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THE IMPACT OF ICT ADOPTION ON PORTUGUESE FIRMS' PRODUCTIVITY - THE CASE OF ICT SPECIALISTS

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Abstract

This work project has the purpose of analyzing if there is an association between ICT adoption and Total Factor Productivity (TFP) on Portuguese firms. The EU digital transition is described, along with some literature and the Portuguese framework on the topic, and the individual analysis use data from Portuguese firms throughout the years 2008-2021, including a wide range of ICT topics. The individual research question presented delves into the dynamic relationship between the presence of ICT Specialists within firms and Total Factor Productivity (TFP). The findings reveal the existence of a statistically significant positive correlation between the presence of ICT Specialists within companies and their overall productivity levels. The common and overall results show that there are several different positive and significant associations between different technologies adopted and TFP, varying on firm size.

Keywords

Digital Transformation

Productivity

ICT

Specialist

Human resources

This work used data and resources provided by GPEARI (Gabinete de Planeamento, Estratégia, Avaliação e Relações Internacionais Ministério das Finanças) and INE (Instituto Nacional de Estatística).

Abbreviations

AI	Artificial Intelligence
BDA	Big Data Analytics
CAE	Classificação Portuguesa das Atividades Económicas
CRM	Customer Relationship Management
CTIC	Council for Information and Communication Technology
DESI	Digital Economy and Society Index
DII	Digital Intensity Index
DIO	Diffusion of Innovation
DMA	Digital Markets Act
DSA	Digital Services Act
EC	European Commission
ERP	Enterprise Resource Planning
EU	European Union
FTTP	Fiber to the Premises
GEE	Gabinete de Estratégia e Estudos
GPEARI	Gabinete de Planeamento, Estratégia, Avaliação e Relações Internacionai
GPT	General-Purpose Technology
GVA	Gross Value Added
ICT	Information and Communication Technology
INE	Instituto Nacional de Estatística
IoT	Internet of Things
IT	Information Technology
IUTICE	Inquérito à Utilização de Tecnologias da Informação e da Comunicação nas Empresas
NACE	European Classification of Economic Activities
NSI	National Statistical Institutes
NSS	National Skills Strategy
OECD	Organization for Economic Cooperation and Development
R&D	Research and Development
RRF	Recovery and Resilience Facility
RRP	Recovery and Resilience Program
SCIE	Sistema de Contas Integradas das Empresas
SMEs	Small and Medium-sized Enterprises
TFP	Total Factor Productivity

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COMMON PART

Introduction

European Framework on Digital Transition and Skills

We define digital transformation as the strategic adoption of digital technologies like analytics, big data, and cloud computing to significantly enhance business performance and productivity. This process also reshapes organizational operations through technology-driven evolution[1].

In its agenda "Shaping Europe's digital future", published in February 2020, the European Commission introduced the European data strategy and the White Paper on Artificial Intelligence (European Commission, 2020). The Commission's plan recognized the need to not only ensure digital transformation for the benefit of society at large but also to set up regulatory frameworks which support businesses, secure social and environmental sustainability for society, and guarantee a "digital environment that respects privacy, dignity, integrity and other rights in full transparency" (European Commission, 2020). Moreover, taking into consideration the possible interplay with the European Green Deal, the Commission highlighted the opportunity for the Information and Communications Technology (ICT) sector to undergo its own green transition (European Commission, 2020). The 2021 proposed "Path to the Digital Decade" includes four cardinal points: enhancing digital skills, building secure digital infrastructures, digitizing businesses, and modernizing public services, with a comprehensive review scheduled for 2026 to account for to new technological, economic, and societal shifts (European Commission, 2021).

Since 2014, the Commission has annually been publishing the Digital Economy and Society Index (DESI), a comprehensive assessment and measurement of the digital performance and progress of EU member states (European Commission, 2022). DESI's analysis is subdivided

[1] The rationale behind this definition is provided in the chapter "Digital Transformation" below

into four main topics: Human Capital, Connectivity, Integration of Digital Technology, and Digital Public Services. It includes countries' profiles and intends to help Member States to identify areas for action and provide analysis on key digital policy areas (European Commission, 2022). In 2022, the four leading countries were Finland, Denmark, the Netherlands, and Sweden (European Commission, 2022).

The Commission's 2022 Digital Economy and Society Index report outlines a strategic agenda focused on bolstering digital competencies across the continent. By 2030, the Commission seeks to provide at least 80% of its population with basic digital skills and increase the number of ICT specialists to 20 million, equivalent to approximately 10% of the total employment, maintaining an equitable gender balance (European Commission, 2022). Further, the European Skills Agenda, initiated in 2020, aims at empowering individuals and businesses with superior skills and has set a target of 70% of adults aged 16-74 having at least basic digital skills by 2025. In pursuit of this goal, the agenda fosters large-scale partnerships with major industries, such as automotive, consumer goods, and digital. The Commission lends support to Member States in formulating national skills strategies in association with the Organization for Economic Cooperation and Development (OECD), with 13 states having begun the development process and six already implementing theirs (European Commission, 2023). Portugal, which initiated the Building a National Skills Strategy (NSS) project under its XIX government, is currently in the implementation stage. In 2017, the XXI Constitutional Government collaborated with the OECD on the NSS Action Phase, which involved comparative analysis, inter-ministerial teamwork, and extensive stakeholder engagement to identify concrete actions for improving adult learning (OECD, 2018).

As of June 2023, 54% of EU citizens exhibit basic digital skills, a figure that is expected to rise significantly in the coming years. The proliferation of the internet has been a catalyst in this digital revolution. From 2007 to 2021, internet subscription surged from 53% to 92% across the union, marking an 91% increase. Nonetheless, disparities in internet connectivity remain, with Bulgaria and Greece trailing at the lower end of the spectrum. Rural areas are less connected than urban centers; Portugal's rural zones, for instance, registering less than 80% of internet subscriptions (European Commission, 2022).

Moreover, the Commission's analysis discloses significant discrepancies across other various socio-demographic backgrounds. Younger populations exhibit more digital proficiency than their older counterparts; individuals in rural areas demonstrate lower basic digital skills (46%) than those in urban areas (61%). Education also plays a central role, with 78% of individuals with high formal education displaying basic digital skills this figure drops to 50% among those with medium formal education and further decreases to 32% among individuals with no or low formal education. In the active labor force, accounting for both employed and unemployed individuals, 62% possess basic digital skills. However, among the unemployed, this figure drops to only 49% (European Commission, 2022).

Economically, the EU is investing an impressive €65 billion in training initiatives. Germany and France lead in terms of ICT specialists, accounting for 22.5% and 13.9% of the EU's workforce respectively. With digital skills deemed essential for both businesses and workforces, the Commission stresses the "critical shortage of digital experts" that even the front-running member states encounter. On the e-commerce side, the Commission has introduced the Digital Markets Act (DMA) and Digital Services Act (DSA) to strengthen digital rights and establish fair competition. It is noteworthy that approximately one in five EU small and medium-sized enterprises (SMEs) conducted online sales in 2021, contributing to 12% of the total turnover (European Commission, 2022).

The ICT sector in the European Union has shown considerable development over recent years. The sector's value-added rose from €590 billion in 2018 to €642 billion in 2019. While

2020 likely experienced a slight drop due to the COVID-19 pandemic, it was anticipated that 2021 would see a rebound to an impressive €666 billion. A closer look reveals a shift within the sector's sub-sectors; manufacturing's share declined from 29% in 2019 to an estimated 21% in 2021, while services saw an uptick from 71% in 2019 to a projected 79% in 2021. Telecommunications remained steady at 8% (Cardona, et al., 2022).

ICT employment also trended upwards, with 6.1 million workers in the sector in 2019 and an estimated 6.2 million by 2021. Similar to the value-added trend, employment in manufacturing dropped from 10% in 2019 to a predicted 8% in 2021, while the services sub-sector boosted its share from 90% in 2019 to a projected 92% in 2021. Telecommunications maintained its share of 14% (Cardona et al. 2022).

Productivity in the ICT sector per person employed showed a steady rise, from €105 thousand per person in 2019 to an estimated €107 thousand per person in 2021. Sub-sector data mirrored this trend with manufacturing productivity increasing from €89 thousand per person in 2019 to an estimated €97 thousand per person in 2021. Service sector productivity slightly increased from €106 thousand per person in 2019 to an estimated €108 thousand per person in 2021. Telecoms also followed suit with an increase from €173 thousand per person in 2019 to an estimated €174 thousand per person in 2021. These figures demonstrate the resilience and potential of the ICT sector within the EU, even in the face of global challenges like the Pandemic (Cardona et al. 2022).

The digital transition by firms is supported by a variety of technologies and extensive infrastructures. To assess their diffusion, the Digital Economy and Society Index, within the dimension of "Integration of digital technology", measures the degree of digital technologies adoption by enterprises. These range from more simple products, such as electronic information sharing and the use of social media, to more complex ones, such as artificial intelligence (AI), big data analytics, and cloud computing (European Commission, 2022).

Based on the number of digital technologies they have implemented (out of a set of 12), a score of the Digital Intensity Index (DII) is assigned to firms. In 2021, more than half (56%) of European firms had a basic level of digital intensity – achieved with the usage of four of such technologies. In general, a greater share (88%) of large enterprises (250+ persons employed) reach a basic level on the DII compared to small and medium-sized enterprises (SMEs) (55%). Only around 21% of SMEs have reached a level of high (7-9) or very high (10+) digital intensity. To the contrary, almost 4 out of 5 SMEs show low or very low DII scores (less than 7 technologies used) (Eurostat, 2022).

A clear digital divide is then present in the EU, depending not only on the size of the enterprise but also on the sector in which it operates. Large companies are more likely to adopt digital technologies – especially more advanced ones – compared to small-to-medium enterprises, which, nonetheless, account for 99% of EU businesses. In 2021, only 7% of European SMEs used at least one type of AI system, whereas, among large companies, 29% made use of the technology. Given the large number of SMEs relative to large enterprises, the overall rate of adoption in the EU was 8%. With respect to big data analytics, in 2020 14% of companies (with 10+ employees) analyzed data internally or externally; like the case of artificial intelligence, more large firms make use of the technology relative to smaller ones (34% vs 14%). Unlike other advanced digital technologies, cloud computing services have been adopted more extensively – with 41% of companies using these products in 2021. Although they significantly lag behind large enterprises (which show a cloud computing purchase rate of 72%), 40% of SMEs have purchased cloud computing services. Analogous differences can be found when analyzing the adoption rates across sectors. For instance, the ICT sector relies much more on this technology, with 74% of enterprises purchasing it compared to 40% in manufacturing (Eurostat, 2021)

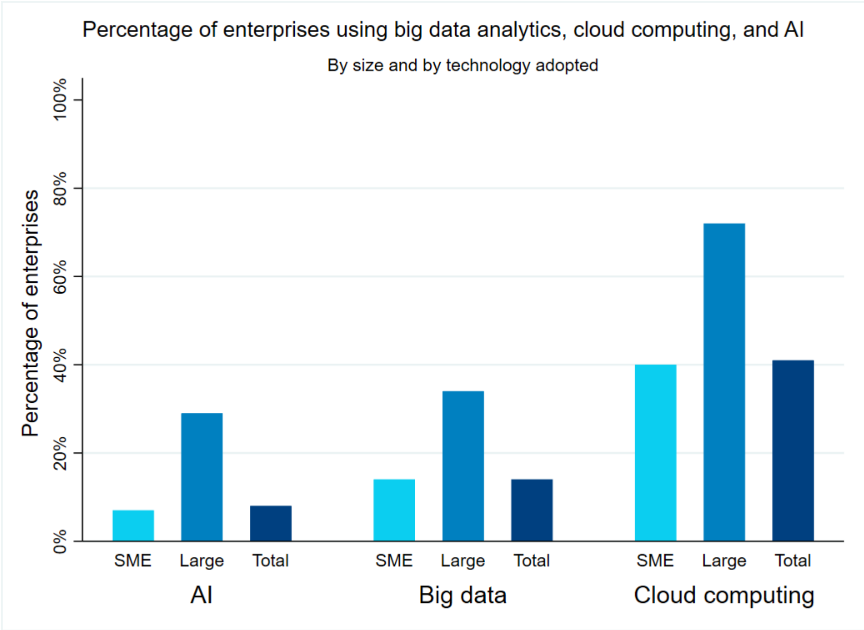

Figure 1. Percentage of enterprises using big data analytics, cloud computing and AI; Source: Eurostat

The Portuguese case

In 2022, according to the Digital Economy and Society Index (DESI), Portugal ranked in the fifteenth place out of the 27 countries of the European Union (EU), just below the average. Although Portugal scores slightly above the EU average in most of the topics analyzed by the Index, a poorer performance in the Connectivity area drives down the country in the overall ranking. 5G coverage is one of the main unsatisfactory indicators, with Portugal lacking any 5G coverage in 2021 - compared to the European average of 66%. The country has strong positive indicators regarding AI usage by enterprises (17% vs 8% of the European average), and Fiber to the Premises (FTTP) coverage (88% vs 50%). The percentage of graduates in ICT fields, as seen in Table 1, is lower than the EU average (2.6%, compared to 3.9%). However, the percentage of ICT specialists in employment in Portugal is slightly higher than the EU value. This increase in ICT specialists can be seen as a positive trend for the future, as digital transformation and overall ICT sector is of increased importance, giving Portugal an opportunity to compete and match the digital skills with other international labor markets (European Commission, 2023)

	Portugal DESI 2020	Portugal DESI 2021	Portugal DESI 2022	EU DESI 2022
1a1 At least basic digital skills % individuals	**NA**	**NA**	**55%** 2021	**54%** 2021
1a2 Above basic digital skills % individuals	**NA**	**NA**	**29%** 2021	**26%** 2021
1a3 At least basic digital content creation skills[4] % individuals	**NA**	**NA**	**61%** 2021	**66%** 2021
1b1 ICT specialists % individuals in employment aged 15-74	**3.5%** 2019	**4.0%** 2020	**4.7%** 2021	**4.5%** 2021
1b2 Female ICT specialists % ICT specialists	**18%** 2019	**21%** 2020	**21%** 2021	**19%** 2021
1b3 Enterprises providing ICT training % enterprises	**28%** 2019	**23%** 2020	**23%** 2020	**20%** 2020
1b4 ICT graduates % graduates	**2.2%** 2018	**2.3%** 2019	**2.6%** 2020	**3.9%** 2020

Table 1: Human Capital Indicator, Digital Economy and Society Index (Portugal, 2022)

Despite all the improvements that Portugal has been doing in the past years, the county still has some catching up to do. Namely, as seen in Figure 3, Portugal still lags behind in the spending on Research and Development (R&D), being far below – close to half - the OECD average (close to 1.5% of GDP vs the OECD average of close to 3%). More specifically, regarding the R&D spending in the ICT sector, Portugal is placed in an even worse position, with less than 0.2% of the budget being placed in the ICT sector. Countries such as the United States (US), Japan and Sweden are some of the countries that lead this indicator, setting the OECD average at 0.4% of GDP (OECD, 2021).

