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Competitiveness and R&D Subsidies: The Case of the Industry 4.0 Program in Portugal

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ABSTRACT

Objective: the objective of this study was to analyze the effects on industrial competitiveness of the subsidies related to the Industry 4.0 Program in Portugal from 2017 to 2019. The following research question arises in this context: What is the influence of the incentive value on the competitiveness of Portuguese industries after the implementation of the Industry 4.0 technology-enabling projects? **Methods:** the methodological approach of the study is correlational in nature, and it seeks to establish relationships between the Industry 4.0 incentive value and competitiveness in order to identify the role of funds/subsidies in the competitiveness of Industry 4.0 in Portugal. The study relied on the use of non-parametric statistical techniques. Kendall's rank correlation coefficient, the Fisher test, and the Wilkinson test were used to interpret the results. **Results and Conclusions:** according to the presented results, the central hypothesis of this study is accepted, since the factors that make up the Industry 4.0 — European 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.

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INTRODUCTION

There are a significant number of recent studies (Ardito et al., 2018; Dalenogare et al., 2018; Ferraris et al., 2019; Klingenberg et al., 2019; Liao et al., 2017; Prasada et al., 2021) associating the emergence of Industry 4.0 with the dimension. In this context, the growing pace of technological innovation can be seen not only as a challenge to organizations or governments, but also as contributing to increased competition in various industrial sectors and, consequently, promoting the economic development.

When outlining the role of the new industrial policy in Portugal, one of the most striking lessons can be taken from the Industry 4.0 Program formulated in 2016 and supported in 2017 on the following axes: qualification of people, technological cooperation, creation of Industry 4.0 startups, funding, investment support, internationalization, and legal and regulatory adaptation. Of the 64 measures included in this initiative, 95% had already been executed in Phase I by 2020, covering more than 24 thousand companies and 550 thousand workers (COTEC, 2020). It is important to put this policy in perspective, considering that Portugal still has clear structural weaknesses in terms of competitiveness, even though it is seeking to improve its positioning in the field of new technologies. According to the International Institute for Management Development [IMD] (2020), Portugal has raised two places in the competitiveness ranking, occupying the 37th position in the global list in 2020. Factors such as skilled labor, opportunity cost, and infrastructure stability have made the Portuguese economy more attractive. Corroborating the same trend, the 2020 edition of the Innovation European Union Scoreboard shows Portugal's entry into the group of highly innovative countries (previously it was a moderate innovator). It is possible that the COVID-19 pandemic outbreak of 2020 will impact on this trend (interrupting or perhaps accelerating it), which is, however, representative of the Portuguese technological drive in the late 2010s, in the sense of seeking to create new sources of competitiveness in this sector.

As part of the discussion, it should be emphasized that the competitiveness of the Portuguese industry ranges across very different stages at the company level. According to data from PORDATA (2020), there were 68.214 companies in the Portuguese manufacturing industry in 2018, 78.431 in 2003, and 81.387 in 2008, made up mostly of small and medium-sized food, clothing and metal products industries, i.e., as expected, the impact of the financial crisis clearly reduced their number (-16.2% between 2008 and 2018). It must be added that structural problems are still the main factors influencing the competitiveness of Portuguese industrial companies, which implies, among other things, that a stabilization of the tax burden, a reduction of bureaucracy, and an improvement of the efficiency of the legal system are required.

In fact, competitiveness requires business strategy, regardless of if we are discussing small, medium-sized, or large companies (Shan et al., 2016). Notably, this explains the importance of competitiveness to achieve business performance in a competitive structure, in the context of the country's economic stability and the government incentives generated by its industrial policy (Alamsyah et al., 2020). Consequently, the role of competitiveness can be maximized and appreciated within an integrated development process built on industrial reconversion, the digital economy, the identification of new skills, and innovative services. In a global scenario, these changes are observed both in the institutional and regulatory scope and in the technological dimension of the Portuguese industrial sectors.

Several studies discuss the content and form that governmental subsidies and incentive policies take to promote the research and development (R&D) activities of businesses and stimulate competitiveness (Brown et al., 2017; Carboni, 2017; Chen & Breedlove, 2020; Crespi et al., 2020; Doh & Kim, 2014; Guan & Yam, 2015; Hong et al., 2015; Hsu et al., 2009; Mardones & Ávila; 2020; Wallsten, 2000). Although there is no linear concept as to how these subsidies in Portugal affect industrial competition, it is possible that, on the one hand, economic concentration allows for the achievement of better productivity rates through European funds, while on the other hand, the industrial policy issues involving small and medium-sized enterprises (SMEs), in particular, have become more important in competitiveness through subsidies and other forms of public support.

