Best Regional Practices for Digital Transformation in Industry: The Case of the Industry 4.0 Program in Portugal

Luciana Peixoto Santa Rita, Joaquim Ramos Silva, and Reynaldo Rubem Ferreira Junior

Abstract The Portuguese government, through its program for Industry 4.0, Portugal I4.0, has been supporting projects aimed at the digital transformation of the economy by mobilizing European funds and governmental subsidies from the Portugal 2020 Program. The objective of this study is to analyze the best regional practices for digital transformation in the industry 4.0 in this context. The following research questions arise: which are the best practices for digital transformation in Portugal under this Program and what was the impact on the competitiveness of Portuguese industries after the implementation of these technologies through the Incentive Value from 2017 to 2019? The methodological approach is correlational, and it establishes a relationship between the I4.0 Incentive Value and Competitiveness in order to identify the best regional practices for digital trans-formation in the Portuguese industry. The hypothesis of this study is accepted for the period 2017–2019, since the factors that make up the industry 4.0—European Fund—Incentive Value dimension are associated to the degree of competitive-ness, which was measured by a set of related variables. Further studies are necessary for longer periods and with a broader scope, the result shows the relevance of the Program.

Keywords Digital transformation · Regional practices · Industry 4.0

L. P. S. Rita (✉) · R. R. F. Junior
Federal University of Alagoas, Campus, AC Simões, Alagoas 57.000-000, Brazil
e-mail: luciana.santarita@feac.ufal.br

R. R. F. Junior
e-mail: reynaldo.junior@feac.ufal.br

J. R. Silva
University of Lisboa, Rua Miguel Lúpi 20, 1279-048 Lisboa, Portugal
e-mail: jrsilva@iseg.ulisboa.pt

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1 Introduction

According to market logic, the convergence between manufacturing and the basic technologies of Industry 4.0 (I4.0) makes it increasingly essential for companies to formulate innovation strategies to strengthen their technological capabilities. Also, digital transformation changes industrial processes and procedures, as well as changes the relative positions of key actors in the value chain and intellectual property regimes. In this shifting landscape, [1, 9, 38, 40, 41] agree on the distinction of three sectors in which industry 4.0 stands: (1) core technologies (hardware, software, connectivity); (2) basic technologies (analytical, security, artificial intelligence, electrical, 3D systems); and (3) application technologies (home, personal, company, manufacturing industry, infrastructure, vehicles, etc.). In view of this distinction, it should be noted that Industry 4.0 is a peculiar concept to the Fourth Industrial Revolution (4IR), which accompanies digital transformation, automation and data exchange in technologies including the internet of things (IoT); big data; 3D printing (additive manufacturing); cloud computing; autonomous robots; augmented virtual reality; industrial internet of things (IIoT); cyber-physical systems; block-chain; artificial intelligence; intelligent sensors; smart logistics; drones; simulation and digital twins; smart factory; nano-technology; biotechnology, among others [2, 4, 6, 10, 14, 17, 18, 24, 26, 27].

Since the technological evolution leads to the convergence between the components and the knowledge of new technologies [29, 30], the I4.0 allows the management of industries that manufacture products with greater complexity, but also with flexibility. Thus, the 4IR, through the digitalization and interconnection of all objects (projects, parts, machines, devices, etc.) implies a significant improvement in the manufacturing systems. In contrast with previous industrial revolutions, I4.0 is based on the creation of networks and interconnectivity between existing assets and technologies, therefore not limiting itself to the replacement of existing assets and technologies, and mainly using Information and Communication Technologies (ICT). After the implementation of the I4.0 concept in Germany, other countries have also progressed in the use of their inherent technologies, and in this context patent rights must be emphasized insofar they are crucial for companies because of their exclusive nature, corresponding to rights of their owner To address the above-mentioned challenges, this paper puts forward the following research objective: to analyze the best regional practices for digital transformation focusing on the case of Industry 4.0 Program in Portugal, from where two research questions arise: which are the best regional practices for digital transformation in the Industry 4.0 Program of Portugal, and what was the impact on the competitiveness of Portuguese industries after the implementation of the industry 4.0 technology-enabling projects through the Incentive Value from 2017 to 2019.

Therefore, based on the Portuguese case, and starting from the questions that were just raised, this research contributes to deepen the study of I4.0 in the domain of the best regional practices for digital transformation in a theoretical, methodological and empirical way. From the theoretical point of view, there is an analysis that allows inserting the digital transformation in the context of the industrial structure. From a methodological point of view, the study contributes applying a comparative analysis to the literature on the relationship between digital transformation and the technological conditions from the I4.0 perspective. In empirical terms, the study focuses on how the digital transformation in industry can configure a prerequisite for the competitiveness of industries in the country. These results are the first step to create a digital platform that delivers a comprehensive assessment of digital transformation over time.

