



RISCOS



**RISKS AND CONFLICTS IN THE FORMATION OF HUMAN CAPITAL FOR
INFORMATION AND COMMUNICATIONS TECHNOLOGY (ICT) ACTIVITY IN THE STATE OF CEARÁ-BRAZIL***

RISCOS E CONFLITOS NA FORMAÇÃO DE CAPITAL HUMANO PARA ATUAR
NA ÁREA DAS TIC (TECNOLOGIAS DA INFORMAÇÃO E COMUNICAÇÃO) NO ESTADO DO CEARÁ-BRASIL

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ABSTRACT

The study presents the results of quantitative diagnoses of human capital formation in information and communications technology (ICT) in higher education institutions (HEIs) based in the State of Ceará in Brazil. The methodology employed uses the information contained in the Higher Education Census (1995 to 2019) and in INEP's Manual for the Classification of Undergraduate and Sequential Courses (CINE Brazil), plus the information provided in the e-MEC database of the Brazilian Ministry of Education, combined with information on sectors of economic interest (ICT clusters) defined by government bodies (SEDET, ADECE and IPECE) and the Observatory of the Federation of Industries of the State of Ceará (FIEC). Descriptive statistical and trend analyses of future scenarios (2020 to 2040) were carried out using ARIMA and SARIMA models. The results show that human capital was trained in the region in the last decade (2010 to 2019) at HEIs located in the metropolitan region of the capital of the state of Ceará. The findings also made it possible to highlight the undergraduate courses that require greater attention and coordination between the public authorities and the productive sector to guarantee sustainability and identify the risks of human capital formation for the development of the region's economy.

Keywords: Human capital formation, information technology and communication, diagnoses and risks.

RESUMO

O artigo apresenta os resultados dos diagnósticos dos quantitativos da formação de capital humano na área das Tecnologias da Informação e Comunicação (TIC) nas Instituições de Ensino Superior (IES) em funcionamento no Estado do Ceará no Brasil. A metodologia empregada usa as informações contidas no Censo da Educação Superior (1995 a 2019) e no Manual para Classificação dos Cursos de Graduação e Sequenciais (CINE Brasil) do INEP, mais as informações contidas no cadastro e-MEC do Ministério da Educação do Brasil, articuladas com as informações dos setores de interesse econômico (clusters das TIC) definidas pelos órgãos governamentais (SEDET, ADECE e IPECE) e pelo Observatório da Federação das indústrias do Estado do Ceará (FIEC). Foram realizadas análises estatísticas descritivas e de tendências de cenários futuros (2020 a 2040) através dos modelos ARIMA e SARIMA. Os resultados apontam que o capital humano foi formado na região na última década (2010 a 2019) em IES localizadas na região metropolitana da capital do Estado do Ceará. Em adição, foi possível destacar os cursos de graduação que necessitam de maior atenção e de articulações entre o poder público e o setor produtivo para garantir a sustentabilidade e identificar os riscos da formação de capital humano para o desenvolvimento da economia da região.

Palavras-chave: Formação de capital humano, tecnologias da informação e comunicação, diagnósticos e riscos.

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Introduction

The state of Ceará is located in the semi-arid region of northeastern Brazil, with one hundred and eighty-four municipalities spread across fourteen planning regions, according to the Institute of Research and Economic Strategy of Ceará (IPECE). In 2013, the State Government of Ceará published a resolution determining that all sectors linked to the bodies and entities of the state's public administration needed to carry out strategic planning for the use of Information Technology and Communication (ICT). This initiative evolved into the launch of the Ceará State Information Technology Strategic Plan (PETIC/CE) in 2018.

The PETIC/EC not only aims to modernize the computing structure of Ceará's public sector but also indicates changes in operating models and strategies, as well as the development of new functions, skills, and competencies through the training of professionals at various levels, training, and continuing education.

As a result, public and private entities have joined forces to advance human capital training and the development of new technologies to contribute to the region's economic development. One of these actions was the launch of Iracema Digital in 2019 (SECITECE, 2019), a private non-profit organization that aims to bring together the government, universities, research institutions and other IT players to create an environment that gives visibility to the potential for research, development and innovation that exists in Ceará state.

These initiatives for developing ICT in the region were motivated by the establishment of the "Digital Belt", which was launched in November 2010. An optical fiber network planned to be implemented over 3,500 km in length, connecting the 184 municipalities of Ceará State in a broadband internet network (Lima, 2020).

