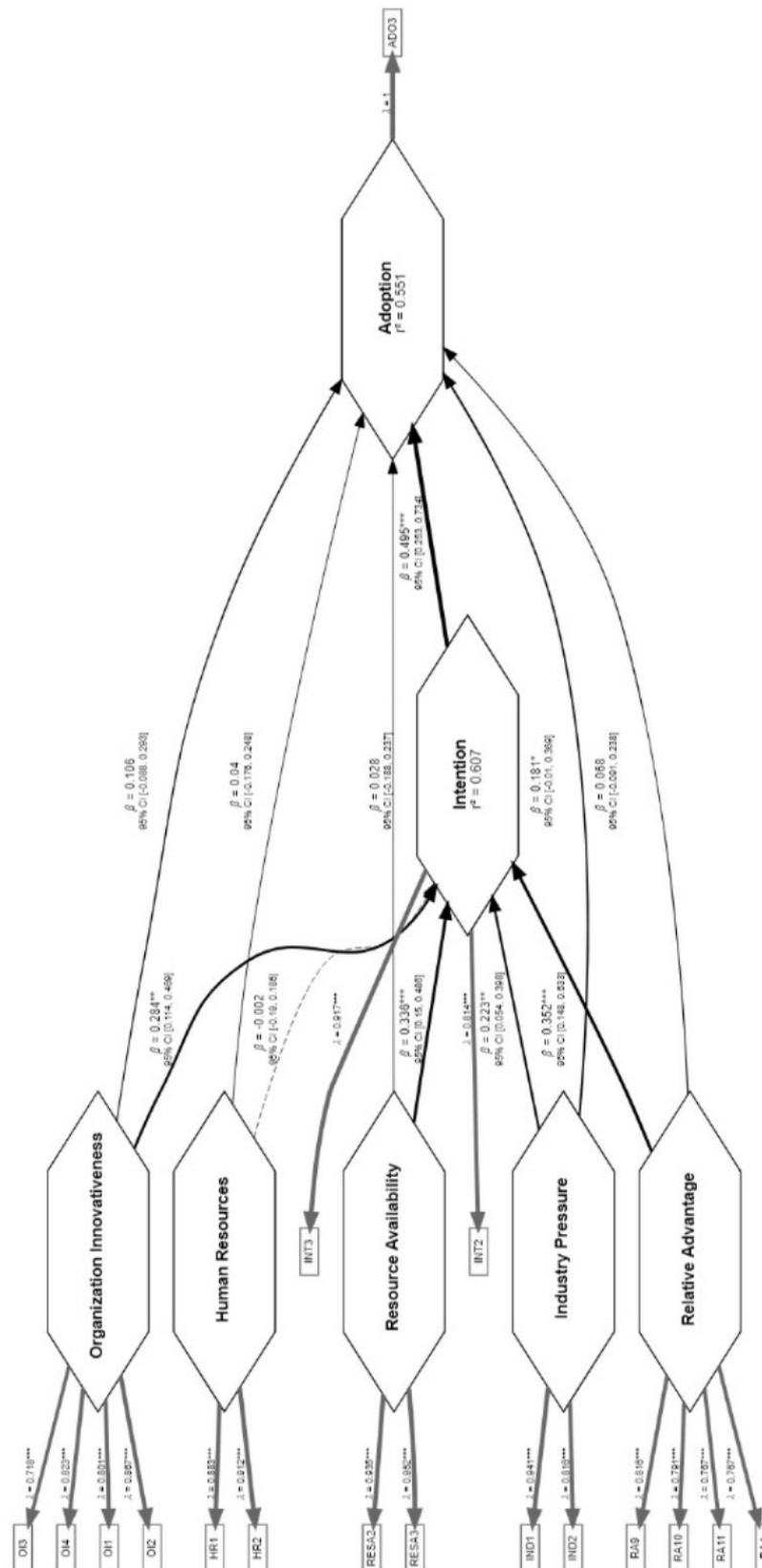
Question	Workers Average Age	BR	%	PT	%
59	<25	1	0,34%	1	1,28%
	26-35	126	43,30%	18	23,08%
	36-45	29	9,97%	49	62,82%
	46-55	135	46,39%	8	10,26%
	56-65	0	0,00%	1	1,28%
	>65	0	0,00%	1	1,28%

Table: Companies Workers Average Age

Annex 6 – Final Model BR



Annex 7 – Final Model PT



FACULDADE DE ECONOMIA