The structure of the article is organized as follows. Section 1 covers a brief introduction to the core issues. Section 2 presents the conceptual framework and develops the analytical structure of our approach. In Sect. 3 the methodology that was followed is described. Section 4 shows the results that were obtained in the empirical research. In Sect. 5 the main results are discussed. The paper closes stating the main conclusions, the study limitations, and offering clues for further research.

2 Background

2.1 Industry 4.0

The literature has investigated many aspects of 4IR, both in the field of applications and in the academy [18, 33, 34]. The I4.0 has been considered a new industrial stage in which several emerging technologies converge to provide digital solutions. For the purpose of this paper, it must be considered that the inventions of 4IR can be classified in three big categories, each of which is subdivided into several technological domains: (i) Main technologies (hardware, software and connectivity) that allow transforming any object into an intelligent device connected through the Internet; (ii) Enabling technologies (big data, artificial intelligence, 3D systems, human–machine interaction) that are used in combination with linked objects; (iii) Application technologies (home, personal, company, transformation industry, infrastructure, vehicles) in which the potential of linked objects can be explored [35, 36].

Under this approach, [38, 39] use a more restricted definition, where I4.0 is connected to intelligent manufactures in which new and distinct technologies change the organization of value chains. The scope is the "digitalization" of production that integrates with the new ICT. This conception of I4.0 has reflected a strong will by national governments to promote reindustrialization, being smart industry its central element [38, 40]. Naturally, smart industry requires wide availability and integration of the factory with the entire product life cycle and production chain activities [7, 16], including changes in the way people work. In fact, the smart industry depends on the adoption of digital technologies to collect real-time data and analyze it, providing useful information to the manufacturing system [42].

2.2 Governmental Subsidies

Moreover, the literature often suggests that I4.0 will expand the opportunities for many regions, create new regional leaders combined with the potential to shift the geography of knowledge production in various directions. This is, in any case, one of the aspects to be analyzed in the present study. On the one hand, there is a focus on management among the different research advances referring to I4.0 [5, 8]. In addition, research is progressing on specific technologies and industry-focused issues [12]. However, little emphasis has been placed on the role of governmental subsidies when executing I4.0 projects and the impact of these technologies on business performance [16].

On the other hand, several empirical studies have described the issue of subsidies to innovation activities mainly using financing, tax incentives, special loans and similar policies. Among these studies, [3, 11, 15] evaluate the impact of an innovation program in Italy, noting that the subsidy increased the number of patent applications submitted by beneficiary companies. Other studies [15, 19, 20] concluded that subsidies are one of the most widely used international instruments because they reduce the costs associated with R&D and innovation. More recently, it has been observed that public interventions are primarily aimed at reducing the effective cost of R&D, promoting cost sharing and encouraging companies to invest in research and thus improving the efficiency of innovation activities [25, 28].

In this context, governmental subsidies can reduce the cost of R&D activities for companies and generate more innovation by motivating additional private R&D spending [28]. Government R&D funding also changes the behavior of recipient companies and affects the innovation pattern [21, 23]. Direct subsidies used in isolation or with tax incentives strengthen the R&D orientation of small and medium-sized enterprises (SMEs) [15]. As such, governmental R&D subsidies play a positive role in innovation. It is also important to note that credit promotion policies, with public guarantee, can also provide incentives for existing low-cost access to financial capital to promote innovation efficiency [8].

Another important aspect pointed out by Sung [11, 28, 29] indicates a positive two-way causal relationship between company innovations and variables like R&D subsidies, availability of internal innovation resources and industry competition. Also, [58] conclude that subsidies can promote technological competition, but they can also limit innovation when there is an oversupply of subsidies. In addition to this issue, the study by [41] stated that special loans and tax credits positively affect a firm's innovation performance, while direct allocations sometimes have negative effects. From this perspective, a preferential tax policy was found to have a significant positive impact on R&D efficiency, but not on the market conversion efficiency. Also, [11] found that financial support from the government has a significant negative impact on R&D innovation efficiency, but government tax support has a significant positive effect on R&D innovation efficiency. And finally, [40] noted that direct financial support from the government has no impact on improving the efficiency of technological innovation in high-tech industry. Regarding governmental R&D

subsidies, this section highlighted that they are used as a tool to foster technological development or support in general, innovation, start-ups, etc. The conclusions of this section indicate that subsidies and their use can be a strategy to differentiate and generate results for organizations as sources of competitive advantages; the results can however be diverse.