These actions have generated the expectation of generating around 10,000 direct jobs in the ICT area, through the attraction and establishment of large national and regionally prominent companies. This has also generated the need for coordination between public entities and the private sector to plan public policies for training, attracting, and establishing specialized human capital to work in the various positions demanded by companies operating in this sector of economic interest (Fontenele, 2021).

In this context, the ICT sector is classified as being of economic interest in the structuring projects of the Ceará State Development Agency (ADECE), in the Economic Clusters for Innovation Program of the Secretariat for Economic Development and Labor (SEDET), in the Industry Observatory of the Federation of Industries of the State of Ceará (FIEC) and the State Plan for Science, Technology and Innovation (PECT&I).

In the reports issued by these public and private entities, there are suggestions for mutual coordination to obtain diagnoses and scenarios for the formation of human capital in the Higher Education Institutions (HEIs) operating in the region, and to plan public policies to encourage this sector. This includes the research and innovation activities to be developed in this area, which is of great importance for the economic and social development of the state of Ceará.

This includes the aim of this study, which is to present the diagnoses from 1995 to 2019, and future scenarios for the period 2020 to 2040 of the formation of human capital in the undergraduate courses in operation at Ceará's HEIs from the perspective of the cluster of economic interest of Information and Communication Technologies (ICT). Data on graduates from undergraduate courses was obtained from the Anísio Teixeira National Institute for Educational Studies and Research (INEP), and data on authorizations for these courses was obtained from the Ministry of Education's National Register of Higher Education Courses and Institutions (e-MEC).

The hypothesis is that the results of this study will provide an assessment of the risks of human capital formation in this area of knowledge and may help in the development of public policies for the future formation, attraction, and settlement of graduate professionals in the state of Ceará. In addition to giving visibility to the information so that it can be made available to public managers and investors, with a focus on improving and expanding collaboration and scientific and technological development, as well as the competitiveness of the region's productive sectors.

The importance of human capital formation in the regional economy

Following a worldwide trend, this study includes an assessment (diagnosis) and forecast of the formation of human capital in Higher Education Institutions (HEIs) operating in the state of Ceará in Brazil, specifically in Information and Communication Technology (ICT).

There is a definition of human capital in the literature that is generally accepted in economic theory: it is the complex of knowledge that is most important for the sustainable development of the economy. Thus, it is mentioned that the main unit of human capital is the member of the creative class. To quantify the formation and accumulation of this capital, it is used techniques with mathematical models or statistical methods as well as economic and human analysis, make it possible to associate the effectiveness of investments (public and private) in the generation of this capital (Gadzhiev *et al.*, 2020).

In addition, it is important to note that the world literature contains studies that present diagnoses

and projections of human capital formation, as well as reflections on the importance of investments and coordination between public and private entities to achieve sustainability in the formation of this capital and, consequently, to reduce the risks in the formation of this capital, which is important for the economic and social development of countries (Agüero *et al.*, 2021; Londar *et al.*, 2020; Podra *et al.*, 2020; Borshch and Krusir, 2019; Löning, 2018; Bayraktar-Saglam, 2016).

Olievskaya *et al.* (2020) recommends that investments in human capital formation should take place from the earliest stages of education. Based on the European experience of financing education for sustainable human capital development, they provide practical recommendations for financing education for sustainable regional human capital development in Ukraine and other European countries. The authors also point to the objective need for cooperation between international organisations and state institutions to finance quality and accessible education, articulated in governance models that provide for the regional development of this capital, proving the impact of investments in education on the regional and sustainable economic growth of these countries.

In this context, Kalinicheva (2021) identified areas of economic potential in Ukraine that are linked to global challenges and require regional investments to ensure the quality of higher education and the formation of qualified and innovative human capital. The study highlights the need to modernize the country's higher education system, including the internationalization of educational spaces for the formation of human capital. This is intended to indicate the adoption of new professional competences and skills with intellectual and innovative potential that should contribute to local economic development during globalization. The author also states that these investments can increase the country's economic competitiveness.

Tretyakova *et al.* (2022) mention that the formation of human capital is the only source of resources for innovative changes in the process of regional economic development. Thus, the formation of this capital should be considered the basis for the main innovative changes in the growth of the modern economy. In a study carried out with information from the Russian Federation, they determined the importance of this indicator as the main driving force for ensuring sustainable sectoral development and for increasing the innovative activity of all participants in the economic system of this region.

Bayraktar-Saglam (2016) studied the relationship between investments in human capital formation and regional economic growth using information from ninety countries from 1970 to 2010, and through mathematical modelling showed that there are different links between this variable

and regional economic growth in developing and OECD countries, where the evidence indicates that university education is the source of technological progress and promotes economic growth in these countries in the face of globalization processes in the world economy.