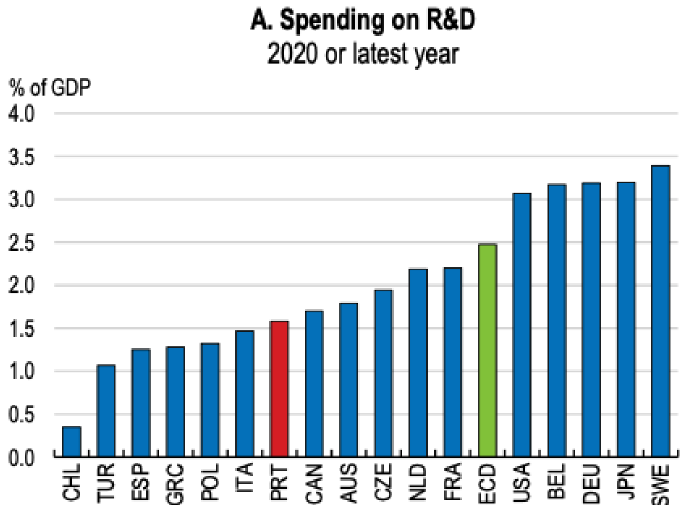

Figure 2: Spending on Research and Development (Source: OECD, 2021)

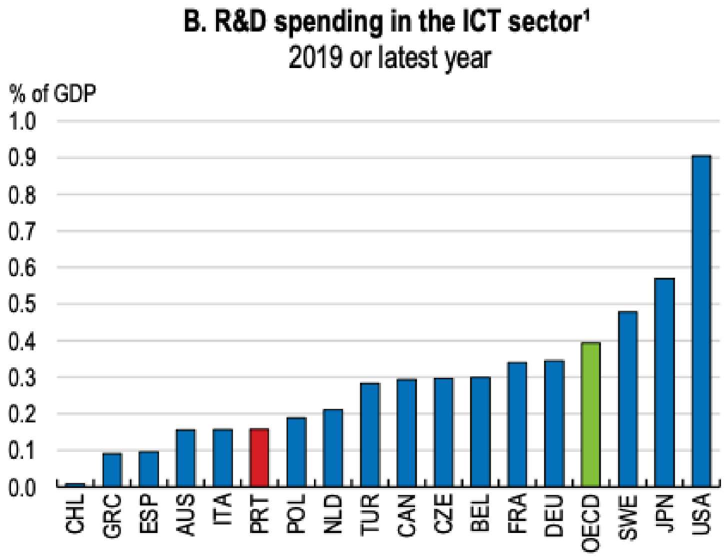

Figure 3: Spending on Research and Development in the ICT sector (Source: OECD, 2021)

The following figure (Figure 4) shows how both Portuguese Small and Medium Enterprises (SMEs) and large firms are performing on four ICT indicators, compared to the EU28[2] average, and to the best performer. Firstly, almost all the Portuguese enterprises use some type of ICT security measure which is in line with the best performer and above the EU28 average. Secondly, 80% of the Portuguese large firms have an ICT security policy, being positioned close to the EU average. However, in comparison to the best performer, there is still room for

[2] The data is from 2019, when Great Britain was still part of the European Union.

improvement. The same applies for SMEs, where only close to 30% of them have this security policy (comparing to close to 60% of the top performer, and close to 40% of the EU average) (OECD, 2021).

Portugal is also behind on enterprises having document(s) on measures, practices, or procedures on ICT security. The frame is similar to the previous one: while Portuguese firms are approaching the European average, especially the largest ones, Portugal still lags behind, when compared to the best performers of this indicator. Finally, on enterprises that make employees aware of their obligations in ICT security related issues, Portugal is slowly catching up to not only the EU average, but also to the best performer. Around 90% of the Portuguese large firms are making their employees aware, and, slowly, so are the SMEs (OECD, 2021).

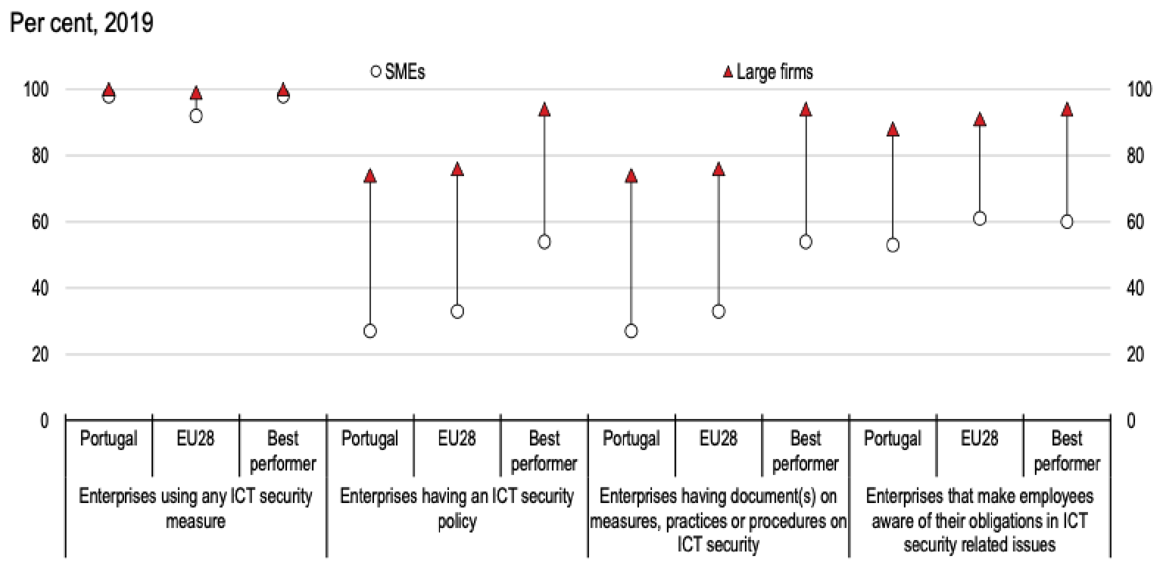

Figure 4: Adoption of Digital Security measures among SMEs and Large Firms (Source: OECD, 2021; EUROSTAT, 2021)

Overall, there is still room for improvement regarding the Portuguese performance on digitalization, and in the ICT sector. In several indicators, although close, the country is still not above the EU average. This shows that the right investment and the providing of the right set of skills to employers and employees can turn this scenario around, boosting the Portuguese case for digitalization and productivity.

In 2016, the Digital Economy and Society Index placed Portugal in the 14th place, above the EU average. The country was the second European country with the most progress from 2015 and 2016 (European Commission, 2016). Among the several indicators studied in this index, there was a clear improvement in broadband network coverage, online public services, and business digitalization. However, between 2016 and 2021, Portugal saw itself falling behind, going from the 14th to the 19th place in just five years (European Commission, 2021).

Until 2020, the European Commission noted the low digital literacy of the Portuguese population and the overall lack of digital skills as one of the major challenges the country was facing. On that year, and although Portugal made significant progress in that area, there was still a concern regarding the use of internet services and overall human capital (European Commission, 2020). There was a steady rise from 2020 to 2021, improving three steps in the European placement (from the 19th to the 16th place), with important actions being taken on increasing the proportion of ICT specialists in the country, and on improving the basic digital skills to its population.

In the past years, the Portuguese government has developed several initiatives to improve the country's performance in digital transformation. Giving the right set of digital skills to both firms and the workers has been a priority, with the creation, among several others, of a National Initiative for Digital Skills, Portugal INCoDe.2030, in 2017, and a governance structure - the Council for Information and Communication Technologies (CTIC). The goal is to give the population the opportunity to further develop their digital skills, with the purpose of facilitating the fast adoption of ICT technologies.

Adding to these initiatives, Portugal's Action Plan for Digital Transition, created in 2020, focuses on three different pillars of action: Capacity building and digital inclusion; Businesses' digital transformation; and public services' digitalization. Regarding the second pillar, it is crucial to note that aiding Portuguese firms in their digital transformation can boost their competitiveness in a globalized market, improving the Portuguese economy. Among the different measures, support for investment and training take on as two of the most important ones (Ministério da Economia e Transição Digital, 2020).

Context

This work project was developed with the support of the Gabinete de Planeamento, Estratégia, Avaliação e Relações Internacionais (GPEARI). GPEARI is the Office of Economic Research and International Affairs of the Ministry of Finance, and its mission consists in: supporting policy making and strategic and operational planning, ensuring, directly or under its coordination, international relations; and monitoring and evaluating the implementation of policies, planning tools and the outcomes of the organization and management systems, in conjunction with other ministry services (GPEARI, 2023).

To conduct the mentioned activities, GPEARI collaborates with different authorities and gathers information from various sources. It collaborates with governmental agencies and academic organizations to conduct research papers and assessments on specific topics, such as the impact of structural reforms (ex-ante and ex-post assessment). At a national level, GPEARI has been closely monitoring the Recovery and Resilience Program (RRP), conducting an ex-ante evaluation of the macroeconomic impact reforms and policies, based on QUEST III R&D model developed by the European Commission.

At the European level, GPEARI contributes to the discussion and formulation of policies and plans on various topics, including the European fiscal policy orientation for 2023, contributing to Draft the Budgetary Plan and the Stability programme, the analysis of EU different initiatives in support of Ukraine, the debate on the reform of the European budgetary framework, and the development of EU legislative initiatives in financial services (GPEARI, 2023). Additionally, at the international level, GPEARI aims at efficiently using the available financial instruments to support other states, Portuguese-speaking African countries, such as Mozambique, Cape Verde, Angola, and São Tomé and Príncipe (PALOP) (GPEARI, 2022).

Furthermore, GPEARI, together with the Office of Strategy and Studies (GEE), coordinates the National Productivity Board, a council overseeing and monitoring public policies in the area of productivity (European Commission, 2019). This Board is responsible for promoting monthly seminars, delivering annual reports, and providing research and analysis, and it supports an annual conference to foster international debate in the field. The RRP advises that each Member State dedicates at least 20% of its Recovery and Resilience Plan's total allocation to measures contributing to the digital transition (European Commission, 2022). GPEARI inserts himself in this equation, as it monitors and evaluates structural reforms and its developments.

GPEARI's goal is to understand the impact of the reforms presented, recently focusing on the policies that affect the digital transition into the Portuguese economy, as it is a crucial pillar of the Portuguese economic development strategy. They are also keen on studying the effects of such polices on productivity: examining if and how digital transition is having a positive impact in the economy, which digital technologies are more relevant, and which firm characteristics are more important for the adoption (possible heterogeneity) of it. This research and evaluation process allows GPEARI to know what policies could be promoted to boost businesses lagging behind.

Motivation

This work project aims at studying the impact of digital transformation in Portuguese firms, using large datasets from Sistema de Contas Integradas das Empresas (SCIE) and Inquérito à Utilização de Tecnologias da Informação e da Comunicação nas Empresas (IUTICE), covering most of the Portuguese firms throughout the period between 2008 and 2021. As it has five different questions of interest, this paper provides various insights on several topics, namely e-commerce, ICT staff and internet usage. All individual parts will use Regression Analysis as the main methodology, after predicting Total Factor Productivity (TFP).

The goal of this paper is to determine what influences and what are the consequences of digital adoption by Portuguese firms, in various sectors of activity, including ICT training to its employees, online platforms, and fast internet connection. With the increasing worldwide connection, and as firms need to reinvent themselves and fastly adapt to these changes in order to remain competitive, the topics on ICT usage by firms and overall digitalization is of growing importance. It is crucial to not only provide managers and clients with updated information and training, but also the workers, fundamental in the production chain.

The results show that most of the ICT adoptions can be favorable to Portuguese enterprises, benefiting from newer technologies and possible international recognition, which has several policy implications. The main one relates to continuing the Portuguese government's investment on these firms' digital adoption.

This study relates to the existing literature on digital transformation, with the advancements that have been done in the past two decades, and its impact on productivity. It also relates to the impact of Information and Communication Technology (ICT), as each individual part presents a different tool that firms may adopt, including big data, cloud computing and social media usage.