3 Material and Methods

In this first moment, the study carried out was of an applied nature, being designed from documental research through the use of secondary data.

In a second moment, the study can be categorized as a causal study with the objective of testing the relationships between variables. The aim was to establish relationships between two or more concepts or the degree of relationship between these concepts, considering that the formulation of hypotheses in studies of a correlational nature validates the association between variables and not the causality of a phenomenon. As such, the effects of the incentive value of the European Union (EU) Funds on the competitiveness of Portuguese industrial companies were analyzed through projects focused on I4.0 technologies in two dependent samples of the periods 2017–2018 and 2017–2019. Thus, the study evaluates companies enrolled for the receipt of EU Funds, which had implemented I4.0 projects in the same period, arising from the Partnership Agreement between Portugal and the European Commission, called Portugal 2020, under the scope of the Operational Program of Competitiveness and Internationalization—COMPETE 2020.

In this sense, the COMPETE database was used, consisting of the set of projects that were approved between 2016 and June 2020. It should be noted that only companies receiving subsidies for projects with an initial project execution date of January 2017 were considered, with those companies being analyzed that appeared in the indicator base from 2017 to 2018 and from 2017 to 2019, i.e., a period of 1 or 2 years. Companies with projects executed after 2018 were not considered. At first, in the selection of the two samples, the definition of specific I4.0 measures was not identified in the COMPETE base, but projects in different measures were included, such as R&TD—Copromotion, R&TD—Individuals, R&TD—Mobilizing Programs, SIAC, Innovation—Productive, Innovation—RCI, IQ SME—Individuals, IQ SME—Sets, IQ SME—Vouchers. Therefore, a first search was made with keywords related to the subjects and description of the projects supported by these measures. Specifically, keywords related to I4.0 were applied: I4.0, Industry 4.0, Artificial Intelligence (AI), Internet of Things, Robotics, Cloud Computing, Machine Learning, Additive Manufacturing and Simulation.

After searching for keywords with the terms in Portuguese, English and acronyms, a second criterion was applied regarding the year the project started. This returned 123 companies with projects implemented in I4.0 enabling technologies. Next, teaching and research institutions were discarded, leaving 91 companies. After a new analysis of the companies, there were companies with projects executed after 2017, resulting in the exclusion of about 44 companies and leaving about 36 (thirty-six) industries for analysis with projects implemented between 2016 to 2018.

Subsequently, a research model was developed that allowed for the proposal of the relationship between variables: the dependent variable was Industry Competitiveness (Operating Revenue, Number of Employees, Total Factor Productivity (TFP), Gross Value Added, EBITDA and Net Profit) and the independent variable was Industry 4.0 Incentive Value (EU Financing).

The following precepts explain the choice for the model with its dimensions and factors. The traditional ex-post competitiveness indicators (performance, market-share and profitability, the so-called revealed competitiveness), as well as the ex-ante indicators (efficiency), provide the means, within the new productive paradigm, to determine the factors that generate competitiveness. As competitive performance is a variable summarizing all the conditions that influence competition over a given period of time, there is a way to derive causes or interconnections between the variables that determine competitiveness in the industry.

For the set of companies with subsidized projects that were filtered from the COMPETE base, the economic-financial database Orbis Europe was accessed, which contains detailed financial information on 120 million European companies. The database has 10 years of detailed financial information and analysis and modeling of the financial indicators, including the variables used in the research model.

The data obtained through the research were analyzed with statistical techniques that allowed us to decide on the acceptance or rejection of the established associations. Non-parametric statistics were chosen because of the small number in the samples and the suspicion that the data were not normally distributed. The number of companies was 36 (thirty-six), thus constituting a small group of information for analysis according to non-parametric statistical techniques (Siegel, 1975). In order to test some associations in the SPSS software, the group was divided into two samples, one considering the time frame 2017–2018 and the other the time frame 2017–2019, which were also considered of a higher degree and a lower degree, both in terms of dimensions and factors, allowing for the application of difference tests. A level of 5% was established as significant for the hypothesis test. This is the standard level applied in social sciences and appropriate for samples with a size close to 50, which is the specific case of this study.