In the theoretical framework that underlies the Industry 4.0 vision (Boyes et al., 2018; Chiarello et al., 2018; Kagermann et al., 2013; Mouef et al., 2020; Paluch et al., 2019; Reischauer, 2018; Thoben et al., 2017; Zhong et al., 2017) there are many determinants for competitiveness in organizations. Some previous studies have proposed maturity models for the implementation of enabling technologies (Lee & Lee, 2015; Lu & Weng, 2018; Mittal et al., 2020; Schuh et al., 2017), while others have advanced the measurement of the impact of technologies on industrial performance (Dalenogare et al., 2018).

However, when searching for TITLE-ABS-KEY ("industry 4.0" AND "Portugal") on the Scopus database, we found 60 documents, of which only four address the Industry 4.0 Program in Portugal (Faria et al., 2022; Nowacki, 2021; Santa Rita et al., 2022; Savu & Dumitrescu, 2021). Other articles focus on specific enabling technologies such as the work of Dias et al. (2022) and Reis et al. (2018), or even specific sectors such as the research of Sá et al. (2021) and Simões et al. (2022). This way, it is possible to say that there is a lack of studies on Industry 4.0 that provide empirical evidence on the effects on competitive performance through government subsidies, which constitutes a theoretical gap to be filled with this empirical research.

From this perspective, we have the following research question: What is the influence of the incentive value on the competitiveness of Portuguese industries after the implementation of the Industry 4.0 technology-enabling projects? In order to fill this gap, the objective of this study is to analyze the effects on industrial competitiveness of the subsidies of the Industry 4.0 Program in Portugal from 2017 to 2019.

The methodological approach of the study is correlational in nature (Selltiz et al., 1985), and it seeks to establish relationships between the Industry 4.0 incentive value and competitiveness in order to identify the role of subsidies. For the purpose of the research model, it was assumed that those industries with projects executed in the period with the receipt of European funds had a better competitive performance. It was also assumed that a subsidy was, above all, a way to expand the location of the competitive dimensions. The study relied on the use of non-parametric statistical techniques, and Kendall's rank correlation coefficient, the Fisher test, and the Wilkinson test were used to interpret the results.

Thus, the use of distinctive models and productivity aspects was considered as justification for the development of this paper. On the one hand, these models and aspects involved traditional currents, which propose to explain competitiveness as a function of production, using empirical criteria that sometimes are not found in theory. On the other hand, there are the evolutionary currents, which try to explain the changes that occurred in the sectors through microeconomic aspects. Moreover, this study is justified due to the potential transference effect to other sectors of the economy. In the theoretical field, the study could also be further relevant in two ways: first, in relation to the national production of (basic and applied) research; and second, in relation to the flow and intersectoral diffusion of Industry 4.0 in Portugal. In this sense, the proposal and choice of a model does not exhaust the analysis of competitiveness but is used as a proxy for a conceptual model that may enable new lines of research or replication to other countries. As another theoretical/methodological contribution, the proposal of a metric is highlighted allowing for correlational inferences on the Industry 4.0 and policy measures to encourage industrial competitiveness.

Based on these assumptions, the discussion proposed in this paper is structured in five sections. In the introduction, the research problem is approached, and the subject, justification, and objectives of the paper are presented. Subsequently, the next section focuses on the conceptual frameworks concerning competitiveness, governmental R&D subsidies, and a characterization of the Industry 4.0 Program in Portugal. Then, in the next section the methodological procedures are described. After that, the results obtained from the research are presented and discussed. Finally, the final section summarizes the concluding remarks and suggests lines for further research.