The remaining structure of this work project is as follows: the next section will present an analysis of the development in the digital transition of European countries, through the usage of Eurostat data; afterwards, a small chapter will show what the Portuguese government has been doing in what regards to this topic, showing policies and plans that have been adopted. Moreover, a review of the existing literature on digital transformation, the productivity paradox, among other topics, will be shown. After a brief description of the datasets this work project will use, all six individual parts will be presented. Finally, the main conclusions and limitations will be described, along with some policy implications.

Developments in the European Union

As previously described, the main goal of this work project is to study the possible impact of incorporating several ICT tools in the enterprises' businesses has on the productivity of these firms. This section will present the evolution of some ICT indicators, such as the employment of ICT specialists, employed people with ICT education, among other indicators. The goal will then be to compare the Portuguese case with the rest of the European Union, focusing on several countries that are described just below.

The macro data of the following analysis was taken from the Digital Economy and Society database, from Eurostat. The data concerns topics such as Digital Skills, the overall ICT sector, ICT usage in enterprises, among other indicators.

The data concerns all the European Union (EU) countries[3], in addition to other European ones, including Serbia, the United Kingdom, Norway and Montenegro. The goal of this analysis is to not only place Portugal in the European sphere, comparing it in the different topics described above, but also to perform a more in-depth analysis with a few selected countries. The countries selected were based on differences or similarities, along with both their placement in the DESI report and overall digitalization intensity. It goes as follows:

- Spain, considered to be the most similar country to Portugal. Although similar in various aspects, Spain ranked in 7th place in the 2022 DESI report (European Commission, 2022). With a strong performance on connectivity (3rd place, out of the European countries), along with serious improvements both on digital public services and integration of digital technology, the country has been having a strong investment in

[3] Austria, Belgium, Bulgaria, Croatia, Republic of Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden.

digitalization. Regarding its national Recovery and Resilience Plan, Spain has the most ambitious framework regarding its digital transition, with 28.2% of its budget allocated on this area (Parliament, 2023).

- Italy and Greece, both considered to be alike Portugal. When the 2008 financial crisis hit, these three countries were particularly negatively affected (Investopedia, 2021). Greece takes a step further as, much like Portugal, had to receive an EU/IMF bailout and implement an austerity program. On the one hand, Italy ranked 18th in the DESI 2022 report, and, although the country is advancing in some indicators, there is still a gap between it and the EU average, for instance, in the access to basic digital skills, and the percentage of digital specialists in its workforce (European Commission, 2022). On the other hand, Greece ranked 25th place, out of the 27 countries that are in this analysis (European Commission, 2022). Although it has some strengths, including the number of users of e-government services, there is still a lot of catching up relative to the other economies, mainly in terms of connectivity and SMEs with the basic digital intensity levels.
- Belgium is similar to Portugal in terms of population, having just more one million people than Portugal. Most importantly, there are also similarities in terms of digitalization. Belgium ranked 16th in the 2022 Digital Economy and Society Index, just one position below Portugal. This country presents a bigger integration of digital technology and less connectivity, but both countries present dissimilar results in the components of Digital Public Services and Human Capital (European Comission, 2022).
- France is one of the largest and most advanced economies in Europe, with a diversified industrial sector, strong investment in research and development and a robust presence in international trade (OECD, 2023). The enterprise situation in the country sees a total

of more than 4 million enterprises in 2020, most of which are micro-enterprises (OECD, 2023). In terms of technological development applied to the labor sector, France is a technologically advanced country that prioritizes meeting the needs of its large consumer market.

- As the EUs leading economy, Germany will be included since its progress on digital transformation will be vital for the EU to reach its goals for the digital decade. Moreover, the country is, like Portugal, in the middle of the field in the DESI, ranking 13th in 2022. Germany and Portugal display similar rankings in the DESI (Digital Economy and Society Index) dimensions of human capital, integration of digital technology, and digital public services. However, a significant deviation can be observed in the connectivity dimension, where Germany markedly outperforms Portugal (World Economic Forum, 2023) (European Commission, 2023).
- Austria ranked 10th in the 2022 Digital Economy and Society Index ranking, with an above-average score of 54.7. With most dimensions of performance above EU averages, Austria presents quite a different context for the advancement of digitalization. Still, similarly to Portugal, the country scores low on the aspect of connectivity. Furthermore, the value added to GDP by the ICT is quite low (Eurostat, 2022).
- Bulgaria and Estonia differ from Portugal in cultural and economic factors. Language, historical influences, and traditions are very different. Additionally, each country has distinctive economic structures and challenges. Nevertheless, not only both countries belong to the EU and are considered small countries such as Portugal, but they also invest intensively in digital transformation, showing a high value added by the ICT sector at current prices. By adding them to the analysis we are comparing apparent success cases with the Portuguese ones, to observe if and how they are similar.

- Over the last years Poland has been one of the fastest growing economies not only in Europe but also globally, the country’s well-diversified economy has proven to be very resilient and recovered quickly from the COVID-19 Pandemic (Marciniak, 2023; The World Bank, 2023). In its 2023 Economic Survey on Poland, the OECD highlights the growth of ICT innovation in Poland, and underscores the urgent need to improve digital skills, especially among older adults, while suggests a more practical and flexible education system to address skill gaps as well as targeted awareness campaigns and scholarships to increase women's participation in ICT (OECD , 2023). In the 2022 DESI, Portugal consistently outperforms Poland across several key indicators. In terms of the overall ranking, Portugal stands at 15th, substantially higher than Poland's 24th position (European Commission, 2023).

As previously mentioned, this dataset includes several indicators on the ICT sector and ICT usage in enterprises. It is important to go through the most crucial topics, as this data provides the opportunity to compare the Portuguese case with other European countries.

An important indicator is the number of employed people with ICT education by sex. As the two following tables show (Table 2 & Table 3), there is still a high prevalence of males with ICT education in employment. Throughout the years analyzed (2004-2021), in Portugal, close to 78% of the employed people with this type of education were men. This percentage was more favorable to women in the beginning years of the analysis, given that in 2004 almost 30% of the employed persons with ICT education were women. In 2021, this value was only 19.5%. Comparing Portugal with other countries, it is easy to notice a continued male prevalence in this sector: in France, around 85% of these people are men. The highest value, 89.7% was verified in 2021, where only 10.3% were women. When looking at the EU average, Portugal is below average when it comes to males (80.97%, compared to the Portuguese average of

77.67%). As for employed females, Portugal is above the European average, as the latter is set at 19.03%.

	Mean	Median	Min	Max	IQR	SD
AUT	85.27	86.05	75	90.7	4.8	3.825
BEL	87.21	87.1	83.2	92.6	3.7	2.314
BGR	70.19	71.7	59.3	78.6	9.95	6.37
DEU	86.02	86.3	80.9	88.8	1.2	1.714
ESP	78.38	78.4	74.1	82.6	5.07	2.93
EST	75.09	78.5	45.4	84.5	12.4	11.95
EU27	80.97	82.2	72.5	84.6	5	3.405
FRA	84.9	85.4	77.7	89.7	4.2	3.087
GRC	65.57	63.6	57.2	78.5	10.8	6.762
ITA	76.08	77.8	63.9	84.0	10.2	5.876
POL	85.94	87.1	79.9	90.4	6.2	3.49
PRT	**77.67**	**77.6**	**70.8**	**85.1**	**7.1**	**4.533**

Table 2: Descriptive statistics on employed males with ICT education.

	Mean	Median	Min	Max	IQR	SD
AUT	16.39	15.3	10.7	25.0	5.43	4.07
BEL	12.79	12.9	7.4	16.8	3.7	2.31
BGR	34.54	31.5	24.4	54.1	12.5	9.62
DEU	14.43	13.8	13.3	19.1	1.57	1.61
ESP	21.62	21.6	17.4	25.9	5.08	2.93
EST	25.77	20.55	16.5	54.6	13.3	10.6
EU27	19.03	17.8	15.4	27.5	5	3.41
FRA	14.93	14	10.3	22.3	4.5	3.09
GRC	34.43	36.4	21.5	42.8	10.8	6.76
ITA	23.92	22.2	16	36.1	10.2	5.88
POL	14.06	12.9	9.6	20.1	6.2	3.49
PRT	**22.33**	**22.4**	**14.9**	**29.2**	**7.1**	**4.53**

Table 3: Descriptive statistics on employed females with ICT education.[4]

The scenario is similar in what regards ICT specialists divided by sex. An ICT specialist is a "worker who has the ability to develop, operate and maintain ICT systems, and for whom ICT constitutes the main part of their job"[5]. As seen in

[4] Note: Tables 5 and 6 represent, out of the overall employed people with ICT education, the share of males and females, respectively.
[5] (Eurostat, 2023)

Table 4, Portugal's average is close to 83% of male ICT specialists. The country with the least disparity, but still with a high number is Bulgaria, with an average of 70%. The only other country with this average below 80% is Estonia, both Eastern European countries. This can show an investment that these countries might be doing in providing the female population with ICT skills and opportunities.

	Mean	Median	Min	Max	IQR	SD
AUT	83.158	83.050	79.6	86.8	4.9	2.657
BEL	83.417	83.250	80.4	85.9	1.95	1.578
BGR	70.133	70.650	67.1	71.9	2.6	1.651
DEU	83.092	83.400	80.6	84.8	.8	1.229
ESP	81.75	81.650	80.6	83.6	1.4	.925
EST	77.567	77.450	73.8	80.6	3.15	1.967
EU27	82.608	82.950	80.9	83.8	1.4	.967
FRA	81.108	80.650	79.1	84.2	1.8	1.464
GRC	80.15	79.750	73	84.6	4	3.219
ITA	84.725	84.800	83.9	85.8	1.4	.72
POL	85.217	85.500	83.3	86.4	1.2	.92
PRT	**82.383**	**82.300**	**78.9**	**86.7**	**2.8**	**2.446**

Table 4: Descriptive statistics on Employed ICT Specialists that are male (% of total ICT Specialists, from 2011-2022)

Regarding the percentage of ICT personnel in total employment, Portugal's average is of around 1.80% in ICT services (Table 5). This value has been increasing since the beginning of the analysis. In 2008, the Portuguese employment was only constituted by around 1.32% of ICT personnel and, twelve years later, it expanded to 2.53% in 2020.

Comparing the Portuguese case with other countries, several European countries have much higher records (2.79% for Estonia, and 2.71% for France, on average, for instance), which shows that Portugal still has room for improvement and catching up in these types of services. By providing the right incentives and investment, the country may find a way to have higher employment, in relative terms, of ICT personnel.

	Mean	Median	Min	Max	IQR	SD
AUT	2.18	2.19	1.92	2.51	.28	.18
BEL	2.58	2.52	2.46	2.82	.07	.12
BGR	2.16	2.04	1.4	3.07	.81	.52

DEU	2.31	2.29	1.9	2.83	.49	.35
ESP	2.19	2.13	1.85	2.70	.32	.24
EST	2.79	2.7	2.05	3.97	.89	.57
FRA	2.71	2.73	2.52	2.97	.19	.13
GRC	1.37	1.39	1.2	1.59	.17	.12
ITA	2.16	2.15	2.06	2.33	.1	.08
POL	1.81	1.73	1.22	2.51	.75	.44
PRT	**1.80**	**1.73**	**1.32**	**2.53**	**.44**	**.36**

Table 5: Descriptive statistics on the percentage of ICT personnel (in services) in total employment[6]

Another important indicator of ICT usage in enterprises is to analyze the differences in the percentage of enterprises employing ICT specialists, depending on the size class. Usually, companies are classified small-sized if they have 10 to 49 employees, medium-sized if it ranges from 50 to 249 and large when they have 250 employees or more.

As the following tables show (Table 6 & Table 7), as companies grow larger, the number of ICT workers increases. They demonstrate that Greece (28.73% and 55.81%, respectively) and Belgium (27.83% and 54.33%) have the highest percentages of small- and medium -sized enterprises employing ICT specialists, while Poland has the lowest, with only 14.66% and 30.86%.

	Mean	Median	Min	Max	IQR	SD
AUT	23.971	23.8	19.8	31.8	4.7	3.963
BEL	27.829	28.2	25.7	29.4	1.8	1.232
BGR	20.229	21	14.7	22.4	2.1	2.585
DEU	21.057	21.6	19.2	22.6	3.2	1.446
ESP	22.143	22.9	16.9	25.6	7.3	3.535
EST	15.471	15.3	13.5	18.2	.9	1.416
EU27	19.9	19.7	19.3	20.5	1	.493
FRA	16.229	16.3	14.8	17.5	2.2	1.086
GRC	28.729	27	23.1	37.2	8.1	5.048
ITA	16.114	16.4	14.5	17	1.6	.899
POL	14.657	13.2	10.8	24.3	2.2	4.433
PRT	**21.129**	**20**	**18.7**	**29.300**	**2.1**	**3.699**

[6] Note: The EU average is not in this table as there was not enough data in the different countries to provide these descriptive statistics.

Table 6: Descriptive statistics on the percentage of small-sized enterprises employing ICT specialists.

	Mean	Median	Min	Max	IQR	SD
AUT	50.214	50.1	44.8	56.6	8.1	4.191
BEL	54.329	54.5	51	57.4	2.9	2.049
BGR	31.157	32.6	20.5	34.7	1.4	4.788
DEU	45.3	45.4	42.1	48.3	3.7	2.137
ESP	45.586	47.5	37.6	51.0	9.4	5.012
EST	32.957	32.6	30.3	37.4	1.7	2.208
EU27	42.286	42.4	41.5	43.3	1.4	.71
FRA	39.186	38	36.6	43.3	4.6	2.649
GRC	55.814	57.5	48.5	62.9	8.4	5.053
ITA	42.371	42.7	39.9	43.8	2.6	1.406
POL	30.857	30	25.7	40.4	3.8	4.652
PRT	**46.7**	**47.3**	**41.1**	**50.2**	**5.1**	**3.604**

Table 7: Descriptive statistics on the percentage of mediuml-sized enterprises employing ICT specialists.