In relation to the impacts of globalization and human capital formation on economic development on a regional scale, Zaidi *et al.* (2019) showed that there is a long-term relationship between these variables, with a positive and significant impact of globalization on the formation of qualified human capital, and thus on the financial development of European Union countries.

Such impacts may be related to the characteristics of the relationship between the level of digital technologies and the development of human capital in these regions, particularly with the emergence of modern society (Society 5.0). Thus, Stryzhak (2022), making use of statistical metrics and cluster analysis, showed that the level of human capital development in a region is associated with the level of digital technology development in society and that the results obtained from studies of this nature can assist in the development and implementation of public policies to support the planning of the formation of this capital taking into account regional factors and characteristics.

The study by Kozlov *et al.* (2019) presents the difficulties faced in the formation and development of human capital in the Arctic region, based on an analysis of the competencies and skills taught in higher education that are associated with knowledge of ICT, skills needed by future professionals in modern society. Using a sample of students from Murmansk Arctic State University, they identified that socio-economic vulnerability hinders the development of digital skills. It should be mentioned that the results of this study agree with the conclusions presented by Borshch and Krusir (2019), in which they indicate that the formation of a system for training and developing personnel using ICT can help to build qualified human capital and provide better jobs and wages for the population, and thus reduce the risk of socioeconomic vulnerability in a region.

The relationship between public spending on human capital formation, particularly in ICT, and economic growth in Nigeria was presented by Olopade *et al.* (2020). The study concludes that there is a causal relationship between the variables, although economic growth has been observed with the increase in human capital formation in the country and indicates that the hypothesis for this result is the failure to identify the competencies and skills demanded by this area of knowledge in international markets.

So, in agreement with the authors mentioned above, we highlight the importance of developing human

capital for the development of modern society, and the importance of studies into the demand, quantification and forecasting of this capital. Which can help to guide investments in the education system (public and private) and in the production of Science, Technology, and Innovation (ST&I), as well as contributing to the strategic management of this capital and reducing the risks associated with the sustainability of this training.

Materials and Methods

The sectors of economic interest in Ceará state, known as economic clusters, were defined in this study by cross-referencing information obtained from publications by the Economic Innovation Clusters Project of the Secretariat for Economic Development and Labor (SEDET), the Ceará State Development Agency (ADECE), the Ceará Institute for Economic Research and Strategy (IPECE), the collaborative platform Project Ceará 2050 and the Observatory of the Federation of Industries of Ceará (FIEC).

The objective methodology used in the study is made up of two stages: a diagnostic stage and a future trend (“perspective”) stage for projecting the training of qualified human capital to work in the various sectors in the ecosystem of research and production of ST&I and Ceará’s productive and economically strategic sectors.

The information used to quantify the formation of human capital in the area of ICT in the undergraduate courses of the HEIs (public and private) operating in the state of Ceará (TABLE I), is contained in the Higher Education Census of the Anísio Teixeira National Institute for Educational Studies and Research (INEP) and in the Manual for the Classification of Undergraduate and Sequential Courses (CINE Brasil) from the Brazilian Ministry of Education.

TABLE I - Undergraduate courses currently being offered by HEIs in the State of Ceará-Brazil.

TABELA I - Cursos de graduação em funcionamento nas IES do Estado do Ceará-Brasil.

ICT Cluster	Undergraduate course
	System Analysis
	Analysis and System Development
	Informatics
	Computer Science
	Digital Design
	Graphic Design
	Computer Engineering
	Teleinformatics Engineering
	Information Technology Management
	Digital Games
	Computer Networks
	Radio, TV and Internet
	Information Systems
	Digital Media and Systems
	Internet Systems
	Computational Mathematics

According to the INEP’s online portal, CINE Brazil is based on the International Standard Classification of Education, adapted for undergraduate and sequential courses in operation in the country. It references the methodology of the International Standard Classification of Education - Fields of Education and Training (ISCED-F 2013), with adjustments to the Brazilian educational reality. The INEP further states that ISCED is produced by the UNESCO Institute for Statistics to obtain national educational statistics in a standardized format that can be compared to metrics from other regions, enabling the categorization of courses by levels of education and fields of study.

Statistical analyses were carried out on the historical series (from 1995 to 2019) of the annual totals of graduates from the undergraduate courses authorized to operate at the HEIs (average, standard deviation, trend, seasonality, among others) and quantitative mathematical modeling using the ARIMA and SARIMA models (Pellegrini, 2000; Gaither and Frazier, 2002; Teixeira, 2004; Wanke and Julianelli, 2006), with 95 % statistical significance, to obtain projections of future human capital trained to work in the ICT sector in Ceará. In this way, information was obtained to guide future discussions with interested entities (public and private) on the sustainability and risks pointed out for this sector of economic interest.