The following tests were used in the analysis [38]:

A. Kendall rank correlation coefficient tests are applied when several variables are studied simultaneously to determine how they are interrelated. The more the given index approaches a certain level, the higher the correlation.

$$S = \sum_{i<j} (sign(x[j] - x[i])) * (sign(y[j] - y[i])) \quad (1)$$

The following equation is used to test the significance of the Kendall coefficient:

$$c2 = k(N - 1)W \tag{2}$$

B. The Wilcoxon signed-rank test is used to compare whether the rank measurements of two samples is equal when the samples are dependent.

$$\{(X^1, Y^1)\ldots(X^n, Y^n)\}. \tag{3}$$

Thus, Di = Xi – Yi, for i = 1, 2, …, n. Therefore, the sample D1, D2, …, Dn is obtained, resulting from the differences between the values of each pair.

Hypotheses are established to perform the Wilcoxon Test:

$$\begin{aligned} H0 &= \sum pi(+) = \sum pi(-) \quad \sum pi(+) > \sum pi(-) \\ H1 &= \sum pi(+) \neq \sum pi(-) \quad \sum pi(+) < \sum pi(-) \end{aligned} \tag{4}$$

H0: There is significant correlation between the variables (Operating Revenue, Number of Employees, Total Factor Productivity (TFP), Gross Value Added, EBITDA and Net Profit) when they are correlated with the EU Fund variable (Industry 4.0 Incentive Value).

H1: There is no significant correlation between the variables (Operating Revenue, Number of Employees, Total Factor Productivity (TFP), Gross Value Added, EBITDA and Net Profit) when these are correlated with the EU Fund variable (Industry 4.0 Incentive Value).

4 Results

4.1 Best Regional Practices for Digital Transformation in Industry 4.0 in Portugal

The industry 4.0 Program in Portugal is part of the National Strategy for the Digitalization of the Economy developed by the Ministry of Economy and the Digital Transition Strategy to be deployed through a set of measures based on three axes of action: (1) Accelerate the adoption of I4.0 in the structure of Portuguese businesses; (2) Promote Portuguese technological suppliers as I4.0 players; and (3) Turn Portugal into an attractive pole for investment in I4.0.

The industry 4.0 Program is currently in Phase II. Phase II of the program was launched with the objective of fulfilling a decade of sustained convergence with the European Union, described in the National Strategy for the 2030 Horizon. This phase was developed with contributions from over 50 entities and is characterized as transformative in relation to Phase I, which was mainly demonstrative and mobilizing in nature. In this new phase, it is estimated that 600 million euros in public and private investments will be mobilized in the next two years. The various initiatives should involve 20.000 companies, train more than 200.000 workers and finance more than 350 transformation projects.

The government has set up COTEC to supervise the implementation of I4.0 in the country. COTEC Portugal is responsible for industrial transformation solutions and the mobilization of decision makers and entrepreneurs within that purpose. This context created a collaborative platform (PI4.0) co-financed by public funds, involving business groups and state agencies like the Strategic Committee [16].

According to data from, the strategy is based on above-mentioned three action axes. The process was designed from the bottom up, with contributions from hundreds of stakeholders from various key sectors and the definition of over 60 measures. Since 2016 (when the first phase began) the organization has been based on six priority directions: human resources training, technological cooperation, creation of I4.0 startups, funding, investment support, internationalization and legal and regulatory adaptation. Four working groups were also created for priority sectors where digitalization has more impact (tourism, clothing, agri-food and automotive). Later, sectors such as construction (in particular with the diffusion of Building Information Modeling, or BIM), and connected healthcare were added.

Through the various initiatives carried out inside and outside the country - national meetings, innovation conferences, technical visits to manufacturing facilities and missions at international industrial trade shows such as Hannover Messe—the organization promoted reflection on such topics as the transformation of professions and jobs, the role of collaboration in innovation, the relationship between humans and machines and business training. The importance of the circular economy, the imperative of cyber-security and the distinction of excellence in industry were also highlighted.

The measures include the sharing of knowledge, experiences and benefits as a way to stimulate the massive transition to I4.0. To this end, it uses such tools as Shif 4.0, which allows companies to make a self-diagnosis about their digital maturity. The new phase of the industry 4.0 Program also provides for a set of measures to promote, facilitate and finance the access of companies to experimentation with I4.0 methods and technologies, as well as to support their scale-up and digital transition, employing tailored credit solutions. New support tools for Productive Innovation will be launched and, among other measures, technology-industry collaboration platforms and cyber-security training will be promoted.