CONCEPTUAL FRAMEWORK

Competitiveness

Classic texts by Durand and Giorno (1987), Porter (1990), and Barney (1991) discuss competitiveness as a form of relative positioning of a country, sector, or organization regarding its levels of technical efficiency. The authors of these texts see competitiveness not as a simple indicator, but as a set that incorporates measures, strategies, and competitive forms. Although there is an important theoretical discussion whether we can simply transfer the same logic of competitiveness from one organization (or company) to the level of a nation-state (Krugman, 1994), in this context we will focus on the former case. The establishment of these elements allows for the organization of the various concepts of competitiveness into two distinct groups: (a) competitiveness as performance, in which competitiveness is somehow expressed through the market share achieved by the company in a certain period, or, particularly, the volume of its exports in the total international trade of the sector, and (b) competitiveness as efficiency, which is translated as the ability of the company to generate certain products, equaling or exceeding the observable levels of efficiency in other companies, especially with regard to prices, quality, services, price-quality ratio, technology, wages, and productivity.

It builds upon the classical economic analysis models of firms that have a position in the rational allocation of resources. In the tradition of pure classical economics, based on the model of perfect competition where — among other hypotheses — price is a given and the produced goods are homogeneous, the concept of competitiveness makes no sense. At the firm level, however, some authors (Bain, 1956; Buckley, 1988; Fee et al., 2004) approach the concept of competitiveness associated with market structure and its imperfections. In an alternative logic to the mainstream, the evolutionist current should also be emphasized, which prioritizes technical progress as a factor for productivity increase.

The logic of this current of thought is that the innovation process and its diffusion have a strong impact on economic activity and competitiveness (Dosi, 1982; Dosi, 1998; Nelson & Winter, 1982).

A vast theoretical and empirical literature (Amendola et al., 1993; Fagerberg, 1996) and contemporary texts (Baumann et al., 2019; Dosi et al., 2015; Lamperti et al., 2020; Laursen & Meliciani, 2010) analyzes the influence of technology and technological change on competitiveness at the micro, meso, and macro levels. In this context, the inclusion of technological factors, besides those related to costs, goes back to the work of Rosenberg et al. (1992), which postulates that one of the main sources of absolute advantage of a country is derived from its relative technological position comparing to its competitors.

More specifically, since the second half of the 1980s, empirical studies have consolidated Dosi, Pavitt, and Soete's (1990) evolutionary perspective, in which trade flows are driven by sector-specific absolute advantages, arising from technological asymmetries between countries, considering differences in the capabilities to produce innovative products, develop process innovations, or use existing processes more efficiently or faster. According to this line of reasoning, the main driver of sector-specific advantages is the technical knowledge of product and process innovations, not only at the factory level, but also at the market level. Fagerberg et al. (2007), in turn, describe country-industry competitiveness as a function of technological and cost factors.

The most recent studies on competitiveness (Chabowski & Mena, 2017; Gordeev, 2020; Laureti & Viviani, 2011; Prasetyo, 2016; Wang & Turkina, 2020; Zhang & London, 2013) measure industrial productivity and use variables related to the value added and monthly physical production (relative prices, industrial organization, and quality), variables related to hours worked, hours paid, and occupied work force. The following theoretical currents on productivity stand out: the neoclassical mainstream (total factor productivity), evolutionist, X-efficiency, managerial and behavioral, neo-Marxist, industrial organization, Kaldor-Verdoorn, comparative advantage, and endogenous growth theories (Bulgarelli & Porto, 2011; Cao et al., 2015; Jamalnia et al., 2019; Lee, 2021; Mendonça et al., 2021; Mendonça et al., 2022; Saboia & Carvalho, 1997).

When evaluating a company's competitiveness, its business performance and sustainability are measured. As such, authors such as Rodriguez-Fernandez (2016), Sutapa et al. (2017), and Bostan et al. (2019) highlight the measures using qualified business strategies that need to be considered, not only in providing the best value for the products and services offered, but also through sustainable practices, industrial ecosystems, or the digitalization of the economy.

Still regarding the wide diversity of works on competitiveness, studies evaluating the efficiency of innovation using data envelopment analysis (DEA) have achieved notoriety in academia (Cruz-Cázares et al., 2013; Diaz-Balteiro et al., 2016; Ferreira et al., 2021; Pan & Yang, 2014), even considering that the inputs and outputs of innovation can vary significantly across different industries. In a recent study, the authors Yang and Yu (2020) analyzed patents, national scientific and technological awards, and sales as output variables, while using R&D expenses and R&D personnel as input variables to measure the efficiency of innovation in high-speed railway companies. Song and Oh (2015) employed DEA to measure the innovation efficiency of publicly traded companies using the cost of R&D and technical personnel as two input variables. The authors used the return on total assets, profit margin, technology asset ratio, and sales revenue growth rate as their output variables. Kim and Shin (2019) measured the innovation efficiency of 72 logistics companies in South Korea using sales as the production factor and the number of employees and cost of innovative activity as the input factors.