The ARIMA and SARIMA models were proposed by George Box and Gwilym Jenkins in the early 1970s (Box *et al.*, 1994) and are used as tools for forecasting variables in a wide range of scientific fields (Rinaldi, 2005). In general, they use the inference of self-correction between the variables and the variable to be predicted or estimated (trend), combining them with simple or multiple regression mathematical equations depending on how many variables are correlated.

Contained within the generalities of these models (Box-Jenkins) is the simple exponential damping model, which uses weighting to predict future values or future trends (Wanke and Julianelli, 2006), used in this study.

The accuracy of these models is related to the definition of the values of the damping coefficients (Wanke and Julianelli, 2006), so the performance of this estimation method in the future can be assessed with statistical metrics commonly used in the literature and which are used in the diagnostics of this study.

Figure 1 shows the representation of the product obtained by applying the methodology applied in this study. Thus, for each series of undergraduate graduates, diagnoses were made. For courses with sufficient information, forecast scenarios were obtained through mathematical modeling.

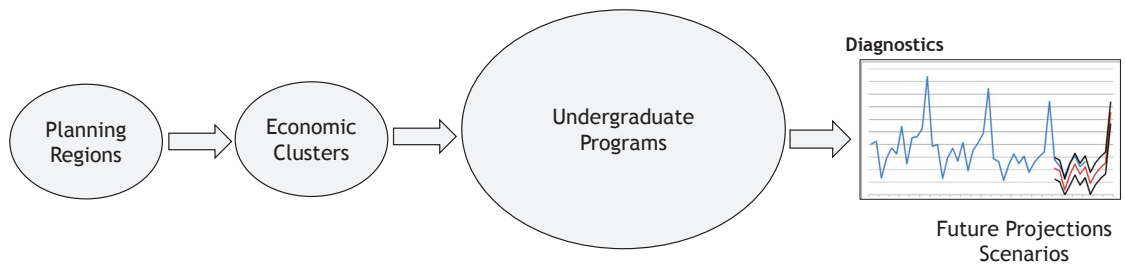


Fig. 1 - Schematic diagram of the methodology applied in the study.

Fig. 1 - Ilustração da aplicação da metodologia aplicada no estudo.

Results and discussions

The quantitative numbers of human capital graduates from ICT undergraduate courses offered at Ceará's HEIs (public and private) between 1995 and 2019 (fig.2). The courses with the highest number of graduates are Systems Analysis and Analysis and Systems Development (4,095), Informatics and Computer Science (2,896), Computer Networks (2,507) and Information Systems (2,353).

The remaining courses in this cluster have lower numbers of graduates. This is usually because some of them have only been registered recently in INEP's Higher Education Census and the Brazilian Ministry of Education's National Register of Higher Education Courses and Institutions (e-MEC). They are Digital and Graphic Design (664), and Computer Engineering (421). Others no longer graduate professionals, as exemplified by the Computer Science degree course that ran from 1995 to 2007.

Concerning the diagnosis of future human capital training scenarios in the ICT area for the training courses in Systems Analysis and Analysis and Systems Development,

The INEP records show a growth trend over the period (2005 to 2019) with 401 graduates in the last year of the analysis and the forecast scenarios (2020 to 2040) maintained the positive characteristic of human capital formation (fig. 3a).

Information on Informatics and Computer Science degrees shows there is high inter-annual variability with a growing trend in the number of graduates in this area, reaching 178 graduates in 2019 (fig.3b). The forecast scenarios (2020 to 2040) capture the characteristics of the graduate series and show high inter-annual variability, with two of the three forecast scenarios showing a downward trend in the number of graduates in this area. It is worth mentioning that this situation deserves attention, as the ICT Cluster's demand for professionals is growing every year on a global, regional and local scale, and thus requires coordination between the Secretariat for Science, Technology and Higher Education (Secitece) and the sectors concerned to discuss the future of training, attracting and retaining human capital in this area of knowledge for the development of the state of Ceará.

