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Dynamics of Entry and Exit of the Software Industry

Beatriz Vieira de Jesus

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DYNAMICS OF ENTRY AND EXIT OF THE SOFTWARE INDUSTRY

Beatriz Vieira de Jesus

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Joana Rita Pinho Resende
Anabela de Jesus Moreira Carneiro

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Abstract

This dissertation seeks to detailly explore the main sectoral characteristics and business dynamics of the Portuguese software industry, by making use of a longitudinal matched employer-employee database, from 2010 to 2019. To achieve this and provide new evidence on topics that are mostly scarce in the existing literature, the analysis that follows presents a bifold approach. Firstly, the attention will be centered in studying the most relevant descriptive data for the industry, at the firm, employee, and business dynamics levels. Secondly, the aim will be to provide empirical evidence on the determinants of the firm exit outcome for the Portuguese software industry. In general, results show that the industry has expressively grown throughout the 2010-2019 period, particularly in the number of firms and workers, as well as in the weight of foreign capital in the industry's total social capital. The industry also presents the highest business dynamics levels, when compared with other knowledge intensive sectors, and showcased consistently positive net entry rates. Empirical evidence suggests that older and larger firms, with higher labor productivity and located in the North or Center regions, have a lower probability of becoming an "exiting" firm (i.e., *vis-à-vis* younger and smaller software firms, that are less productive and located in the Lisbon Metropolitan Area). Employee-level results suggest that software firms that employ a younger and more qualified workforce, with a higher proportion of ICT-based workers, present a lower probability of exiting the market (i.e., *vis-à-vis* older and less qualified employees, with a non-ICT job occupation).

JEL Codes: D22; L11; L86.

Keywords: Software Industry; Firm Dynamics; Entry; Exit.

Resumo

A presente dissertação visa explorar detalhadamente as principais características setoriais e dinâmicas empresariais da indústria portuguesa de software, através do uso de uma base de dados longitudinal, que cruza as dimensões empregador-empregado, de 2010 a 2019. Para alcançar isto e produzir novo conhecimento em tópicos que são maioritariamente escassos na literatura atual, a análise que segue assumirá uma estrutura bipartida. Primeiramente, o foco centrar-se-á no estudo dos dados descritivos mais relevantes, aos níveis da empresa, empregado, e dinâmica empresarial. Segundamente, o objetivo será o de providenciar evidência empírica relativamente aos determinantes do *outcome* de saída de empresas, na indústria de software portuguesa. No cômputo geral, os resultados demonstraram que a indústria cresceu expressivamente no período 2010-2019, particularmente em termos de número de empresas e colaboradores, assim como na proporção de capital estrangeiro no total de capital social. A indústria apresentou também os níveis mais elevados de dinâmica empresarial, nomeadamente quando comparada com outros setores intensivos em conhecimento, e demonstrou consistentemente taxas líquidas de entrada positivas. A evidência empírica sugere que empresas mais velhas e maiores, com níveis de produtividade laboral mais elevados e localizadas nas regiões Norte ou Centro, têm uma probabilidade menor de se tornarem uma empresa sainte (i.e., *vis-à-vis* empresas de software mais jovens e pequenas, com menor produtividade laboral e localizadas na Área Metropolitana de Lisboa). Ao nível do empregado, os resultados sugerem que empresas de software que empreguem uma força de trabalho mais jovem e com níveis mais elevados de qualificações formais, assim como uma maior proporção de indivíduos com ocupações de trabalho nas áreas TIC, apresentam uma menor probabilidade de saírem do mercado (i.e., *vis-à-vis* empresas com uma força de trabalho mais velha e menos qualificada, com mais cargos não TIC).

Classificação JEL: D22; L11; L86.

Palavras-chave: Indústria de Software; Dinâmicas Empresariais; Entrada; Saída.