Based on the exposed theory, we can say that competitive companies are those capable of developing their own specific system of 'strategic adequacy' to the environment. This fit allows companies to effectively match their competencies to the needs and requirements of the environment, so that companies undergo systematic positive selection and retention, receive the necessary resources to operate, and achieve long-term gains and social legitimacy (high position in the market). Consequently, in addition to ensuring permanence in the market, these companies generate profits and gain a good reputation. In this approach, competitiveness is configured in the company's state of dynamic equilibrium, developed due to its strategic adjustment, which comprises a relatively permanent system that meets the demands of the relations between the company and its external and internal environment (Adamik, 2015; 2019).

From this perspective, when considering the organizational approach to technological competitiveness, according to Alvarez-Aros and Bernal-Torres (2021), in developed economies key elements such as research, development, and innovation (RD&I), supply chain, decision-making, and knowledge management help convert tacit knowledge into explicit and maintain it in the organization.

Industry 4.0 represents a new era of opportunity for billions of people, companies, and governments around the world. Along with these opportunities, growing inequality and geopolitical problems between countries have heightened societies' concerns about globalization and raised political issues. Thus, it is evidently necessary for leaders to take innovative long-term measures, in the search for solutions aimed at development, with a view to dynamic balance and, consequently, permanence in the market. Human capital, innovation, technology, flexibility, and agility are critical factors to achieve economic success in Industry 4.0. For countries to improve economically, they must use technology better and combine it with other competitiveness factors (Bal & Erkan, 2019).

Governmental subsidies through the Industry 4.0 Program in Portugal

Industry 4.0 and government R&D subsidies

Among the different research advances related to Industry 4.0, the focus on management can be seen (Brennan et al., 2015; Buer et al., 2018; Li, 2018; Melnyk et al., 2018; Müller et al., 2018; Oztemel & Gursev, 2018). In addition, research is progressing on specific technologies and industry-focused issues (Chen & Lin, 2017; Lu & Weng, 2018; Mittal et al., 2020; Strozzi et al., 2017; Tao et al., 2014; Xu et al., 2018). However, little emphasis has been placed on the role of governmental subsidies when executing Industry 4.0 projects and the impact of these technologies on business performance.

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, Bronzini and Piselli (2016) 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 (Guan & Yam, 2015; Kang & Park, 2012; Li et al., 2018) 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 (Bianchini et al., 2019; Minford & Meenagh, 2019).

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 (Howell, 2016; Lee, 2018; Mukherjee et al., 2017). Government R&D funding also changes the behavior of recipient companies and affects the innovation pattern (Hsu et al., 2009). Direct subsidies used in isolation or with tax incentives strengthen the R&D orientation SMEs (Radas et al., 2015). As such, governmental R&D subsidies play a positive role in innovation (Kang & Park, 2012). 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 (Fan et al., 2018).

Another important aspect pointed out by Sung (2019) indicates a positive two-way causal relationship between company innovations and variables like R&D subsidies, availability of internal innovation resources, and industry competition. Furthermore, Liu et al. (2019) 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 Guan and Yam (2015) 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. Fan et al. (2017) 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, Li et al. (2019) noted that direct financial support from the government has no impact on improving the efficiency of technological innovation in high-tech industry.

Industry 4.0 Program in Portugal

The Industry 4.0 initiative 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: (a) accelerate the adoption of Industry 4.0 in the structure of Portuguese businesses; (b) promote Portuguese technological suppliers as Industry 4.0 players; and (c) turn Portugal into an attractive pole for investment in Industry 4.0.

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 Industry 4.0 in the country. COTEC Portugal is responsible for industrial transformation solutions and the mobilization of decision-makers and entrepreneurs in the country. This context created a collaborative platform (Pi4.0) co-financed by public funds, involving business groups and state agencies like the Strategic Committee (COTEC, 2020).

According to data from COTEC (2020), the strategy is based on the three action axes mentioned at the beginning of this section. 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 Industry 4.0 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, agrifood, and automotive).