Table 8, which illustrates the same indicator among large enterprises, shows that Austria (86.2%) joins Greece (81.03%) and Belgium (85.69%) with the highest percentages and Bulgaria becomes the lowest with 56.23%. Moreover, in each size class, it is noticeable that the percentage of Portuguese firms employing ICT specialists is close to the EU average and the country with the highest similarity to Portugal is Spain. Additionally, among the three greatest economies in the EU, Germany in every size class is the country with more firms hiring ICT workers, nonetheless, Italy and France have similar values.

	Mean	Median	Min	Max	IQR	SD
AUT	86.2	86.9	82.6	89.3	3.3	2.264
BEL	85.686	85.4	84.6	87.6	2	1.199
BGR	56.229	61.1	23.9	64.7	5.2	14.401
DEU	78.914	77.1	76.1	83.3	5.1	2.844
ESP	71.586	72.3	64.8	74.7	3.7	3.359
EST	68.757	69.7	61.7	74.3	5.6	4.066
EU27	75.214	75.1	74.2	77.4	1.1	1.067
FRA	73.6	72.4	71.2	77.1	4.2	2.373
GRC	81.029	82.8	66.4	88.2	6.1	7.041
ITA	73.214	73.2	71.5	75.6	2.2	1.44
POL	74.8	73.8	73.4	81.3	.3	2.872
PRT	**75.843**	**75.2**	**72.6**	**79.4**	**3**	**2.265**

Table 8: Descriptive statistics on the percentage of large enterprises employing ICT specialists.

A strong component of this research is to analyzes the impacts of the ICT specialists on productivity and how the ICT sector can be changing the whole spectrum of the economy. Therefore, it is highly relevant to analyze how the employment of ICT specialists, as a percentage of total employment, has been progressing throughout the years.

In the European Union (27 countries), there has been a tremendous progress since 2004, since it started with a level of 3,1 % and in 2022 it increased to 4,6%. This alone shows signals of a transforming economy, with more and more people being employed in this sector.

In the case of Portugal, the transformation has been outstanding, as the country started with a level of 2,3% and almost doubled it with a level of employment of 4,5% in 2022. Even though this evolution has been able to start closing the gap between Portugal and other European countries, Table 9 shows that the countries with the highest ICT specialists' employment averages are Belgium and Estonia. Portugal has shown a steady increase since 2013, although with a slight decrease from 2021 to 2022, from 4.7% to 4.5%. The country has been closing its gap with the European Union, showing an important focus in having ICT specialists on its enterprises.

	Mean	Median	Min	Max	IQR	SD
AUT	3.832	3.600	2.9	5	1.1	.58
BEL	4.395	4.200	3.4	5.6	1	.648
BGR	2.753	2.500	2.2	3.8	.7	.483
DEU	3.826	3.700	3.1	5	.3	.509
ESP	3.368	3.200	2.8	4.3	.5	.4
EST	4.4	4.100	2.5	6.6	2	1.215
EU27	3.616	3.500	3	4.6	.5	.443
FRA	3.789	3.900	2.7	4.5	.8	.551
GRC	2.305	2.200	1.6	2.9	.9	.453
ITA	3.295	3.200	2.9	3.9	.4	.276
POL	2.884	2.800	2.3	3.6	.5	.362
PRT	**2.958**	**2.800**	**1.9**	**4.7**	**.7**	**.74**

Table 9: Descriptive statistics on Employed ICT specialists (% of total employment 2004-2022)

It is also important to analyze whether these employed specialists have an impact of the economy. In theory, it is easy to associate the success of a nation to how well they are doing technologically: the more digitalized and technological a society is, the more advanced and economically prosperous is considered.

To find some correlation, GDP per capita and the employed ICT specialists (ICT Total), in percentage of total employment to the year of 2022, were computed. Figure 5 shows that these two appear to be positively correlated. The regression line in red shows the upward trend: a country with more ICT specialists, should have a higher GDP per capita. By looking closer, the countries with less than 5% of ICT specialists, have a lower GDP per capita than the countries with more than 5%, except for Iceland and Estonia. Although it is not a rule, the countries with more ICT specialists seem to present higher values of GDP per capita, showing that, in fact, a more digitalized society, with more specialists in ICT, can be more economically prosperous.

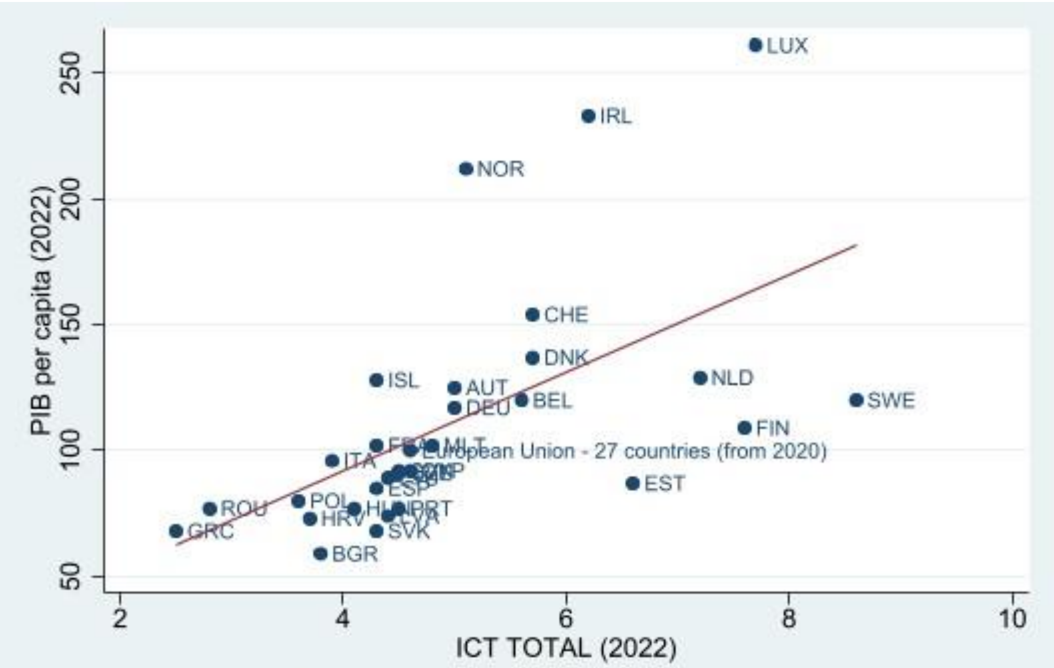

Figure 5: Comparison between GDP Per Capita and percentage of ICT specialists' total employment (2022).

Variables	Mean	Median	Min	Max	IQR	SD
AUT	76.667	76.85	57.6	89.6	16	10.73
BGR	87.012	88.1	71.5	95.0	9	6.397
DEU	62.406	62.55	57.7	66.6	4.7	2.795
EST	69.994	66.2	55.7	92.4	11.8	10.954
ESP	91.469	91.1	87.9	96.0	3.45	2.375

EU27	68.806	69.9	58.6	73.1	4.3	4.205
EU28	68.581	70.05	57.7	73.7	4.55	4.635
EU15	69.5	71.2	57	75.6	5.4	5.347
FRA	98.233	98.5	95.7	99.3	1.2	1.074
GRC	52.228	54.55	30.2	74.7	29.5	15.422
ITA	28.372	30.25	15.1	37.3	11.8	7.388
POL	64.271	64.6	56.1	69.1	2.5	3.09
PRT	**32.006**	**32.15**	**24.5**	**39.6**	**8.5**	**4.483**

Table 10: Descriptive statistics on employed persons with ICT education by educational attainment level

Looking at employed individuals with ICT education, categorized by educational attainment levels, reveals several important insights (Table 10). Firstly, the median and mean percentages of employed persons with ICT education are relatively close in most regions, suggesting a consistent presence of ICT-educated workers in the workforce during the studied period. Notably, France stands out with the highest median and mean percentages, indicating a strong representation of ICT-educated individuals in the French workforce throughout the years. Conversely, Italy and Portugal have lower median and mean percentages, indicating a smaller proportion of the employed population with ICT education in these countries.

Moreover, Greece shows a wide interquartile range, implying significant variability in the percentage of employed persons with ICT education over time. Austria demonstrates the highest maximum value, reaching 89.6%, suggesting a peak in the percentage of employed persons with ICT education in 2016. In contrast, Italy exhibits the lowest maximum value of 37.3% in 2017, indicating a comparatively lower peak in the representation of ICT-educated workforce during the same period.

In addition to this, it is important to analyze the education attainment level of the ICT specialists. In most of the European Countries, from 2004 to 2022, the mean percentage of employed ICT specialists with tertiary education was above 50%, almost in every country. This shows that more and more of these workers have tertiary education, explained by an increasing specialization of this sector. In a further analysis at the countries in comparison (Table 11), Portugal is one of the countries that has less than most of the workers with tertiary education, as Italy, Austria, and Germany. However, it is important to refer that this is a mean for an interval of 18 years. Portugal started with a level of 30,3% of employed ICT specialists with tertiary education in 2004 and more than doubled it until 2022 (63,9%). This is a significant improvement, which shows the investment the country has been doing on specializing and on providing the right education to these workers.

	Mean	Median	Min	Max	IQR	SD
AUT	48.032	40.300	31.8	67.2	28.5	14.209
BEL	71.889	73.000	61.1	81.3	11.1	6.2
BGR	60.126	64.900	43.1	76.2	21.3	12.016
DEU	48.853	48.100	46	54.1	3.3	2.363
ESP	77.558	80.000	68.1	83.1	9.3	5.064
EST	55.784	56.900	47.9	59.6	5.8	3.235
EU27	56.216	56.400	46	65.2	13.8	6.622
FRA	69.642	74.000	51.4	81.4	23.2	11.102
GRC	63.932	66.000	52.9	72.6	12.3	6.843
ITA	31.016	31.600	19.6	41.3	9.6	6.267
POL	63.4	65.800	48.4	73.6	19.5	9.327
PRT	**46.021**	**42.600**	**30.3**	**63.9**	**20.4**	**10.989**

Table 11: Descriptive statistics on Employed ICT Specialists with Tertiary Education (% of total ICT Specialists, from 2004-2022)

In conclusion, not only has the country been increasing its employed ICT specialists as a percentage of total employment, but also that these are more academically educated. Portugal might be catching up with other European countries, although this sudden rise must be sustained, and the country should have an appropriate strategy to cope with that.

Regarding the enterprises that provided training to develop and/or upgrade the ICT skills of their personnel (Table 12), it is noticeable that the activity Information and Communication has the highest mean (51.426) and the highest maximum (88.5), the level of training in the I&C area is expected to be high. Excluding the high value for I&C the means fluctuate between 14.601 for transportation to the 29.782 for Professional and Technical. Comparing to I&C and Accommodation that have an highest standard deviation the numbers for other sectors are lower.

	Mean	Median	Max	Min	IQR	SD

Accommodation	28.349	17.5	82.600	2	42.3	23.133
Administrative	19.631	18.15	57.600	4.7	11.6	8.847
Construction	11.351	10.5	26.500	2	7.1	5.188
Elecricity&Gas	27.478	26.35	66.600	6.1	13.8	11.882
Info & Comm	51.426	53.3	88.500	11.8	22.85	16.428
Manufacturing	19.657	17.7	66.100	0	12.9	10.116
Profess & Tec	29.782	30.3	57.700	8.9	13.1	10.245
Real Estate	21.978	20.65	41.400	5.4	15.5	9.768
Transport	14.601	14.85	26.300	3.7	7.6	5.268
Water	24.375	26.2	38.000	6.7	17.55	10.827
Retail	19.068	18.15	48.200	3.5	10.7	8.1
Others	43.886	47.55	88.900	0	19.2	20.111

Table 12: Enterprises that provided training to develop/upgrade ICT skills of their personnel by NACE Rev.2 activity

The Portuguese Institutional Framework

In an increasingly digital and technological world, governments around the world have had some difficulty in keeping up with the transition. Much effort has been made in this regard, as every country has the ambition of having increasingly digital, efficient, and technological economies and societies. Portugal is no exception, as seen by recent investment plans that aim precisely at digitalizing society, promoting economic growth, and spurring innovation.

The country's economy, which heavily relies on low wages and low value-added, as well as a combination of low qualifications among workers and business owners, are the key hindrances to Portugal's growth and recovery (Cortes, Hoerning, & Trigo Pereira, 2022).

Adding to that, there is also a problem regarding the public administration and its connectivity and interconnection with its citizens and businesses. In 2019, only 41% of individuals used the internet to interact with public authorities, much below the OECD average of 57.9%. Portugal ranked slightly under the OECD average in the user-driven index measuring the extent to which policies and public services are delivered based on the needs of citizens and enterprises (OECD, 2020).

To reach its full potential, the public administration should take advantage of the opportunities presented by new technologies. This would help create greater investment venues in the country and place public administration at the service of their citizens.

Aware of that, Portugal has launched two major plans that give emphasis to take advantage of new technologies in public services. However, these plans are much more than that. They aim at transforming the Portuguese society and economy by investing into a green and digital transition through public policies focused on firms and its workers. The first plan is the Action Plan for Digital Transition presented in 2020, which served as a base to the recent Recovery and Resilience Plan, part of the European Recovery Plan, NextGenerationEU.