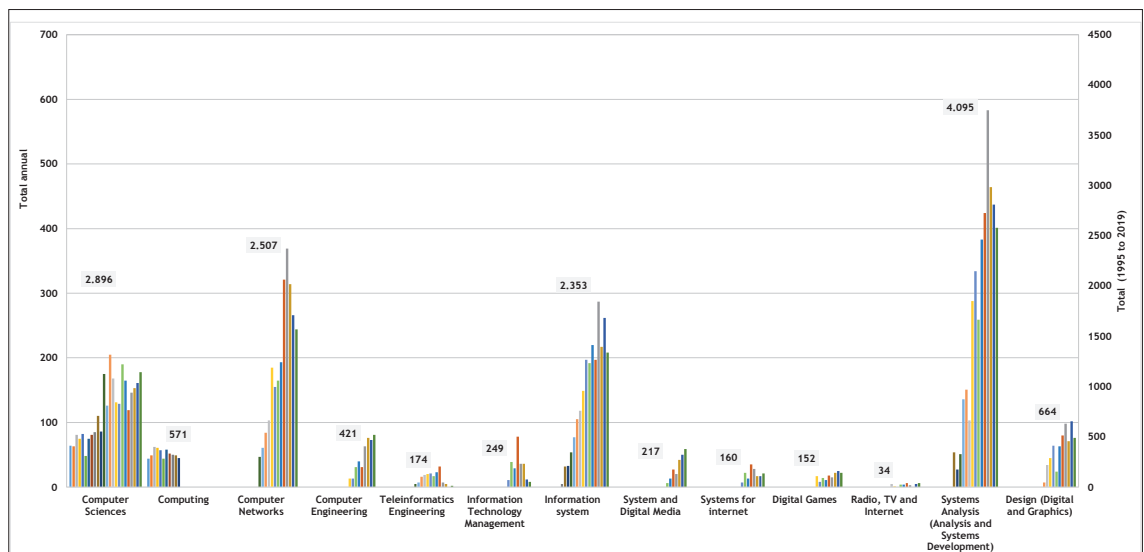


Fig. 2 - Human capital trained at Ceará's HEIs - ICT Cluster.

Fig. 2 - Capital humano formado nas IES do CE - Cluster das TIC.

The design degrees (Digital and Graphics) show a positive trend and growth in the number of graduates in the diagnosis, graduating 76 professionals in 2019, and in the forecast scenarios (fig. 3c). The Computer Engineering degree shows an upward trend with low variability in the number of graduates from 2011 to 2019, graduating 81 professionals in 2019. The forecast scenarios follow this growth trend and the variability characteristics of human capital formation in this area (fig. 3d).

For the Teleinformatics Engineering degree course, INEP records show a low number of graduates from 2007 onwards, with a downward trend, reaching just two graduates in 2019. The forecast scenarios also indicate a decrease in these numbers. These results draw attention to the need for coordination between the sectors concerned to discuss public policies and private investment in human capital training, given that the deployment of the 5G internet is likely to require many professionals with this qualification profile (fig. 3e).

The Technology and Information Management degree course has a similar situation to the aforementioned, with a tendency towards a decrease in information capital in the diagnosis and forecast scenarios, as well as the need for discussions with those interested in graduates with this profile (fig. 3f).

The Digital Games degree has had a low number of graduates in INEP's records since 2011, with twenty-two in 2019. The forecast human capital formation scenarios show, as do the diagnoses, high inter-annual variability with an upward trend (Figure 3g). The Radio, TV and Internet degree course, like the Digital Games degree course, has a low number of graduates over the 2011-2019 period, with six professionals in 2019. Characteristics captured by the forecasting method used in this study (fig. 3h).

It should be noted that of the four courses analyzed (Teleinformatics Engineering, Information Technology Management, Radio, TV and Internet, and Digital Games), three of which are in operation at private HEIs and one at a federal public HEI, there is a tendency for human capital training to decline in the future. As such, since these are important training profiles for the development of the ICT Cluster, there is also a need for public authorities to act with the sectors concerned to promote discussions on training, attracting, and retaining professionals with these training profiles for the state of Ceará.

Undergraduate training in Computer Networks and Computer Network Management (fig. 3i) saw the first graduates in 2007, reaching 244 graduates in 2019. A positive and sustainable trend in the training of professionals is also captured by the forecasts of future scenarios for the training of human capital in this area of knowledge.

The Information Systems degree course (which has been running since 2004) graduated 208 professionals in 2019 (fig. 3j), showing high inter-annual variability, which is also observed in the forecast scenarios. The first graduates from the Systems and Digital Media degree course were in 2013, and 59 in 2019, with a positive trend in the forecast scenarios (fig. 3k).

Finally, the degree course in Internet Systems has a low number of graduates and future scenarios that follow these characteristics (fig. 3l), pointing to the need for support, public policies, and private investment to reduce the risks of forming professionals in this area.