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Acronyms

CAE – Classificação Portuguesa das Atividades Económicas

EC – European Commission

Eurostat – Statistical Office of the European Communities

GDP – Gross Domestic Product

ICT – Information and Communication Technology

IMF – International Monetary Fund

INE – Instituto Nacional de Estatística

ISIC – International Standard Classification of Activities

IT – Information Technology

KIS – Knowledge Intensive Services

NACE – Statistical Classification of Economic Activities in the European Community

OECD – Organization for Economic Cooperation and Development

UNCTAD – United Nations Conference on Trade Development

1. Introduction

The emphasized role of digital transformation processes for the competitive growth of businesses has been progressively reinforcing the strategic relevance of Information and Communication Technology (ICT) firms within today's economic landscape (OECD, 2017b). While just a decade ago the top ten biggest global companies by market capitalization were mostly from oil and manufacturing industries, the past years have seen the rising market ascendency of ICT businesses (UNCTAD, 2019), pushed by the prevalent growth of digital and internet-based software firms, such as Microsoft Corporation or Alphabet Inc. (Bloomberg, 2022).

Given the current widespread and general-purpose adoption of these technologies, the ICT sector has been positioned as the most recent diffuser of great surges of techno-economic developments (Perez, 2010), standing as the basis for the deployment of today's frontier technologies (i.e., novel technologies, sustained by digitalization and connectivity trends), such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, or Cloud Computing (UNCTAD, 2021b). Whilst these technologies gradually come to maturity, the expectation is for such developments to virtually shape and impact all sectors of the economy in coming years, nourishing the digital transition of many countries and the growth of the digital economy (OECD, 2020a).

In this scenario, the software industry has become a ubiquitous, baseline component of the digital economy, standing at the heart of most of its expansion in the last decades (van Ark, 2016). Through the deployment of novel and digitally-based products, services, and business models, that increasingly permeate to most other sectors, software firms have been harnessing wealth creation across both developed and developing economies (UNCTAD, 2012). Thus, the industry's typical "Schumpeterian" profile, justified by the small marginal and fixed costs, minimal entry and exit barriers, and short innovation cycles (Li et al., 2010, p. 632), has been translated into a business dynamism (i.e., in terms of firms turnover in the industry) that stands out from most of the remaining economic sectors.

In general, these firms turnover processes have been the target of particular attention from scholars for several decades, due to the preponderant role in explaining the behavior and performance of individual firms, markets and, even, economies as a whole (Brandt, 2004). Accordingly, since the work of authors such as Adam Smith or Schumpeter, these processes have been recognized as decisive promoters of "technical and allocative efficiency" in markets (Mata & Machado, 1996, p. 1305), while also acting as a "conduit through which new ideas and innovations are introduced" (Baldwin & Gorecki, 1991, p. 301).

Thus, the creation (and, reversely, the decline) of firms can be thought of as the process under which competitive markets select amongst established and entrant businesses, in a survival experience that tends to continuously push for the reallocation of resources towards the more productive players (Geroski, 1991; Geroski & Schwalbach, 1991). From a strategic standpoint, the study of these topics supports an improved comprehension of the type of decisions and competitive behavior taken by both incumbents and entrants, that results from an industry's typical competitive dynamic (Besanko et al., 2017).

The multiplicity of empirical work developed throughout the last decades has resulted in an extensive but, in general, rather disperse body of literature on the processes of entry and exit. Therefore, by focusing on distinguished specificities of this phenomenon, for particular time, geographical, and sectoral contexts, authors have tended to outline diverse (and sometimes contradicting) results. Some resulting stylized facts have, however, been summarized by authors like Geroski (1995). In Portugal, authors such as José Mata or Pedro Portugal have conducted noteworthy studies in this area throughout the years, mostly centered on the manufacturing industries.

In this context, and despite software's underpinning role for the current and future activity of a wide array of stakeholders (e.g., households, businesses, governments, among others), there seems to be an overall scarcity of economic literature focusing on the independent activity of this industry (UNCTAD, 2012). Particularly, while it has been generally accepted that technological sectors tend to display high entry and exit rates (and, usually, low survival rates), the analysis of the existing literature seems to point towards a national and international gap in the study of the dynamics of entry and exit of the software industry, as an independent business activity (e.g., Raz and Gloor (2007) or Li et al. (2010)).