Action Plan for Digital Transition (Plano de Ação para a Transição Digital, 2020)

The Action Plan for the Digital Transition is, according to its definition, "the country's transformation engine, aiming to accelerate Portugal by leaving no one behind, through capacity building and digital inclusion among people, businesses' digital transformation and public services' digitization" (Ministério da Economia e Transição Digital, 2020). This program, presented in 2020, has 56 initiatives that aim to foster the digital transition of the Portuguese economy. This plan focuses on three different areas: digital empowerment of people, businesses' digital transformation and public services' digitization.

The e-Residency Program, intended to create a digital identity concept using the Digital Mobile Key. This would allow the use of the Portuguese public services online by its citizens, nationals, and foreigners not resident in the country.

The Action Plan also includes the Cloud Strategy for Public Administration**,** which creates a strategic framework for the integration of Public Administration in the cloud through the adoption of cloud computing tools.

In the area of business digital transformation, this plan incorporates measures from the program Industry 4.0 (*Indústria 4.0*). This program was launched in 2017 to stimulate the Industry 4.0

in Portugal, contributing to the strengthening of the technical and technological capacities of SMEs in the context of Industry 4.0. With a view to accelerating their digital maturity and contributing to relevant productivity gains and greater competitiveness, this would make Portugal an attractive pole for investment.

One of these measures is the Digital Capacity Building Program for SMEs inland. This program aims at the reskilling of ICT professionals and its establishment in the interior regions of Portugal, by first focusing on intensive training of staff, in a polytechnic institute, followed by an integration in a qualified SME.

By converting inland workers into ICT professionals, the competitiveness of the country will get better (Ministério da Economia e Transição Digital, 2020).

Recovery and Resilience Plan (Plano de Recuperação e Resiliência, 2021) in Portugal

The COVID-19 pandemic had a devastating effect on the Portuguese economy, similarly to other European economies. It resulted in increased public health and social spending, a slowdown in the economy and the destruction of jobs (Monteiro & Jalali, 2022).

Adding to that, according to the European Commission, Portugal needs to invest in the digital transition, particularly in the development of digital skills, in the use of digital technologies to ensure equal access to quality education and training, and to boost firms' competitiveness. There is also a sluggish productivity growth, held back by relatively low levels of investment and R&D intensity, general low skill levels of the population and a business environment hampered by inefficiencies in the justice system and regulatory restrictions (European Comission, 2021).

To ensure a robust recovery after the COVID-19 crisis and to address these problems the Portuguese government established the Recovery and Resilience Plan (RRP) in compliance with the Recovery and Resilience Facility (RRF) of the European Union.

The RRP is designed to be a powerful instrument that enhances recovery, assuming the goal of relaunching economic activity through capacity building and modernization of the productive structure, in order to make it more competitive, more resilient to face future challenges, and in general, more able to capitalize on the opportunities associated with the dual transition - digital and climate (Ministério do Planeamento, 2021).

The Plan is structured around the three elements of resilience, green and digital transitions in an initial investment projected at 16,644 million euros. 22% of the budget will be invested into the digital transition, with similar policies to the previous Action Plan for the Digital Transition, as RPP was based on the planning instruments previously established by the Portuguese government. With this, Portugal satisfies the EU requirement of dedicating at least 20% of total investment to digital objectives.

A considerable amount of this budget is allocated to digital transition in education, fostering educational and pedagogical innovation, the development of skills in digital technologies, and the modernization of the education system. There is also a strong component regarding the Digitalization of the Portuguese workforce with the program “Digital Academy”. This project offers specialized training to the Portuguese workforce to increase the number of individuals with digital skills, improve the competitiveness and resiliency of enterprises. This will improve citizens’ digital skills and promote digital inclusion in society. Adding to that, it exists the ambition of strengthening the digitalization of enterprises and catching up with the digital transition process. Companies must be able to reposition their businesses in a digitally advanced ecosystem. In this context, the programs National Network of Test Beds, Digital Commerce, Coaching 4.0 and Entrepreneurship were created.

The National Network of Test Beds establishes a national network of test beds with proper infrastructures conditions for companies to develop and test new products and services. The Digital Commerce Program focuses on the digitalization of SMEs in the commerce area, with the goal of activating their digital trade channels, by the incorporation of technology into business models, as well as dematerializing processes with customers, suppliers and logistics using information and communication technologies. Therefore, this will support internationalization via e-commerce.

Supporting Business Models for Digital Transition (Coaching 4.0) is an initiative framed in the national program Industry 4.0 that fosters the integration of technology in companies, supporting the development of processes and organizational skills that foster the digital transformation of their business models.

The Entrepreneurship program is made by investments that materialize the reinforcement of the strategic commitment to the development of the entrepreneurial ecosystem, which involves directly supporting startups, usually in the seeding phase, with a strong digital and green component, by consolidating the existing structure to support entrepreneurship (Startup Portugal) and by supporting the development of support for the development of incubators and accelerators.

It is expected to support more than 50,000 SMEs, support the creation of 30 Test-Beds and reach 4,000 companies with theoretical training and consultancy focused on Industry 4.0 and issue vouchers to 3,000 startups.

The digitalization of the economy should foster job creation in new branches of potential business areas to explore such as big data analytics, climate change and cybersecurity that are considered the biggest drivers of job growth for the next 5 years (World Economic Forum, 2023) and can lead to a further expansion of the economy.

This plan should make a significant contribution to boosting the country’s economic rebound and contribute to a green, digital, inclusive, and resilient future (European Comission, 2021).

Literature Review

Digital Transformation

Digital transformation, although a term commonly used in academia and industry, still possesses diverse interpretations. According to Westerman et al. (2011), digital transformation refers to the utilization of technology to drastically improve the performance or reach of enterprises. Fitzgerald et al. (2014) and Liere-Netheler et al. (2018) expanded on this concept, positing that digital transformation involves leveraging new digital technologies to enable significant business improvements. Like them, both Nwankpa and Roumani (2016) and Remane et al. (2017) provide intersecting viewpoints on digital transformation, associating it with significant enterprise changes precipitated by the diffusion of digital technologies. They accentuate shifts to analytics, big data, cloud computing, mobile internet, and social media platforms, framing digital transformation as the evolution of organizational processes and operations. Complementing this, Remane et al. (2017), observe digital transformation as fundamental alterations in existing business models, as well as the genesis of new ones, in response to the spread of similar digital technologies. This unified perspective underscores how digital technologies can instigate changes on both an operational and strategic level, spurring the modification and creation of business models in the digital era.

However, Matt et al. (2015) and Tabrizi et al. (2019) view digital transformation strategy as a blueprint to assist companies in managing transformations caused by the integration of digital technologies and post-transformation operations.

These definitions, while offering valuable insights, underscore the complex, multifaceted nature of digital transformation, making its unambiguous conceptualization a challenge. While each definition of digital transformation provides valuable insights, several challenges emerge due to the ambiguity and breadth of the term. For instance, many definitions struggle with unclear terminology, often using "digital technologies" as a catch-all phrase without explicit delineation. Additionally, they often conflate the concept of digital transformation with its impacts, such as enhanced performance or new business models, obscuring the nature of the transformation process itself (Vial, 2019).

Based on previous definitions of digital transformation and the research surrounding it, we define digital transformation as the strategic process of integrating and leveraging digital technologies to facilitate drastic improvements in business performance, reach and productivity. This includes the evolution of organizational processes and operations, driven by the adoption and diffusion of technologies such as analytics, big data, cloud computing, CRM, mobile internet, and social media platforms. Digital transformation embodies significant enterprise changes, fundamentally altering existing business models and spawning the genesis of new ones in response to the evolving digital landscape. It's essential to approach digital transformation with a comprehensive understanding of its intricacies and nuances, recognizing it as a strategic, ongoing journey rather than a finite project. As such, the concept and practice of digital transformation represent the continuous adaptation and innovation necessary for businesses to thrive in the digital era.

Productivity:

Techno-pessimists Vs Techno-optimists

Techno-pessimists maintain that the observed decline in productivity is simply a reversion to the norm following an extraordinary period of IT-driven growth that lasted about a decade. They argue that this deceleration is primarily observed in sectors that either produce or heavily utilize IT, and they view this slowdown as a lasting trend. They contend that the groundbreaking innovations of the early 20th century, such as electrification, far outweigh any technological advancements made since then or anticipated for the future. They also propose that as technology continues to evolve and ideas accumulate, the cost of innovation for researchers escalates. This perspective is further supported by the noticeable decrease in business dynamism, particularly in leading economies like the United States, as noted by several scholars (Andrews et al. 2016).

In contrast, techno-optimists, such as Brynjolfsson and McAfee (2011), assert that the fundamental pace of technological advancement remains steady and that the IT revolution is poised to significantly reshape advanced economies. They suggest that the growing digitalization of economic activities has sparked four key innovative trends: enhanced real-time tracking of business operations; quicker and more cost-effective business experimentation; broader and simpler idea sharing; and the capacity to duplicate innovations more rapidly and accurately, a process known as scaling-up. Techno-optimists maintain that the advancements in computing power and ICT could stimulate future productivity growth by making scientific breakthroughs more probable and reducing the costs of access, thereby creating a positive feedback loop between technology and science. However, they also caution that poor institutional practices and policies could hinder this positive cycle. Techno-optimists further posit that the full advantages of the "digital economy" may not yet be apparent due to the ongoing transition phase marked by staggered adoption of new technology and associated transition costs. They suggest that the observed productivity slowdown could reflect the dynamics related to these complementary investments (Andrews et al. 2016).

Productivity paradox

Since the late 1980s, the question of productivity has become a central peace on the agenda of policy-makers across the world. Much of the attention came after Robert Solow's famous Phrase: "You can see the computer age everywhere but in the productivity statistics". Productivity growth has, since the 1980s, gradually fallen by 50% in the G7 countries (Erber, Fritsche, & Harms, 2017) Additionally, OECD economies' diminishing productivity growth is a new general feature of economic growth (Bergeaud, Cette, & Lecat, 2015). It has become a widespread economic phenomenon.

In the context of an economy that is progressively going digital and where intangible assets, rather than tangible ones, are a significant driver of productivity development, many scholars have suggested that national accounts may not be able to assess productivity (Dettori, Marrocu, & Paci, 2012). This is due to structural change, the transformation of the economy from an industrial to a services-oriented one, as well as the expansion of the unorganized sector in a number of OECD countries. Others object to the use of total factor productivity, commonly known as the Solow residual, as a gauge of innovation and, consequently, of technological advancement (Crafts, 2018). The magnitude of the mismeasurement, however, does not appear to be sufficient to fully explain the consistently dropping rates of productivity in OECD nations (Ahmad, Ribarsky, & Reinsdorf, 2017)

The basic idea that guides our understanding of the global productivity slowdown is likewise called into serious question (Crafts, 2018). The productivity impact of radical technological innovation is by no means linear and proportional from the perspective of evolutionary (neo-Schumpeterian) growth theory, nor is it possible to achieve significant productivity gains from radical technological innovation in a short period of time (Freeman & Louçã, 2001). Adding to that, it is proven that prospective GPTs might not be able to produce significant gains in productivity for several decades. (David, 1990)

To summarize, the existing literature on the productivity slowdown suggests that the productivity slowdown is more likely to be the outcome of economic factors, rather than solely of methodological issues, and theory matters when it comes to conceptualizing the paradox in question (Fragkandreas, 2021).

ICT adoption and productivity

The adoption of digital technologies has been shown to empower companies to innovate, such as by enhancing business processes, and automating specific routine tasks. Additionally, they diminish the expenses associated with engaging with suppliers and customers (Brynjolfsson et al 2008; Gal et al 2019). There has been a wide range of studies at the firm- and industry-level suggesting positive linkage between the investment in digital technologies and productivity (Dedrick et al. 2003, Draca et al 2009). Recently, when analyzing cross-country data related to the implementation of digital technologies by businesses researchers have found significant disparities in the level of adoption of digital technologies among firms, with these differences being especially pronounced across countries (Gal et al. 2019). Relich (2017) determined that selected ICT components have a positive and significant influence on labor productivity in EU countries. Additionally, the impact of ERP, e-commerce, and CRM software on labor productivity is greater in transition economies compared to developed economies of the EU. Furthermore, the impact of ICT hardware investment, ICT specialist skills, and software specialist skills differs significantly between manufacturing and services, with a more substantial effect observed in services (Borowiecki et al. 2021). Similar results were found for Estonia, where firm-level productivity effects from digital technology were stronger in services compared to manufacturing (Mosiashvili and Pareliussen, 2020). Criscuolo and Himbert (2021) found that insufficient investment in intangible assets can lead to lower productivity for firms operating in digital-intensive sectors. Additionally, industries relying more on ICT specialists tend to have weaker catch-up of laggard firms, contributing to productivity divergence (Gal et al. 2019). Gal et al. (2019) found that skill and occupational shortages hinder the productivity benefits of digital adoption, indicating synergies between digitalization and other intangible factors. Multiple studies indicate that digital technologies exhibit strong complementarities with organizational capital and management skills, R&D and intangible investments, human capital and ICT-related skills, and a regulatory environment that enables the efficient reallocation of resources (Gal et al. 2019).

The relationship between the adoption of digital technology and productivity is complex and nuanced, as demonstrated by diverging views from techno-optimists and techno-pessimists, and further complicated by issues in productivity measurement and underlying theoretical considerations. Techno-optimists see potential for future growth, while techno-pessimists view the decline as a lasting trend. Questions regarding productivity measurement, the nonlinear impact of technological innovation, and historical evidence of time-lagged effects all contribute to the multifaceted nature of this subject. This complexity underscores the challenges in empirically identifying the precise links between digital technology adoption and productivity, reflecting the intricate interplay of technological, organizational, and economic factors. Our research is aimed at addressing some of these issues in regards to the Portuguese economy.