Undergraduate courses currently running at HEIs in Ceará State

Figure 4 shows the distribution of undergraduate courses listed in INEP's latest Higher Education Census (2019) and in the e-MEC register that can contribute to the training of human capital to work in the sectors of this cluster. It can be seen that the only undergraduate course in System Analysis is based in a private HEI in the Metropolitan Region of Fortaleza (RMF) (fig. 4a), the capital of the State of Ceará. The undergraduate course in Analysis and System Development has twenty active registrations, nineteen of them in private HEIs and one in a Federal Public Institution (PF-HEI), fifteen of which are in the RMF (fig. 4b). The Computer Science degree program has eighteen courses, eight in private institutions and ten in public HEIs, eight in federal institutions and two in State Public Institutions (PE-HEI); the RMF has ten of these courses (fig. 4c).

The Graphic Design and Digital Design courses are in private institutions. There are four degree courses in Graphic Design, three of them in the RMF (fig. 4d) and one Digital Design course in the inland state of Ceará (fig. 4e). Training in Computer Engineering is divided into two private courses and five courses at federal public HEIs, four of which are in the RMF (fig. 4f). Training in Teleinformatics Engineering has one course at a federal public HEI in the RMF (fig. 4g).

Undergraduate courses in Information Technology Management, Digital Games, RTI (Radio, TV and Internet) and Internet Systems are in operation at private HEIs. There are three Information Technology Management courses (fig. 4h), two Digital Games courses (fig. 4i) and one RTI course in the RMF (fig. 4j).

There are sixteen courses in Computer Networks, thirteen in private HEIs and three in federal public HEIs, all in the RMF (fig. 4k). There are fourteen undergraduate courses in Information Systems, ten in the private sector and four in federal public HEIs, six of which are in the RMF (fig. 4l). The two undergraduate courses in Systems and Digital Media are at federal public universities in the RMF (fig. 4m). There are three courses in Internet Systems, two of which are in the Metropolitan Region of Fortaleza/CE (fig. 4n).