In this context, IAPMEI, which is the public institution for the support of SMEs, is the partner of firms in the promotion of the available Incentive Systems that are distributed according to three types of action: R&D, Productive Innovation and the Digital Economy for R&D projects in cyber-physical systems; Virtualization and Simulation; Artificial Intelligence; Digitalization; Augmented Reality and Wearables; Nanotechnology and Advanced Materials; Energy. According to, the following incentives are in place for the R&D action:

- SI R&D to support projects comprising industrial research and experimental development activities leading to the creation of new products, processes or systems, or to significant improvements in demanding products, processes or systems. The beneficiaries of this measure are companies of any nature and legal form, and the following subsidies are part of the action: Non-Refundable Incentive (INR) up to 1 M euros per beneficiary (after 1 M euros: 75% Non-Refundable and 25% Refundable); Base Rate 25% up to (Limit (ESB)):—Industrial Research Projects: 80%—Experimental Development Projects: 60%.

- SI R&D Centers that support projects seeking to create or reinforce the internal competencies and capabilities of the companies through the creation of structures dedicated to the implementation of R&D and the necessary certification of research, development and innovation management systems through the NP 4457 standard, contemplating direct costs (expenses with technical personnel dedicated to streamlining the R&D centers; HR training; technical, scientific and consulting assistance required to structure the centers; scientific and technical instruments and equipment, software for the project, among others) and indirect costs. The beneficiaries of this measure are SMEs of any nature and legal form. In the case of co-promotion projects, non-business entities of I&I system are also beneficiaries through the Non-Refundable Incentive (INR)—50% for SMEs and 15% for Non-SMEs (only in co-promotion).

For Productive Innovation projects, the focus is on connectivity actions, intelligent production processes, additive manufacturing, intelligent machines, advanced materials, modular operations, 3D printing, and autonomous robots. The incentives vary between 15 and 75%, with 50% of the total amount provided through a non-refundable subsidy, to be granted under SI Innovation; 50% of the total amount is provided through a bank loan without interest, associated to a financial instrument funded by strategic program of Portugal 2020.

Industry 4.0 vouchers seek to promote the definition of an own technological strategy in order to improve the competitiveness of the company, aligned with the I4.0 principles [58]. This measure is meant to achieve digital transformation through the adoption of technologies that allow for disruptive change in the SME business models (acquisition of consulting services in order to identify a strategy conducive to the adoption of technologies and processes associated with I4.0, particularly in the strategy design and implementation areas applied to digital channels for the management of markets, channels, products or customer segments; design, implementation, optimization of Web Content Management (WCM) platforms, Campaign Management, Customer Relationship Management and E-Commerce, etc.). These vouchers have a unit value of 7.500 euros and are meant to support more than 1.500 companies, representing a public investment of 12 million euros.

The SI Individual Project Qualification aims to strengthen the business training of SMEs through organizational innovation, applying new methods and processes and increasing flexibility and responsiveness in the global market by using intangible investments in the area of competitiveness (organizational innovation and management, digital economy, brand creation and design, product, service and process development and engineering, protection of industrial property, quality, knowledge transfer, distribution & logistics, eco-innovation, professional training, HR hiring).

The strategic plan for phase I of Portugal i4.0 was composed of 60 public and private measures and private measures grouped into six major axes of priority action: Capacity Building of Human Resources; Cooperation Ecosystem; StartUp i4; Financing and support to investment; Internationalization; Legal and Normative Adaptation.

Among the various existing public instruments in the Phase I (Table 1) that support investment in the transition to a more digital economy, two stand out: the Vale Industry 4.0 and the Incentive System for Productive Innovation i4.0.

It also connects those best regional practices for digital transformation in industry to the eleven initiatives identified in COTEC's Industry 4.0 Phase II report (Table 2). In order to fill the identified gaps and leverage a generalized transition to Industry 4.0, phase II of Portugal i4.0 considers it necessary to act in three strategic lines: Generalize i4.0, Empower i4.0, Assimilate i4.0, and strategic lines: Generalize i4.0, Empower i4.0, Assimilate i4.0 [22].

4.2 Analysis of the Non-parametric Tests

As explained above, Kendall's correlation was used to assess whether variables were correlated or not when interconnected (Table 3).

As can be seen, the variable Industry 4.0 Incentive Value has no correlation with the variables Productivity and Employees. However, a high correlation can be observed between Operating Revenue (0.958) and the Ind. 4.0 incentive value, followed by a high correlation between EBITDA (0.776) and the Ind. 4.0 incentive value. This is important to confirm the fact that they are dependent variables and belong to the same order group.