Data

In what regards to the development of the digital transition in the European Union, two different sources were considered: a large dataset from Eurostat, related to the Digital Economy and Society database.

The individual parts of this report use two Portuguese databases for its analyses: IUTICE and SCIE. These were provided by INE in collaboration with GPEARI for the evaluation of the impact of digital transition on productivity.

Digital Economy and Society

Since 2002, Eurostat has worked to coordinate the annual collection of information on ICT usage and e-commerce in enterprises (and by households and individuals) by providing standardized questionnaires – for comparison purposes. This effort is taken in collaboration with Members States' national statistical institutes (NSIs) and the OECD, with ongoing adjustments to changing EU regulation. The data is collected annually, except for two-yearly benchmarking indicators. The following sections are written with reference to the 2021 edition of the European business statistics compilers' manual for statistics on ICT usage and e-commerce.

For the ‘Survey on ICT usage and e-Commerce in Enterprises’, the unit of observation is the enterprise, defined as “the smallest combination of legal units that is an organisational unit producing goods or services, which benefits from a certain degree of autonomy in decision-making, especially for the allocation of its current resources.” As they can work in a variety of sectors, enterprises can be classified according to their main economic activity; this is achieved by using NACE (European Classification of Economic Activities) Rev. 2 classification. For the purposes of this Survey, 12 classes (and related subclasses) of activities are considered, among others Manufacturing (Section C), Wholesale and retail trade (Section G), Information and communication (Section J). Additionally, the Survey investigates firms with 10 or more employees and self-employed persons – with the option to include also businesses of less than 10. Finally, all enterprises on the territory of the country shall be accounted for.

The survey questions are categorized as follows:

Questions	Description
A (1-7)	Access and use of the internet
B (1-12)	E-Commerce sales
C	Sharing of information electronically within the enterprise (ERP, CRM, CRM)
D (1-2j)	Use of cloud computing services
E (1-2g)	Internet of Things (IoT)
F (1-5h)	Artificial Intelligence (AI)
X (1-3)	Background information: main economic activity, number of employees, total turnover

Figure 6: Main Topics of the Survey Questions

The data concerning Portuguese enterprises was collected between February and July 2021 by the National Statistical Institute (INE). The survey comprehended web and postal surveys, with mandatory and stand-alone surveys. With a population size of enterprises of more than a hundred thousand entities, the sample drawn was stratified according to economic activity, number of employed persons, and turnover – for a sample of 8,083 (of which 3,952 micro-enterprises). The overall response rate was 94% for enterprises with 10 or more employees and 83% for micro-enterprises (less than 10 employees).

IUTICE

Information on ICT use by enterprises is collected at the national level in Portugal through the "Survey on Information and Communication Technologies Use in Enterprises" (Inquérito à Utilização de Tecnologias da Informação e da Comunicação nas Empresas, hence IUTICE). This process is carried out yearly by the Portuguese National Institute of Statistics (INE), specifically by the Department of Economics Statistics/Service of Business Statistics (DEE/EP). Over the years, the survey has been modified to comply with the European guidelines and criteria, while remaining a firm-level inquiry; the following sections are written with reference to the 2022 Methodological Document.

The information is collected through sample surveys, with the target population being active enterprises located in Portugal (operating in sectors of Annex I). A stratified (probabilistic) sampling method is employed, based on the economic activity, size class, turnover, and region; the overall sample size is approximately 8,000 companies. In addition to basic firm information – such as tax number, contacts, and location – the survey investigates the following categories: Internet Access and Use, E-Commerce, Human Resources and Skills in ICT, ICT Security, Use of Robotics, and ICT and the Environment. It is important to note that the set of firms surveyed have relatively changed over time; similarly, part of the survey questions have been modified to comply with European legislation or to match technological advancement.

SCIE

The Integrated Business Account System (Sistema de Contas Integradas das Empresas - SCIE), a firm-level database compiled by INE, was created in 1994-1995. The database includes financial and economic information on firms reported in IES (simplified business information), complemented with other sources of information available in INE or provided under protocols established with other Portuguese government agencies. The SCIE system was reformed around 2007 and recent surveys are not compatible for analysis with past data, which is why only data from 2007 onwards are considered in the study.

The annual study focuses on enterprises in mainland Portugal and the Autonomous Regions of Azores and Madeira. The population covered in the dataset consists on all firms that engage in at least one activity producing goods and or services during the period analyzed.

SCIE and IUTICE

The IUTICE database provided covers the years between 2007 and 2022 while the SCIE covers years between 2008 and 2021; a merged dataset was created based on individual firms' IDs for years from 2008 to 2021. The dataset consisted of 47,119 individual firms and 82,750 observations. A cleaning process was then carried out to satisfy the following conditions:

- Keeping only firms with three or more employees; this step was taken to limit sample bias, reducing the number of observations to 66,396 and of firms to 34,409 firms;
- Verifying consistent reporting for the information provided, in terms of positive turnover, positive total assets, positive total liabilities, positive number of employees, and positive payroll. The dataset then consisted of 34,133 firms for 66,001 observations.

A variable to indicate the size of the enterprise was created, following the European Commission classification of small and medium-sized enterprises (SMEs) (European Commission, 2023). Size depends on the headcount and either the turnover or balance sheet total, with the following thresholds (where large companies are those that do not satisfy either of these conditions):

Company category	Staff headcount	Turnover	Balance Sheet Total
Medium	< 250	≤ € 50 m	≤ € 43 m
Small	< 50	≤ € 10 m	≤ € 10 m
Micro	<10	≤ € 2 m	≤ € 2 m

Table 13: Firm Size Matching

Descriptive statistics

To further characterize the used dataset, descriptive statistics for two years, 2010 and 2020, have been produced, according to the sector of activity of the enterprises (using NACE Rev. 3) and the size of the firm (using the previously mentioned definition by the European Commission) (excluded sectors due to very low number of observations: Agriculture, Education, Health and Social Activities, Extractive).

Erro! A origem da referência não foi encontrada. shows rates of adoption of ICT technology mong the sample firms by sector of activity, in two years – 2010 and 2019. For computer and internet use, the data supports the idea of increasing relevance of ICT for enterprises benefit across all sectors. The ICT sector, administrative activities, and manufacturing generally shows above-average rates for the variables considered. Even if the rates of ICT staff and online sales seem to be decreasing over time, this may not be true in practice, as the enterprises surveyed change year by year.

Sector of Activity	Computer use		Internet use		Website use		ICT Staff		Online Sales	
	2010	2019	2010	2019	2010	2019	2010	2019	2010	2019
Accommodation	79	93	87	98	75	42	30	12	27	20
Administrative Activities	99	99	100	100	88	80	40	29	31	22
Construction	90	98	97	100	68	51	42	27	13	4
Consulting & Science	100	100	100	100	61	68	43	35	12	10
Electricity & Gas	92	95	100	97	100	74	45	42	0	22
Information & Communication	99	100	99	100	93	89	69	65	28	20
Manufacturing	95	99	98	100	76	67	51	36	32	9
Other Services	100	98	95	100	90	79	73	83	50	26
Real Estate	88	99	98	100	72	67	27	12	10	12
Transport	96	98	100	100	83	49	54	29	23	15

Water	100	100	98	100	85	90	47	48	13	14
Wholesale & Retail	97	100	97	100	76	71	46	40	36	24

Table 14: Percentage of sampled firms that use computers and the internet, have a website, employ ICT Staff, and make online sales, by sector of activity (NACE Rev.3)

	Computer use		**Internet use**		**Website use**		**ICT Staff**		**Online Sales**	
Size	2010	2019	2010	2019	2010	2019	2010	2019	2010	2019
Large	100	100	100	100	95	96	71	79	37	26
Medium	100	100	100	100	86	89	56	57	31	23
Small	98	99	98	100	67	61	31	20	24	13
Micro	79	97	90	99	48	43	18	12	15	10
Total	95	98	98	100	77	67	47	35	28	16

Table 15: Percentage of sampled firms that use computers and the internet, have a website, employ ICT Staff, and make online sales, by size of activity (NACE Rev.3)

Table 15 shows rates of adoption of ICT technology among the sample firms by size, in two years – 2010 and 2019. The above-mentioned divide is clear in the data: large firms display significantly higher rates in all categories, although middle-sized enterprises have been approaching the rates of larger ones – particularly in terms of computer, internet, and website use. As in the previous case, declining rates for ICT staff and online sales may be misleading (particularly for small and micro firms), as the sample composition varies every year.

These tables show an increasing adoption of ICT over the last years. Online presence and activity have been become ever more relevant. Large firms have contributed greatly to this positive trend, although improvements can be seen also in SMEs.

INDIVIDUAL PART- THE CASE OF ICT SPECIALISTS

Introduction

"Productivity isn't everything, but, in the long run, it is almost everything" (Krugman, 1997). Krugman has perfectly described the economic importance of productivity. The real impact of productivity in the long run can be interpreted as a measure of the value that inputs generate in the economy, evaluating the gains that each unit of input produces. The gains obtained by having higher productivity and revenues to the company, can potentiate higher levels of investment. R&D investments are, in general, associated with having more productivity and revenues. This loop will go on and on as the time goes by. It shows why so many policymakers are interested in promoting policies that foster productivity, usually by promoting the use of new technologies, such as Information and Communication technologies (ICT), and innovation. In this modern digital age, this sector, commonly referred to as ICT, has become an integral part of our daily lives and the global economy. From the personal use of smartphones and social media to the sophisticated systems that power businesses and governments, ICT has transformed the way we communicate, work, and live. This sector has steadily increase its economic importance over the years. From 2012 to 2022, the number of ICT specialists in the EU increased by 57.8%, almost 7 times as much as the increase (8.8 %) for total employment (Eurostat, 2022).

Adding to that, there is also a possible link with productivity, as intangible assets, like human capital and qualified personnel in ICT, can be considered drivers for productivity development, (Dettori, Marrocu, & Paci, 2012)

This research question goes precisely into studying these effects, regarding the impact of having qualified ICT specialists. Does having qualified ICT staff promote productivity? And does giving training to the firm´s staff increase productivity gains?

The remaining paper is structured as follows: literature review, where an analysis of the current literature about the importance of ICT on productivity will be made; contextualization of the country between the European goals and with an explanation about the plans taking place; data and methodology, describing the used data and the methodology used; results, where the main findings of the analysis will be presented and at the end, the conclusions, limitations and policy implications that should be taken into account.

Literature Review

New technologies have always been linked to productivity gains on a firm-level. However, since Solow defined his paradox in 1987, the researchers have been focusing on discovering the real effects of ICT on productivity.

It is not clear whether ICT adoption will always lead to an increase in productivity, as digital technologies might be a gamechanger for some firms, but usually seem more like a sideshow for most of them, whom are not able to reap its productivity gains, despite being increasingly digital (Anderton, Botelho, & Reimers, 2023).

Regarding investment, the effect of investing in ICT becomes significantly positive when it is combined with organizational transformation. Nevertheless, there is a delay between the moment of ICT investment and the recognition of a positive influence on productivity. This temporal gap primarily results from the organizational adjustments that a company must undergo to fully harness the advantages of ICT investment (Biagi, 2013).

Biagi (2013) additionally asserts that the distribution of skills within the workforce and the extent of human capital play crucial roles in shaping the consequences of ICT investment and organizational change.

Spillover effects might also be part of the story. The usage of ICT by “neighboring” firms can induce more ICT adoption through learning, network effects or fostering the growth of skilled labor pools (Bloom, Draca, Kretschmer, & Sadun, 2010).

The ICT adoption by the firms depends heavily on the human capital that these firms have. A more qualified staff will foster a quicker organizational change and will reduce the time-lag between the investments and the observation of productivity gains.

In Europe, recent studies using firm-level data have been made and they present similar positive results (Cette, Gilbert, Nevoux, & Loriane, 2020; Borowiecki, et al., 2021; Amador & Silva, 2023).

In France, the employment of ICT specialists and the use of digital technologies improve a firm's labor productivity by about 23% and its total factor productivity by about 17% (Cette, Gilbert, Nevoux, & Loriane, 2020). In the Netherlands, results show that intangibles, measured by levels of digital skill intensity, have a positive and statistically significant impact on firm-level productivity growth in the service sector and for younger firms. Also, ICT specialist skills have the strongest association with productivity growth (Borowiecki, et al., 2021)**.**

In Portugal, overall ICT adoption by the firm leads to an increase of 25 percent in TFP and an increase of 58 percent in labor productivity (Amador & Silva, 2023).

Context

The future plans of the European Union are a direct interconnection between digital and green transition. Following up the covid-19 Crisis, the European Commission launched the NextGenerationEU programme, an 800 billion temporary instrument that will foster Europe's economic recovery precisely focused on the green and digital economy.

This goal of the digital transition is so important that the European Commission defined the next decade as the Europe's Digital Decade (Official Journal of the European Union, 2022).

The Digital Decade Policy Programme focuses on 4 different areas: Skills, Government, Infrastructure, and Business. For each of these areas there are highly ambitious objectives. This plan targets at having 20 million employed ICT specialists (9,6 million in 2022), while a minimum of 80% of the population should have the basic digital skills, Key public services

100% online, Mobile Coverage everywhere, and 75% of the companies using Cloud, AI or Big Data (Official Journal of the European Union, 2022).

In the context of Portugal, the Action Plan for Digital Transition (2020) and the Recovery and Resilience Plan (2021), resultant from the NextGenerationEU programme, are the recent plans launched by the government.