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 like 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 Industry 4.0. 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 Industry 4.0 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, the Institute for Supporting Small and Medium-Sized Companies and Innovation (IAPMEI) is the partner institution of SMEs in the promotion of the available incentive systems, which 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; digitization; augmented reality and wearables; nanotechnology and advanced materials; energy (COMPETE, 2020). According to IAPMEI (2020), the following incentives are in place for the research and development (R&D) action:

a. Incentive system 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 million euros per beneficiary (after 1 million euros: 75% non-refundable and 25% refundable); base rate from 25% up to (Limit — ESB): industrial research projects: 80%; experimental development projects: 60%.

b. Incentive system 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 innovation system incentive; 50% of the total amount is provided through a bank loan without interest, associated to a financial instrument funded by 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 Industry 4.0 principles (IAPMEI, 2020). This measure is meant to achieve digital transformation through the adoption of technologies that allow for disruptive change in the SMEs business models (acquisition of consulting services in order to identify a strategy conducive to the adoption of technologies and processes associated with Industry 4.0, 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, 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 incentive system qualification can be an individual project or a project for a set of SME: (a) Individual project qualification: the beneficiaries of this measure are SMEs of any nature and under any legal form. This project 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 and logistics, eco-innovation, professional training, human resource hiring); (b) Joint project qualification: the main difference compared with the individual modality is the usage recommendation of a structured intervention action plan considering a group of SME.

METHODOLOGY

In this first moment, the study carried out was of an applied nature, being designed from documental research using 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 expresses the association between variables and not causality as a phenomenon (Gujarati & Porter, 2011; Pindyck & Rubinfeld, 2004). 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 Industry 4.0 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 Industry 4.0 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 that received grants for projects whose initial project execution date was January 2017 were considered, with the companies that appeared on the indicator base from 2017 to 2018 and from 2017 to 2019 being analyzed, that is, a period of one or two years. Companies with projects executed after 2018 were not considered. At first, in the selection of the two samples, the definition of specific Industry 4.0 measures was not identified in the COMPETE base, but projects in different measures were included, such as research and technological development (R&TD) — copromotion, R&TD — individuals, R&TD — mobilizing programs, collective action support system (SIAC), innovation — productive, innovation — RCI, incentive for SME qualification (IQ SME) — individuals, incentive for SME qualification — sets, incentive for SME qualification

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 Industry 4.0 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 industries for analysis with projects implemented between 2016 and 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 Ind. 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, 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, 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 (Contador & Senne, 2016):

1. 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 (Kendall, 1938).

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

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

$$c2=k(N-1)W \quad (2)$$

2. The Wilcoxon signed-rank test is used to compare whether the rank measurements of two samples is equal when the samples are dependent (Wilcoxon, 1945).

$$\{(X^{1,}Y^{1}) \dots (X^{n},Y^{n})\}. \quad (3)$$

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:

$$H0=\sum pi(+)= \sum pi(-) \; \sum pi(+)>\sum pi(-)$$

$$H1=\sum pi(+) \neq \sum pi(-) \; \sum pi(+)<\sum pi(-) \quad (4)$$

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 (*Ind. 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 (*Ind. 4.0 incentive value*).

RESULTS

Analysis of the non-parametric tests

Kendall's correlation was used to assess whether variables were correlated or not when interconnected.

Table 1. 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

Note. Source: Developed by the authors based on the research data.

As can be seen, 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 *Ind. 4.0 incentive value*, followed by a high correlation between *EBITDA* (0.776) and *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* (OR) variable, which is defined as sales and services rendered during the financial year, excluding value added taxes and other directly related taxes.

$\{HA{,}0{:}\ \mathrm{OR}t-1=\mathrm{OR}t+1\ HA{,}1{:}\ \mathrm{OR}t-1<\mathrm{OR}t+1$

In turn, the efficiency analysis was carried out first through the employment variable. The efficiency indicator translates a company's capacity (EMP) 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.

$\{HB{,}0{:}\ \boldsymbol{E}\mathrm{MP}t-1=\boldsymbol{E}\mathrm{MP}t+1\ HB{,}1{:}\ \boldsymbol{E}\mathrm{MP}t-1<\boldsymbol{E}\mathrm{MP}t+1$

In general, competitiveness depends on adjusting the strategies of the 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 plan and in the market performance of the organization. One of the conditions for the implementation of Industry 4.0 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.