Subsequently, the normal distribution of both samples was verified, adopting the Wilcoxon signed-rank test with the defined hypotheses (HA, HB, HC, HD, HE, HF) in order to assess whether there were statistically significant differences between the *ex ante* and *ex post* periods for the receipt of the Industry 4.0 Incentive Value. Revenue volume is a performance indicator par excellence. The analysis of performance was carried out through the Operating Revenue variable, which is defined as sales and services rendered during the financial year, excluding value added taxes and other directly related taxes.

In turn, the efficiency analysis was carried out first through the employment variable. The efficiency indicator translates a company's capacity to generate products at efficiency levels equal to or higher than those observed in other companies, mainly with regard to prices, quality, services, price-quality ratio, technology, wages and productivity. Indeed, the qualification indicators consider the incorporation of technical progress in products as well as business organization and the cooperation between firms and public and private investments.

In general, competitiveness depends on adjusting the strategies of companies to the current competition standard. It is important to highlight that the success of companies ultimately depends on the reproduction of these factors in the internal

Table 1 Policy measures phase I [13]

Measure	Description	Benefits	Execution
Framework program horizon 2020	It sets out the framework for EU support for R&I activities, strengthening Europe's scientific and technological base and promotes the benefits for society as well as better exploitation of the economic and industrial potential of innovation and R&TD policies	It contributes to creating a society and economy based on knowledge and innovationby exerting a leverage effect that mobilizes additional funding for research development and innovation, in order to achieve the R&D targets and the 3% GDP target forresearch and innovation across the EU by 2020	Implemented
Portugal 2020—Vale I Industry 4.0	Supports projects in the scope of Portugal 2020 that aimed at acquiring consultancy services in R&TD activities and technology transfer services, aiming to intensify the national intensify the national effort in R&I and create new knowledge to increase the competitiveness of companies	The support is aimed at companies, under any legal nature and form, being considered as eligible as eligible investments the acquisition of consultancy services in R&TD activities and acquisition of technology transfer services through non-refundable incentives. reimbursable incentives	In implementation Applications open periodically
SIFIDE II SI R&D	The Entrepreneurial Research and Development Tax Incentives System, in force during the period from 2013 to 2020, aims to support R&D activities. It has the goal of continuing to increase the competitiveness of companies by supporting their efforts in R&D	The support is aimed at the creation or improvement of a product, a process, a program or an equipment or equipment, which present a substantial a improvement and which do not result of a simple use of the current state of the art. of existing techniques	Implemented

Table 2 Policy Measures Phase II [13]

Measure
Evaluation of digital maturity
Industry 4.0 experience
Innovation stimulus
sectorial and digital training and development
Learning factories
Experimentation and apprenticeships
Digital connectivity
Industry 4.0 coaching
Innovation risk management
Access to finance
Financing and transformation

Table 3 Kendall correlation

	Gross added value	EBITDA	Net profit	Productivity	Employees	Operational revenue	Ind. 4.0 incentive value
Gross added value	1	0.032	0.023	0.239	−0.003	0.098	0.545
EBITDA	0.076	1	0.276	0.176	−0.009	−0.007	0.776
Net profit	1	0.454	1	0.041	0.189	0.085	0.486
Productivity	0.041	−0.029	0.087	1	0.183	0.038	−0.034
Employees	0.189	−0.056	0.075	0.183	1	−0.057	−0.032
Operational revenue	0.085	0.176	0.006	0.038	−0.057	1	0.958
Ind. 4.0 Incentive value	0.086	0.005	−0.008	0.045	−0.032	0.958	1

plan and in the market performance of the organization. One of the conditions for the implementation of I4.0 is the impact on industrial productivity. In this work, total factor productivity (TFP) was used as the amount of product obtained with a weighted unit of all production factors [1]. TFP = Y/aK + bL), where: Y is the product; K is the capital factor; L is the labor factor; a and b are the weights of the respective factors.

Gross Value Added (GVA) is another variable related to competitiveness and production efficiency. It is the final result of the productive activity over a given period. GVA is the difference between the value of production and the value of intermediate consumption, leading to surpluses.

EBITDA is an indicator of a company's financial profitability and efficiency year by year. It shows a business' potential to generate cash, because it indicates how much money is generated by operating assets. EBITDA means Earnings Before Interest, Taxes, Depreciation and Amortization. By also eliminating the effects of depreciation and amortization of the company's assets, EBITDA brings the result closer to the cash potential of the business.

Finally, net profit makes it possible to analyze the competitiveness and efficiency of the company, especially through the comparison of different years and its competitors.

The situation was analyzed based on the mean difference test of the scores obtained for the dimension Ind. 4.0 incentive value and the factors Operating Revenue, Number of Employees, Total Factor Productivity (TFP), Gross Value Added, EBITA and Net Profit (Table 4).