The Recovery and Resilience Plan dedicates 22% of the budget to this transition, enhancing programmes that provide a transformation of the ICT skills of the population and the modernization of the education system. The "Digital Academy" programme offers specialized training to Portuguese workers in order to boost their digital skills, aiming at having gains at the business level, regarding competitiveness and productivity. The programme Coaching 4.0 will also educate workers and firms on organizational skills, facilitating the integration of technology into these companies, contributing to the digital transformation of the Portuguese society (Ministério do Planeamento, 2021).

Data

I use the firm-level database "Inquérito à Utilização de Tecnologias da Informação e da Comunicação nas Empresas" (IUTICE) and "Sistema de Contas Integradas das Empresas" (SCIE), provided by "Instituto Nacional de Estatística" (INE). The first one is a survey that aims to analyse the use of ICT technology by Portuguese Firms, with data from 2006 to 2022. This survey is divided into several areas of analysis, such as Internet Acess and Use, Human resources and Tic competencies or Online Shopping. The SCIE is an administrative data set covering the universe of Portuguese private firms, with information on a wide range of firm characteristics, such as the number of workers, tangible fixed, levels of investment providing data from 2008 to 2021.

The data from the surveys were merged and some cleaning procedures were taken into account. The first step was to eliminate the years from 2008 to 2013, since the term ICT specialist, related to the variables of interest, was defined in the IUTICE in 2014. After that, firms with self-employed and with less than 3 employees, financial corporations and public administration were excluded. To conclude, firms with inconsistent information such as negative values related to turnover, total assets, total liabilities, number of employees and payroll were eliminated.

The sample was reduced to 47,199 observations with data from 2013-2021. Adding to that, the variables of Interest were not recorded in 2021, meaning that this year was not taken into account in the final sample. In the final regression, there were 34,495 observations.

The variables of interest are dummies indicating whether or not the firm has ICT specialists[7] in the firm (ICT_Specialist), recruited or tried to recruit specialized staff in the previous year (ICT_Demand), provided ICT training to their specialists (ICT_Train_Specialist) or to other employees in the previous year (ICT_Train_Others). On the Table 25 in the appendix, it is possible to see the questions associated with the variables.

Descriptive Statistics

In this subsection a set of basic descriptive statistics are presented, illustrating relevant background information regarding the sample. An analysis between the variables of interest and the control variables, such as Dimension and Sector is going to be made for a correct understanding of this sample information.

On average, the firms which have staff specialized in ICT across the years, only make 33,77% of the observations. The level for the demand of this staff is low, since just 12,16% of the firms recruited or tried to recruit ICT specialists (Tables 16 and 17).

Another interesting fact is that there are more firms providing ICT education to other employees than the firms that provide training to ICT specialists, accounting for 27,9% and 19,78% of the observations, respectively (Tables 18 and 19).

[7] Staff in service for whom ICT is the main job

ICT_Demand	Freq.	Percent
0	31,492	87.84
1	4,358	12.16
Total	35,850	100.00

Table 17: ICT Demand adoption in the sample

ICT_Specialist	Freq.	Percent
0	23,742	66.23
1	12,108	33.77
Total	35,850	100.00

Table 16: ICT Specialists adoption in the sample

ICT_Train_Specialist	Freq.	Percent
0	28,760	80.22
1	7,090	19.78
Total	35,850	100.00

Table 19: ICT Specialists training adoption in the sample

ICT_Train_Others	Freq.	Percent
0	25,847	72.10
1	10,003	27.90
Total	35,850	100.00

Table 18: Training of other employees, non-specialized in ICT, adoption in the sample

The relationship between ICT workers and the sectors is also relevant, due the simple fact that some sectors are more digitalized than others and for that reason have more propensity to have qualified staff.

The sectors that have more specialists are the sectors of Manufacturing, Wholesale and Retail, and Information and Communication. The same holds for the ICT demand, but in a different order, since they are more observations registered in the sectors of Manufacturing, Information and Communication and Wholesale and Retail, respectively (Table 26 in the Appendix).

On Table 27 in the appendix, is possible to do the comparison between the training of the employees and the specialized personnel. In every sector, with the exception of Information and Communication and Other services, there are more firms giving ICT education to other employees than to ICT specialists.

To have more information about the data in analysis, is also important to make a connection between the variables of interest and the Dimension of the enterprises. In Table 20, it is possible to see that across the years, only 11% of the observations regarding micro firms, had specialized ICT staff. However, this number grows to a whopping 68% regarding large enterprises.

In the demand, the percentage goes from 3, 8% to 27% (Table 21). The same happens with the training of the specialists, 5,4% to 44% (Table 22) and also with training to the non-specialized, starting from a level of 11,7% to making up the majority of the observations when it comes to large firms, at the level of 53% (Table 23). These results suggest some type of connection between qualified ICT personnel, training and the dimension of the firms.

		Dimension					
ICT_Specialist	*Micro*	*%*	*Small*	*Medium*	*Large*		*Total*
0	11,564	89	6,970	2,696	2,512	32	23,742
1	1,429	11	1,673	3,670	5,336	68	12,108
Total	12,993	100	8,643	6,366	7,848	100	35,850

Table 20: ICT specialists adoption according to the Dimension of the firms

		Dimension					
ICT_Demand	*Micro*	*%*	*Small*	*Medium*	*Large*	*%*	*Total*
0	12,501	96,2	8,017	5,241	5,733	73%	31,492
1	492	3,8	626	1,125	2,115	27%	4,358
Total	12,993	100	8,643	6,366	7,848	100	35,850

Table 21: The ICT_Demand adoption according to the Dimension of the firms

	Dimension						
ICT_Train_Specialist	*Micro*	*%*	*Small*	*Medium*	*Large*	*%*	*Total*
0	12,290	94,6	7,789	4,291	4,390	56	28,760
1	703	5,4	854	2,075	3,458	44	7,090

Total	12,993	100	8,643	6,366	7,848	100	35,850

Table 22: Training of ICT Specialists adoption according to the Dimension of the firms

		Dimension					
ICT_train_others	*Micro*	*%*	*Small*	*Medium*	*Large*	*%*	*Total*
0	11,469	88,3	6,977	3,720	3,681	47	25,847
1	1,524	11,7	1,666	2,646	4,167	53	10,003
Total	12,993	100	8,643	6,366	7,848	100	35,850

Table 23: Training of other employees, non-specialized in ICT, adoption according to the Dimension of the firms

Methodology

We begin by estimating Total Factor Productivity (TFP) for each firm in the data set. TFP measures the efficiency in which inputs (typically labor and capital) are transformed into output in an economy or a specific industry.

There are several methods to estimate TFP, including the instrumental variables approach, fixed-effects approach and control function approach.

Olley and Pakes (1996) were the firsts to propose this control function approach, an innovative method that addressed concerns related to endogeneity. Further research was made by Levinsohn and Petrin (2003), focusing on firm-level data, addressing particularly heterogeneity and unobservable factors. The method used on this research is the method created by Woodbridge (2009) which provides a consistent estimation within a single-step generalized method of moments framework.

The estimation of the TFP follows the following Cobb-Douglas production function:

$$yit = \alpha + \boldsymbol{wit\beta} + \boldsymbol{xit\gamma} + \omega it + \varepsilon it \qquad (1)$$

Where *yit* is the log gross or the value-added output, **w***it* is a 1 × *J* vector of log free variables, and **x***it* is a 1×*K* vector of log state-variables. The component *ωit* represents the technical efficiency or unobservable productivity, and *εit* is an idiosyncratic output shock distributed as white noise (Rovigatti and Molissi, 2018). The log free variables are related to labour inputs and the state variables represent capital inputs. Adding to that, the *ωit* represents the proxy variable, related to intermediate costs.

In this analysis, I rely on the method created by Rovigatti and Molissi (2018), which predicts the total factor productivity through a control function approach, using the prodest command (Figure 7 in the appendix).

The estimation of the TFP, in logarithm, will further be necessary to do a regression, using the panel data command xtreg on STATA, to estimate correlation effects between the variables. The main importance and relevance to this regression is to evaluate the impacts of 4 explanatory variables, that are also dummies created from the questions present in the survey (Table 25 in the Appendix). Thus, it is important to estimate their coefficients to better estimate their possible correlation with productivity. It is also important to take into account that this model only addresses correlation, as no causality relations should be retrieved from this analysis.

The model is the following:

$$\begin{aligned}\ln(TFP) = \alpha + \beta_1 \ln\_payroll + \theta_2 ICT\_specialist + \theta_3\, ICT\_Demand \\ + \theta_4\, ICT\_Train\_Specialist + \theta_5\, ICT\_Train\_Others + \beta_2\, Region \\ + \beta_3\, Dimension + \beta_4\, year + \beta_5\, Sector + \varepsilon\end{aligned} \tag{2}$$

The variables Region, Dimension, year and Sector represent control variables. They are also categorical variables. Region represents the region the firms are registered, following the NUTS II definition. Sector represents the sector of the firm´s activity, following the CAE definition and year controls for the year.

The Dimension is defined according to the definition of the European commission on (micro, small, medium and large firms), which combines turnover and number of employees.

They will evaluate the correlation of such conditions on productivity. This model has also a control variable related to the payroll of the companies.

B. **Results**

The primary research objective of this study is to explore whether having qualified ICT personnel, referred to as ICT Specialists, contributes to enhanced productivity at the organizational level. Additionally, this research examines the productivity effects resulting from ICT education and training provided to employees.

The following results, presented in the Table 24 were taken from the regression. The full results are presented on the Table 28 of the appendix, and this estimation takes into account that estimation. Table 24, is just an abbreviation with the explanatory variables.

	(1)
VARIABLES	Regression_Results
ICT_Specialist	0.008*
	(0.004)
ICT_Demand	0.012***
	(0.003)
ICT_Train_Specialist	0.005
	(0.003)
ICT_Train_Others	0.007***
	(0.002)

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 24: Regression coefficient results for the presented model

According to the results, it is possible to take positive correlations with different levels of significance.

Given the empirical strategy previously described the coefficient for the variable ICT specialist measures the productivity impacts of having ICT specialists within the firm.

The findings suggest a positive and statistical significant correlation, at level of 10%, this correlation accounts for an 0,8%[8] increase in Productivity.

Furthermore, it is possible to observe two positively correlated and statistically significant relationships at a 1% significance level. The first on involve the ICT_Demand for workers who perform their duties in the field of Information and Communication Technology, this variable account for an 1,2% [9] increase in productivity.

The other statistically significant variable at the level of 1% refers to non-specialized workers who receive training (ICT_Train_Others). This effect accounts for an 0,7%[10] increase on productivity.

Giving training to ICT specialists (ICT_Train_Specialist), reveals a positive but statistically insignificant correlation with TFP. Promoting training in ICT to an employee already specialized on that area does not have the same correlation than the training that is given to non-specialists.

There were also tests made regarding the heteroskedasticity, regarding missing variables and multicollinearity. With multicollinearity, there is no evidence on that in terms of the explanatory variables. However, ln_payroll seems to have a moderate correlation, which means that the conclusions from this variable should not be taken into account (Table 29). There is no evidence of heteroskedasticity in this regression (Figure 8). The situation is different in terms of the omitted variables. The test reveals that there is omitted variables from the model that will influence productivity (Figure 9). The reason for this can be explained by the complexity of the

[8] The calculation follows the following equation (exp(0,008)-1)*100

[9] The calculation follows the following equation (exp(0,012)-1)*100

[10] The calculation follows the following equation (exp(0,007)-1)*100

productivity estimation, since this variable depends on a several range of inputs, which are not often easy to identify.

Conclusion

The COVID-19 pandemic expedited the long-term growth of specialized personnel in Information and Communication Technologies (ICT). The significance of having a digital economy has never been greater, particularly in the European context during this decade dedicated to digitization. This process of digital transition will induce organizational changes that will alter the way the business world operates. In this research, I analyzed the impact of ICT on productivity, along with the provision of ICT education by companies to their employees. The results suggest that there is a positive correlation in having specialized personnel, going accordingly to the theory (Borowiecki, 2021). Firms with ICT specialists have more productivity gains. The effect of providing ICT training to specialized personnel in this area is not significant. However, it is not possible to assume that this training does not have positive results within the firm. On the other hand, the analysis demonstrates that there are positive and significant effects in providing ICT training to non-specialized personnel, which may imply that the same ICT training service can be more cost-effective when delivered to individuals who do not possess adequate knowledge in this area. Concerning the demand for specialized workers, although there is a positive impact, this may be correlated with structural changes, as the company's growth could lead to the hiring of workers to adapt to the increasingly digitized business environment.

The described results are significant for the human resources policies of companies, as the hiring of specialized personnel and a training policy for non-specialized workers are likely to yield significant gains in the future.

Limitations

The variables of interest are all dummy variables and only assess the possibility of having workers with those conditions or not. It would be important to understand how many workers possess those characteristics within the company, as the staff count will certainly impact the results. In addition to this, the fact that these variables are related to the size of the companies may imply that larger companies will necessarily require more specialists due to the digital context prevalent in today's society. It is also important to emphasize that the regression and methods used indicate correlations and not causality, so all conclusions drawn from this analysis should be regarded as possible relationships rather than absolute truths. The problems of omitted variables and multicollinearity are also a limitation within this work. Further research should be done, focusing on giving causality conditions.

Policy Implications

The positive impacts of having specialize staff and training on non-specialized individuals may lead policymakers to formulate public policies that enable and facilitate ICT learning for the general workforce.

Policymakers should explore ways to encourage and incentivize organizations to invest in ICT training initiatives for their employees. Options include tax incentives, grants, and subsidies but a solution can be the development of affordable and accessible training materials and online courses, especially for small and medium-sized enterprises (SMEs) with limited resources. This ensures equal access to training opportunities.