Additionally, it is also worth noting that there persists a lack of consistent and internationally comparable studies of the Portuguese software industry. Due to its mostly knowledge-based activity, locational factors like the agglomeration of knowledge, innovation, and entrepreneurial capabilities have become a priority for firms looking to develop software capabilities (Arauzo-Carod, 2021), giving stage to the growth of small and medium-sized technological hubs across the world. Also, the very nature of today's software supply has facilitated the internationalization of these firms, as they may easily focus on an international demand through the use of internet-based technologies. Accordingly, the Portuguese software industry has been growingly obtaining an attractive competitive position in the global technological landscape, namely through the work developed by firms in municipalities such as Lisbon Metropolitan Area (LMA), Porto, or Braga. This calls, then, for a better understanding of the underlying characteristics of Portuguese software firms.

Thus, to the best of our knowledge, this is one of the first comprehensive attempts to quantitatively characterize the software industry and to study its business dynamics, in Portugal. To address the mentioned research gaps, this dissertation will provide an overview of the industry, focusing concretely on the Portuguese business landscape. Thus, departing from a general contextualization of the economic activity of today's software businesses, the purpose of this study will be to deliver a thorough quantitative analysis of Portuguese software firms, using a matched employer-employee dataset from Portugal (Quadros de Pessoal). To gain further insights into the industry's dynamic, an econometric study focusing on the potential determinants of firm exit probability in this industry will also be presented.

This study is organized as follows. Section 2 entails an overview of the software industry, exploring the existing literature to present some baseline information on the industry's typical structural and competitive characteristics. Section 3 presents the dataset used and the sample construction methodology. Section 4 includes a detailed characterization of the Portuguese software industry, at the firm, worker, and business dynamics levels. Section 5 presents and discusses the empirical model, and the respective estimation results obtained, which is followed by some robustness check procedures. Lastly, section 6 concludes this dissertation.

2. Literature Review

This section presents an overview on the main literature developed on the software industry, by focusing on its core characteristics. Accordingly, on section 2.1., the analysis will intend to contextualize the software industry, going from the study of the ICT sector to the broader scope of the digital economy. The section 2.2 will shed the light on some of the software industry's core idiosyncrasies. Thus, going from the industry's definition to its supply and demand dynamics, and to the competitive landscape, the main goal of this section will be to provide the reader with the basic necessary tools to comprehend how the software business works and how the interplay between these dimensions has contributed to the growing economic attractiveness of the industry, namely in Portugal.

2.1. The ICT Sector and the Digital Economy

In the last decades, the rapid proliferation of technology-based innovations and the cross-sectoral growth of digitalization processes have enabled the advancements of society in multiple dimensions (UNCTAD, 2021b). In this regard, the use of ICT networks has allowed for significant amounts of information to be transferred at increasing speed across the world, functioning, today, as an imperative general-purpose technology that permeates almost all sectors (Freeman & Hasnaoui, 2010). ICTs are generally composed by a collection of hardware, communication and software product and services technologies, that sustain the electronic retrieval, processing, and transferability of data (Johansson et al., 2006).

While there persist some ambiguities on what sectors pertain or not to the ICT activity across countries, ICT as an economic sector has been defined by the OECD (2010) as the combined activity of firms that produce the technological goods and/or services that are necessary to "capture, transmit, and display data and information electronically" (OECD, 2010, p. 282). The resulting harmonized framework, that can be segmented in three main levels - manufacturing, trade, and services -, is composed by a total of nineteen industry classification codes (i.e., 4 digits, based on ISIC Rev.4), ranging, for instance, from the manufacturing of electronic components, to the wholesale of computers, and to software-publishing services, among others (OECD, 2011).