The evaluation of the results of the hypothesis tests reveals that of the six variables in the first sample with the 2017/2018 variations, only Operating Revenue had a statistically significant difference between the results of the companies before and after the execution of the projects. Indeed, between the two periods of time and considering the application of the incentive value, only one variable showed an increase or upgrading of competitiveness based on the execution of the projects.

However, the evaluation of the results of the hypothesis tests reveals that in the second sample with the 2017/2019 variation—that is, a longer period of maturity of the competitiveness variables—the six variables had a statistically significant difference between the results of the companies before and after the execution of the projects considering the application of the incentive value (Table 5).

A general result of the indicators analyzed to verify the differences in significance by performing two tests (Kendall Correlation and Wilcoxon test) is that the application of the model to the research problem seems to be reasonable. As such, there is evidence that the stimulated value component (EU funds) could have an association with the degree of competitiveness over a longer period of analysis, i.e., sample 2017–2019.

Table 4 Wilcoxon signed-rank test of samples related to the 2017/2018 variation

2017/2018 variation	Significance	Hypothesis test related samples
Ind. 4.0 Incentive value × Operating revenue	0.162	Retain the null hypothesis
Ind. 4.0 Incentive value × Employees	0.004	Reject the null hypothesis
Ind. 4.0 Incentive value × Productivity	0.002	Reject the null hypothesis
Ind. 4.0 Incentive value × Net profit	0.001	Reject the null hypothesis
Ind. 4.0 Incentive value × EBITDA	0.002	Reject the null hypothesis
Ind. 4.0 Incentive value × Gross added value	0.003	Reject the null hypothesis

Table 5 Wilcoxon signed-rank test of samples related to the 2017/2019 variation

2017/2019 Variation	Significance	Hypothesis test related samples
Ind. 4.0 Incentive value × Operating revenue	0.807	Retain the null hypothesis
Ind. 4.0 Incentive value × Employees	0.278	Retain the null hypothesis
Ind. 4.0 Incentive value × Productivity	0.278	Retain the null hypothesis
Ind. 4.0 Incentive value × Net Profit	0.196	Retain the null hypothesis
Ind. 4.0 Incentive value × EBITDA	0.972	Retain the null hypothesis
Ind. 4.0 Incentive value × Gross added value	0.151	Retain the null hypothesis

5 Discussion

In this section, the research hypotheses are analyzed and the results are discussed, considering the validity of the proposed model and the statistical significance of the coefficients. According to the presented results, the hypothesis is rejected for 2017–2018 and accepted for 2017–2019. The central hypothesis of this study is accepted, since the factors that make up the industry 4.0—EU Fund—Incentive Value dimension have an association with the degree of competitiveness (Operating Revenue, Number of Employees, Total Factor Productivity (TFP), Gross Value Added, EBITDA and Net Profit) in the 2017–2019 period. Although the same did not happen in the 2017–2018 period, that result leads us to conclude that it is important to analyze longer periods for a more consistent evaluation of the process, even when it comes to new and rapidly developing technologies. Moreover, the Wilcoxon Test confirmed the association between the Ind. 4.0 Incentive Value and the degree of competitiveness. In addition, it should be noted that when companies are separated into two samples—one for a longer and the other for a shorter period—the revenue factor has different mean scores in these two groups, discriminating the most competitive ones. This means that operating revenue would be the only variable that would have an implication for increased competitiveness in the smaller time period of 2017–2018.

In this analysis, we highlight that:

H0—There is significant correlation between the variables (Operating Revenue, Number of Employees, Total Factor Productivity (TFP), Gross Value Added, EBITA and Net Profit) when they are correlated with the European Fund variable (Industry 4.0 Incentive Value) in the 2017–2018 period. This hypothesis was rejected. Only Operating Revenue had a statistically significant difference between the results of the companies before and after the execution of the projects.

H0—There is significant correlation between the variables (Operating Revenue, Number of Employees, Total Factor Productivity (TFP), Gross Value Added, EBITA and Net Profit) when they are correlated with the European Fund variable

(Industry 4.0 Incentive Value) in the 2017–2019 period. This hypothesis was accepted for six variables through the Wilcoxon test.

In the Kendall Coefficient test, the variable Ind. 4.0 Incentive Value has no correlation with the variables Productivity and Employees. However, a high correlation can be observed between Operating Revenue (0.958) and the Ind. 4.0 incentive value, followed by a high correlation between EBITDA (0.776) and the Ind. 4.0 Incentive Value.