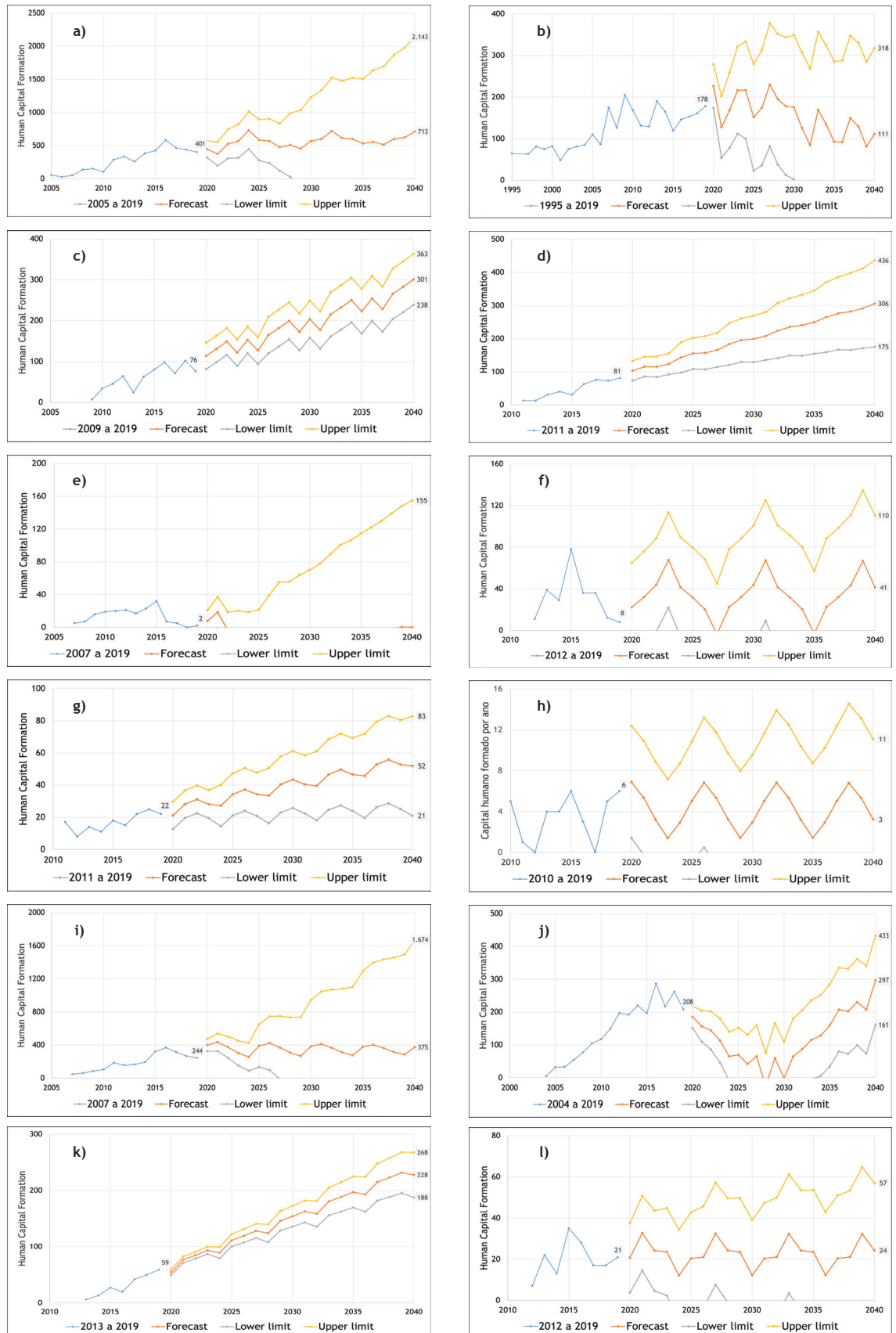


Fig. 3 - Human capital trained in undergraduate courses (1995 to 2019) and forecast of future scenarios - ICT Cluster.

Fig. 3 - Capital humano formado nos cursos de graduação (1995 a 2019) e previsão de cenários futuros - Cluster das TIC.