These programmes could be actively constructed from collaborations between organizations and educational institutions. These partnerships can lead to joint initiatives that benefit both parties and to bridge the skills gap.

Policymakers must establish measurement mechanisms to measure the impact of ICT training on productivity and key performance indicators. This data will serve as a base to future policy decisions and enable organizations to tailor these programmes for maximum effectiveness.

COMMON PART CONCLUSIONS

Limitations

The first caveat of this work project that needs to be considered is that this is not a causational study. There is no cause-and-effect relationship between the different variables, which means that this study cannot have causal claims - no experimental manipulation is involved in the data. Hence, this can only be considered a correlational study, as its goal was to analyze the possible relationship between the dependent and independent variables without making causal conclusions. Correlation does not imply causation.

In addition, there is the possibility of omitted variable bias. The questions on the IUTICE survey were not exhaustive about the different technologies and their adoption, which means that other factors impact productivity. As TFP is a very complex measurement, it is crucial to address this as a limitation of our results.

Moreover, there is no information on the way enterprises use ICT in their daily activities. The group's different questions of interest go through very different topics, such as ICT specialists, Websites, Cloud Computing, and AI, among others. However, even though there is information on the survey concerning the adoption of technological tools, the group is not aware of how well and in what ways companies are implementing them. To minimize this, the survey questions would have to be more exhaustive in each topic, including, for instance, the time and effort firms take to be involved in their adoption.

Finally, most of the data was not available for every year. This potentially created gaps in the different datasets, and significantly decreased the number of observations for some of the questions of interest.

Conclusions

This work project aimed to find significant relationships between adopting different technological tools and productivity, in particular Total Factor Productivity (TFP). As there are five different questions of interest, it is crucial to briefly go over them all, and then provide a more general conclusion.

Firstly, we found a positive and significant association between website existence and productivity. Focusing on website functionalities, having an online recruitment system appears to have a significant association with TFP. As for Social Media, only Wiki-related tools were found insignificant in the analysis. For enterprises with at least one social media type, having the goal to recruit through these channels has a significant effect on productivity.

Secondly, when it comes to Cloud Computing and Big Data on SMEs, the group found that adopting the first individually had a positive and significant correlation with TFP; the latter technology and both tools together showed insignificant effects in these types of enterprises. Possibly, there might not exist enough statistical variation to identify combined effects that are witnessed for single technologies.

The third research question focused on the association between the adoption of advanced digital technologies (AI, Cloud Computing, and Big Data) and TFP in large enterprises. Companies using all three technologies experienced, on average, an increase of 36% in TFP. Other strategies used in this analysis did not yield significant results, although this may not imply a complete lack of association between TFP and advanced technologies.

The fourth study within this paper investigates the impact of Enterprise Resource Planning (ERP) systems, finding a positive correlation between them and productivity. This result was particularly significant for large firms located in Lisbon’s Metropolitan Area.

The final research question is related to the association between ICT and productivity, focusing on the provision of ICT education to firms' employees. A positive and significant correlation was found between having specialized personnel and productivity. Although there was no significant association between providing training to already-specialized employees, there seem to exist high gains in focusing this training on those that do not possess the highest skills on a topic.

Overall, all research questions show the importance of ICT adoption by Portuguese firms. When it comes to the adoption of advanced digital technologies, mainly related to Big Data and Cloud Computing, results found that for smaller firms, it appears to be more significant to focus on only one of these technologies, while larger firms appear to be more productive when using all at the same time. This may be related to the fact that larger firms may have more specialized personnel, increasing productivity gains.

The remaining research questions show that other digital tools, such as websites, social media, and internal systems might be important additions to firms with the goal of increasing their online presence. All of the above were found to have significant associations with productivity.

Policy Implications

Considering all the conclusions described above, and considering the different limitations this research paper has, policymakers should continue and propose new plans that give the opportunity for SMEs and large enterprises to invest in their digital adoption. Incentivizing this may translate into new productivity gains, giving the opportunity for firms to be recognized abroad and increase their target audiences. In addition, policymakers should keep on providing or investing in training for employees who do not possess specialized digital skills, given that this may increase their work productivity and, consequently, the firms'.

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Appendix

The NACE Rev. 2 activities considered in the "'Survey on ICT usage and e-Commerce in Enterprises" are:

- Section C: Manufacturing
- Section D: Electricity, gas, steam, and air conditioning supply
- Section E: Water supply, sewerage, waste management and remediation activities
- Section F: Construction
- Section G: Wholesale and retail trade; repair of motor vehicles and motorcycles
- Section H: Transportation and storage
- Section I: Accommodation and food service activities
- Section J: Information and communication
- Section L: Real estate activities
- Section M: Professional, scientific, and technical activities
- Section N: Administrative and support service activities
- Group 95.1 (Section S): Repair of computers and communication equipment (Other service activities)

Question	Variable associated
Does the company have staff specialized in ICT?	ICT_Specialist
In (year before the survey) did the company recruit or attempt to recruit ICT specialist staff?	ICT_Demand
In (year before the survey), did the company promote ICT training to develop the skills of the staff in service? a) For service personnel specializing in ICT	ICT_Train_Specialist
In (year before the survey), did the company promote ICT training to develop the skills of the staff in service? b) For other categories of personnel at work	ICT_Train_Others

Table 25: Creation of the explanatory variables from the survey questions.

	ICT_Specialist			ICT_Demand		
Sector	0	1	Total	0	1	Total
Accommodation	3 851	538	4389	4187	202	4389
Administrative	1723	766	2489	2174	315	2489
Agriculture	14	1	15	14	1	15
Arts & Sports	5	2	7	6	1	7
Construction	1264	436	1700	1572	128	1700
Consulting & Science	940	523	1463	1235	228	1463
Eletricity & Gas	150	86	236	213	23	236
Exctractive	3	0	3	3	0	3
Health & Social	2	0	2	2	0	2

Information and Communication	870	1708	2578	1517	1061	2578
Manufacturing	7456	3869	11325	10199	1126	11325
Other services	85	255	340	261	79	340
Real State	1080	149	1229	1188	41	1229
Transport	1029	664	1693	1473	220	1693
Water	389	287	676	609	67	676
Wholesale & retail	4881	2824	7705	6839	866	7705
Total	23742	12108	35850	31492	4358	35850

Table 26: ICT Specialist and ICT Demand adoption regarding the sectors of the economy

	ICT_Train_Specialist			ICT_Train_Others		
Sector	0	1	Total	0	1	Total
Accommodation	4 134,00	255	4389	3 785,00	604	4389
Administrative	2107	382	2489	1817	672	2489
Agriculture	15	0	15	15	0	15
Arts & Sports	6	1	7	5	2	7
Construction	1479	221	1700	1304	396	1700
Consulting & Science	1128	335	1463	966	497	1463
Eletricity & Gas	174	62	236	143	93	236
Exctractive	3	0	3	3	0	3
Health & Social	2	0	2	2	0	2
Information and Communication	1354	1224	2578	1445	1133	2578
Manufacturing	9165	2160	11325	8417	2908	11325
Other services	181	159	340	214	126	340
Real State	1150	79	1229	1015	214	1229
Transport	1283	410	1693	1107	586	1693
Water	513	163	676	433	243	676
Wholesale & retail	6066	1639	7705	5176	2529	7705
Total	28760	7090	35850	25847	10003	35850

Table 27: ICT Training adoption regarding the sectors of the economy

```
wrdg productivity estimator gmm                    Cobb-Douglas PF

Dependent variable: value added                    Number of obs      =     14597
Group variable (id): npc_fic                       Number of groups   =     25072
Time variable (t): ano
                                                   Obs per group: min =         1
                                                                  avg =       1.8
                                                                  max =         9
```

ln_value_added	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_employees	.5523256	.0069555	79.41	0.000	.5386931	.5659581
ln_tng_fix_assets	.1071376	.0130196	8.23	0.000	.0816197	.1326554

```
Wald test on Constant returns to scale: Chi2 = 563.60
                                         p = (0.00)
```

Figure 7: Prodest command, calculating ln_TFP

VARIABLES	(1) Regress
ln_payroll	0.499***
	(0.004)
1.ICT_Specialist	0.008*
	(0.004)
1.ICT_Demand	0.012***
	(0.003)
1.ICT_Train_Specialist	0.005
	(0.003)
1.ICT_Train_Others	0.007***
	(0.002)
15.Region	-0.013
	(0.010)
16.Region	0.009
	(0.006)
17.Region	-0.100***
	(0.006)
18.Region	0.002
	(0.009)
20.Region	0.090***
	(0.014)
30.Region	0.007
	(0.014)
2.Dimension	0.143***
	(0.008)
3.Dimension	0.289***
	(0.015)
4.Dimension	0.295***
	(0.017)

2015.year	-0.001
	(0.003)
2016.year	-0.004
	(0.003)
2017.year	-0.009***
	(0.003)
2018.year	-0.017***
	(0.004)
2019.year	-0.027***
	(0.004)
2020.year	-0.026***
	(0.004)
2.Sector	-0.146
	(0.131)
8.Sector	-0.240
	(0.156)
9.Sector	-1.223***
	(0.113)
10.Sector	-0.090
	(0.112)
11.Sector	-0.073
	(0.113)
12.Sector	-0.204*
	(0.117)
13.Sector	-0.098
	(0.112)
14.Sector	-0.186*
	(0.112)
15.Sector	-0.152
	(0.112)
16.Sector	-0.173
	(0.112)
17.Sector	-0.093
	(0.139)
18.Sector	-0.183
	(0.112)
19.Sector	-0.273**
	(0.118)
20.Sector	-0.272**
	(0.113)
21.Sector	-0.320**
	(0.126)
22.Sector	-0.168
	(0.112)
23.Sector	-0.138
	(0.112)
24.Sector	-0.171
	(0.114)
25.Sector	-0.242**
	(0.112)

26.Sector	-0.330***
	(0.125)
27.Sector	-0.242**
	(0.113)
28.Sector	-0.286**
	(0.112)
29.Sector	-0.186*
	(0.112)
30.Sector	-0.216*
	(0.115)
31.Sector	-0.133
	(0.112)
32.Sector	-0.255**
	(0.113)
33.Sector	-0.407***
	(0.113)
35.Sector	-0.406***
	(0.124)
36.Sector	-0.114
	(0.119)
37.Sector	-0.299**
	(0.126)
38.Sector	-0.144
	(0.113)
39.Sector	-0.057
	(0.112)
41.Sector	-0.311***
	(0.112)
42.Sector	-0.238**
	(0.114)
43.Sector	-0.287**
	(0.112)
45.Sector	-0.285**
	(0.112)
46.Sector	-0.384***
	(0.112)
47.Sector	-0.233**
	(0.112)
49.Sector	-0.253**
	(0.112)
50.Sector	-0.267*
	(0.147)
51.Sector	-0.639***
	(0.150)
52.Sector	-0.451***
	(0.115)
53.Sector	-0.178
	(0.138)
55.Sector	0.007
	(0.112)

56.Sector	-0.131
	(0.112)
58.Sector	-0.518***
	(0.113)
59.Sector	-0.326***
	(0.115)
60.Sector	-0.328***
	(0.116)
61.Sector	-0.383***
	(0.116)
62.Sector	-0.545***
	(0.114)
63.Sector	-0.469***
	(0.115)
68.Sector	-0.264**
	(0.112)
69.Sector	-0.394***
	(0.112)
70.Sector	-0.548***
	(0.115)
71.Sector	-0.424***
	(0.113)
72.Sector	-0.280**
	(0.138)
73.Sector	-0.476***
	(0.116)
74.Sector	-0.442***
	(0.115)
75.Sector	-0.027
	(0.112)
77.Sector	-0.182
	(0.114)
78.Sector	-0.296**
	(0.129)
79.Sector	-0.420***
	(0.113)
80.Sector	-0.090
	(0.122)
81.Sector	-0.106
	(0.114)
82.Sector	-0.404***
	(0.113)
86.Sector	-0.070
	(0.112)
88.Sector	-0.649***
	(0.112)
90.Sector	-0.366***
	(0.124)
91.Sector	-0.149
	(0.198)

92.Sector	-0.365***
	(0.112)
93.Sector	-0.145
	(0.123)
95.Sector	-0.354***
	(0.117)
96.Sector	-0.014
	(0.160)
Constant	-3.269***
	(0.121)
Observations	34,495
Number of npc_fic	20,529

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 28: Fully regression, using the xtreg command: xtreg ln_TFP ln_payroll i.ICT_Specialist i.ICT_Demand i.ICT_Train_Specialist i.ICT_Train_Others i.Region i.Dimension i.year i.Sector, robust

```
. vif
```

Variable	VIF	1/VIF
ln_payroll	5.97	0.167537
1.ICT_Spec~t	2.32	0.430662
1.ICT_Demand	1.49	0.668988
1.ICT_Trai~t	2.21	0.451919
1.ICT_Trai~s	1.55	0.647091

Table 29: Test for Multicollinearity

```
. estat hettest

Breusch-Pagan/Cook-Weisberg test for heteroskedasticity
Assumption: Normal error terms
Variable: Fitted values of ln_TFP

H0: Constant variance

    chi2(1) =   1.48
Prob > chi2 = 0.2232
```

Figure 8: Heteroskedasticity test for the regression

```
. estat ovtest

Ramsey RESET test for omitted variables
Omitted: Powers of fitted values of ln_TFP

H0: Model has no omitted variables

F(3, 34398) = 1852.05
  Prob > F =  0.0000
```

Figure 9: Ommited variables test for the regression