The results suggest, therefore, that there are different intensities of the effects of the governmental subsidies of the industry 4.0 Program on the competitive position of Portuguese industries in the two periods under analysis, pointing to a relevant role of industrial policy when the period of analysis is longer, directly identified, in the strategic direction of the firms. The analyses revealed that there were variations in the competitiveness of the industry when the longer 2017–2019 period was considered. As a result, we consider it important to monitor these processes throughout their evolution, including relatively short periods, in order to obtain more accurate and consistent results, as we suggested at the beginning for countries that are filling the progress gap, even if historical experience is scarce. It is important to note that no previous research has been identified addressing the relationships between the constructs that make up the research model, making it impossible to compare the results obtained with the results of other studies.

When measuring the competitiveness, we also found that the means for the period 2017–2018 were lower, but no statistically significant differences were identified with the 2017–2019 period. We also confirmed that the more adherent the project was to I4.0 technologies, the more favorable the competitive position of the industries in 2018 and in the following period. However, the subsidy does not influence the competitive position in relation to the type of company, whether or not it belongs to a group, or due to its location (for example, whether it is from the North, Center or South of Portugal, whose contexts present differences from this point of view). One aspect that deserves to be highlighted is the role of the size of the firm as measured by the number of employees and its direct effect on the competitive position. The results suggest effects of similar intensities of the size on the competitive position in both periods under analysis. In a way, the results point to a greater competitive capability of larger firms, although this is to be expected.

6 Conclusions

The study had peculiar characteristics since it analyzed the best regional practices for digital transformation to the industry 4.0 Program in Portugal and the role of European Union funds regarding the competitiveness perspectives of companies developing I4.0 projects with enabling technologies. Faced with this objective, the I4.0 determinants in Portugal and the role of government agents in promoting these enterprises were presented. As such, it should be stressed that the contextual analysis initially proposed as a general objective enabled an understanding of the industry 4.0 Program in Portugal and of how it consolidated the competitive positions in industry.

The study was developed through a methodological approach as a descriptive and a correlational nature, seeking to establish relationships between the Incentive Value and Competitiveness or the degree of relationship between these concepts, in order to identify, through quantitative arguments, the role of EU funds in the competitiveness of I4.0 in Portugal. For the purpose of the study model, the definition was assumed that the companies that were more oriented to receiving funds had a better competitive performance. Above all, it was assumed that the funds were a way to expand the base of the competitive dimensions. It would be also possible to claim that more dynamic and effective companies are also the ones more attracted to explore European funds. Therefore, the association would probably also happen due to other factors like new markets, more effective training, redesigned processes and so on.

The study relied on the use of non-parametric statistical techniques. Kendall's rank correlation coefficient and the Wilkinson Test were used to interpret the results. Based on this, the study's general results reveal that in the first sample, the incentive value is not fully correlated with competitiveness, since only the hy-pothesis that contained the Operating Revenue factor presented significant levels. According to the presented results, the central hypothesis of this study is accepted, since the factors that make up the industry 4.0—European Union Fund—Incentive Value dimension have an association with the degree of competitiveness (Operating Revenue, Number of Employees, Total Factor Productivity (TFP), Gross Value Added, EBITA and Net Profit) in the 2017–2019 period.

Although the same did not happen in the 2017–2018 period, that result leads us to conclude that it is important to analyze longer periods for a more consistent evaluation, even when it comes to new and rapidly developing technologies. In the field of industrial policy, the results of this study are also important from the perspective of decision makers. As the funds are disputed for various uses (Collie, 2005), even in the context of I4.0, and since their scrutiny is politically relevant, a thorough analysis of these investments, including short periods of a few years, can be a valuable tool to improve decision making and avoid waste.

Despite the methodological care applied in carrying out this study, some limitations should be noted for the adequate understanding of the results expressed here and the consequent consideration of their implications. The focus in a specific country is a study limitation. Within the other limitations of the present work, the restriction of choosing one model to measure the best regional practices for digital transformation in industry and fund receipt dimensions with a limited number of factors should be noted, since the research option was to evaluate only result measurement indicators.

It is clear that the case under study is only a small sample, but its extension or even generalization to other cases may improve the effectiveness of the "upgrade" process that the country wants to put into practice. Thus, comparative studies, both sectoral and cross-country, conducted according to quantitative or qualitative methodologies, may also bring significant added value to the research. Another necessary perspective would be to focus on the management of the funds deployment process in order to understand to what extent it influences the success of the subsidized companies when measured through competitiveness.

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