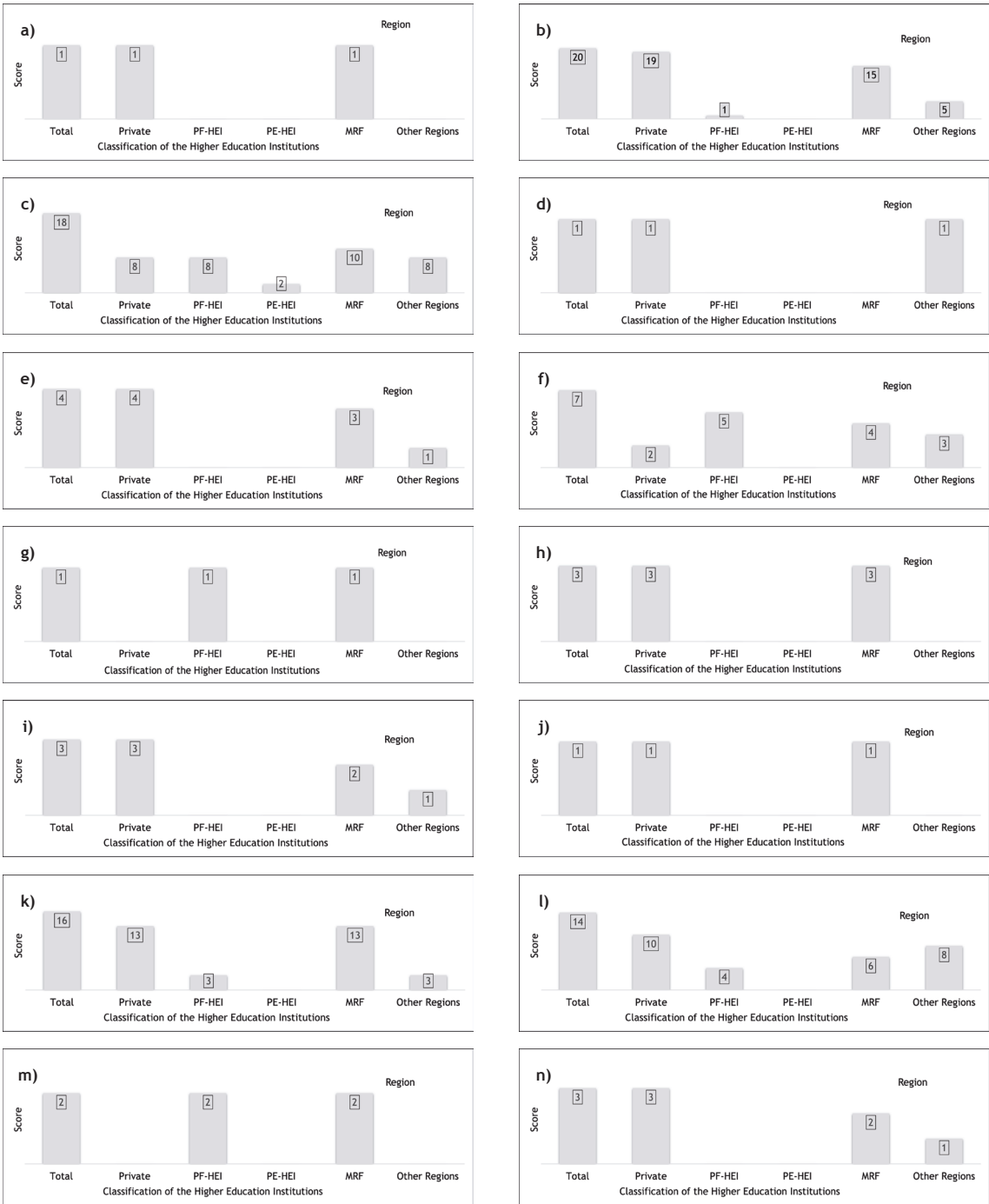


Fig. 4 - Undergraduate courses - ICT Cluster (PRIVATE - private educational institution; PF-HEI - federal public institution; PE-HEI - state public institution; RMF - metropolitan region of the capital of the State of Ceará, Brazil. Source: INEP and e-MEC (Source: INEP and e-MEC).
Fig.4 - Cursos de graduação - Cluster das TIC (PRIVATE - instituição de ensino particular; PF-HEI - Instituição Federal de Ensino; PE-HEI - Instituição Estadual de Ensino; RMF - Região Metropolitana da Capital do Estado do Ceará, Brasil) (Fonte: INEP e e-MEC).

The results indicate a concentration of undergraduate courses in ICT at public or private higher education institutions that are in operation or authorized to operate in the RMF, as a result of which there are approximately 79.5 % of diploma registrations at these HEIs. Of the fourteen thousand graduates in the period under analysis (1995 to 2019), ten thousand

are from private HEIs operating in this region, which corresponds to 71 % of the total number of graduates in this area of knowledge.

The second hub for training human capital in the field of ICT is in the southern region of the state of Ceará. During the period in question, there were approximately 1,100

graduates from courses in this field, which corresponds to 7.85 % of the professionals qualified to work in this area of knowledge.

These facts highlight the need for coordination and the development of public policies for the expansion of higher education in this area in the interior of the state of Ceará so that all the macro-regions can count on the possibility of technological development, which according to the authors can also provide economic and social development in these regions.

Conclusion

In the ICT economic cluster there is a growing demand for qualified professionals, mainly due to public and private investment in infrastructure, which has attracted large technology companies to the state of Ceará.

In terms of training human capital for this area, undergraduate programmers in Systems Analysis, Computer Science, Computer Engineering, Design (graphic and digital), Computer Networks and Systems and Digital Media stand out. It is worth noting that most of these undergraduate programmers are run by private HEIs located in the Metropolitan Region of Fortaleza (RMF), the capital of the State of Ceará.

It can be concluded that some of the undergraduate courses (Information Technology Management, Radio, TV and Internet and Digital Games) classified by the SECITECE project team as being of interest to this cluster need greater attention in the discussions and articulations to be coordinated by the secretariat with a view to sustainability and reducing the risks of training human capital to work in the vacancies offered by the technology companies setting up in the region.

Another relevant point demonstrated by the findings of this study is that the analyses (diagnoses and prognoses) confirm that there is a shortage of specialized professionals on the market, as has been widely reported in the local media. This leads to the conclusion that there are few courses on offer at Ceará's HEIs and that there is a need to discuss the specific demands of the market, as pointed out by Olopade *et al.* (2020). An example of the scarcity of ICT courses on offer associated with market demands is the absence of a degree course in Artificial Intelligence and Data Science, in the face-to-face modality and in public institutions.

Another important feature observed in this, and the other centers of economic interest investigated is the concentration of courses on offer and, consequently, their graduates in the private HEIs operating in the RMF. It can therefore be concluded that the statistical analyses and projections of future scenarios obtained in this study confirm the risk of a shortage of specialized

professionals to fill the vacancies offered by companies in the technology sector that are and have expressed an interest in setting up in the state of Ceará, bringing technological and infrastructural risks to this sector of the local economy.

In this context, the results and analyses presented in this study for the ICT sector, as well as the results being obtained for the other economic clusters (health, tourism, and renewable energies) and which will be presented in the future, will form the basis of information for discussions on the future guidelines of the Strategic Information Technology Plan for the State of Ceará-Brazil (PETIC/CE), a document that guides the implementation of public policies for regional economic development.

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