$\{HC{,}0{:}\ \mathrm{PTF}t-1=\mathrm{PTF}t+1\ HC{,}1{:}\ \mathrm{PTF}t-1<\mathrm{PTF}t+1$

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.

$\{H\mathrm{D}{,}0{:}\ \mathrm{GVA}t-1=\mathrm{GVA}t+1\ H\mathrm{D}{,}1{:}\ \mathrm{GVA}t-1<\mathrm{GVA}t+1$

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.

$\{H\mathrm{E}{,}0{:}\ \mathrm{EB}t-1=\mathrm{EB}t+1\ H\mathrm{E}{,}1{:}\ \mathrm{EB}t-1<\mathrm{EB}t+1$

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.

$\{H\mathrm{F}{,}0{:}\ \mathrm{LL}t-1=\mathrm{LL}t+1\ H\mathrm{F}{,}1{:}\ \mathrm{LL}t-1<\mathrm{LL}t+1$

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, EBITDA* and *Net profit.*

Table 2. 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 x Operating revenue	0.162	Retain the null hypothesis
Ind. 4.0 incentive value x Employees	0.004	Reject the null hypothesis
Ind. 4.0 incentive value x Productivity	0.002	Reject the null hypothesis
Ind. 4.0 incentive value x Net profit	0.001	Reject the null hypothesis
Ind. 4.0 incentive value x EBITDA	0.002	Reject the null hypothesis
Ind. 4.0 incentive value x Gross added value	0.003	Reject the null hypothesis

Note. Source: Developed by the authors based on the research data.

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 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 3. 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 x Operating revenue	0.807	Retain the null hypothesis
Ind. 4.0 incentive value x Employees	0.278	Retain the null hypothesis
Ind. 4.0 incentive value x Productivity	0.278	Retain the null hypothesis
Ind. 4.0 incentive value x Net profit	0.196	Retain the null hypothesis
Ind. 4.0 incentive value x EBITDA	0.972	Retain the null hypothesis
Ind. 4.0 incentive value x Gross added value	0.151	Retain the null hypothesis

Note. Source: Developed by the authors based on the research data.

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.

Discussion of the results

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 *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 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, EBITDA*, and *Net profit*) when they are correlated with the European fund variable (*Ind. 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.

H1: 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 European fund variable (*Ind. 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 *Number of employees*. However, a high correlation can be observed between Operating revenue (0.958) and I*nd. 4.0 incentive value*, followed by a high correlation between EBITDA (0.776) and *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 period 2017-2019 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 Industry 4.0 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 size on competitive position in the two periods under analysis. In a way, the results point to a higher intensity in larger firms, although this is to be expected.

The results of this investigation are in line with the studies developed for the Portuguese economy by the authors Moreira (2001), Martins (2004), Marco (2012), and Correia and Costa (2016), insofar as they mention factors referring to the financial health of the companies (net profit, operating income) as elements of competitiveness. In this sense, Pereira and Romero (2017) highlight the impact of Industry 4.0 in several sectors, as well as in the economy, due to the innovation made possible by enabling technologies, which play a critical role in increasing productivity and, consequently, competitiveness.

CONCLUSIONS

The study had peculiar characteristics since it analyzed the role of European Union funds regarding the competitiveness perspectives of companies developing Industry 4.0 projects with enabling technologies in Portugal. To achieve this objective, a conceptual model was developed, which showed the existence of a significant association. Faced with this objective, the Industry 4.0 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 the industry. As for the specific objectives, it is important to point out that we sought to identify, among other things, how companies processed competitive forces in relation to the number of employees, type, and location of the company.

The study was developed through a methodological approach of a descriptive and 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 Industry 4.0 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 hypothesis 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, 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, 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 Industry 4.0, 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.

The main contribution of this research comprises the perspective of measuring competitiveness, based on operating revenue, number of employees, total factor productivity (TFP), gross value added, EBITDA, and net profit indicators. In addition, the presented results represent a breakthrough for the scientific literature with regard to the development of quantitative studies, which address the effects of government subsidy on the competitiveness of Portuguese companies, in the context of Industry 4.0.

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.

In addition, when considering the context of Industry 4.0, future research can measure competitiveness based on other sets of indicators, or even develop a maturity scale to assess the implementation process of the Industry 4.0 Program in Portugal.

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