In this scenario, the ICT sector has facilitated the development and diffusion of knowledge globally at rapidly decreasing costs, strengthening its role as a strategic and competitive tool for the growth of both developed and developing economies, a tendency that has been accelerated by the notion of digital transformation. The diffusion and development of digital technologies has been pushing for the transformation of economic and social interactions, producing cross-sectoral and structural changes that have been driving the economic growth of many countries (UNCTAD, 2019). Thus, the called "digital transition" and "digital revolution" trends have been potentiating relevant shifts in the production, nature, and delivery of goods and services globally (Johansson et al., 2006).

It is in the advent of these technological developments that the concept of digital economy emerges. But although the concept has become a buzzword, the conundrum on what is precisely meant by "digital" remains ambiguous. At its root, the different terminologies used contain two core concepts: digitization and digitalization. While digitization may be referred to as the technical process through which analog information is converted to digital formats, digitalization can be defined as the "diffusion of digital technologies leading to a digital economy" (Anderton et al., 2021, p. 128), referring to a holistic application of digitization to social and institutional contexts (Bican & Brem, 2020).

This paucity of a unanimous "digital" definition spreads further onto other adjacent concepts, such as that of the digital economy, sector, products, and transactions (IMF, 2018). Although the fast-emerging developments brought by the digital economy have attracted the attention of multiple authors, its definition remains ambiguous. This can be mostly attributed to the fact that the digital economy "has been shaped and is shaping" a broad spectrum of economic activities (OECD, 2017a, p. 27), with a technological potential that is still mostly unrealized and that can, at its limit, increasingly represent the whole economy. The interchangeable use of similar terminology, like the "new economy" or "internet economy", has also contributed to the definition inconsistency (Bukht & Heeks, 2017).

Concurrently, broader definitions have referred to the digital economy as the "spreading of digitalization to all economic sectors" through the use of a wide range of digital technologies (IMF, 2018, p. 1). It follows, then, from these perspectives that the digital economy concept should go beyond the ICT sector's activity, as its effects have spread to most sectors of the economy and the overall society (i.e., meaning it should incorporate any economic activity that is reliant on or significantly improved by digital inputs)(The World Bank Group, 2016). Narrower definitions, typically followed in economic and statistical reports, have focused on more measurable dimensions of the digital economy, namely in terms of the direct production and economic activity of the ICT sector (OECD, 2020b).

Somewhat more flexible definitions have centered the digital economy's definition debate in the output that is "derived solely or primarily from digital technologies, with a business model based on digital goods or services" (Bukht & Heeks, 2017, p. 13). Thus, rather than focusing on the sectors that make an intensive use of digital technologies, the authors sustain that the digital economy is comprised, at its core, by the ICT sector but its scope is extended to also include digital business model innovation[1].

Comparatively, what seems to be common across all definitions is the idea that the diffusion of ICT technologies "motivates the vision" of an expanding digital economy (Johansson et al., 2006, p. 1). Therefore, the sector has been cited as a relevant driver of economic growth in the digital era, acting as a typically disequilibrium-inducer in many markets and creating "prime conditions for entrepreneurial discovery" (Johansson et al., 2006, p. 5). Because the sector founds the basis for the development of the digital economy, players across the business and governmental landscape have increasingly incorporated it as a strategic priority in policy elaboration (EC, 2020).

Within the ICT sector, investments have progressively shifted towards ICT services areas, with the software industry assuming a prominent growth as an independent ICT economic activity, in the last decades (van Ark, 2016). The expanding scope of software businesses has been increasingly interlinked with technological developments like AI, Machine Learning (ML) or IoT, reinforcing its role as an underpinning value creation piece in today's knowledge-based economy (OECD, 2010). It is, then, because the software industry represents an inevitably relevant piece for the current and future development of the digital economy, with spillover effects across a wide set of sectors, that it becomes pertinent to further explore the kernel characteristics of the industry.

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[1] The authors presented an accompanying graphical representation for its digital economy definition, which has been adapted and presented in Appendix A.

2.2. The Software Industry

2.2.1. Definition and Measurement

Software can be described as the set of computer programs, program operating information, and supporting material that enables the functioning of systems and applications software (UN, 2009). In other words, software concerns the set of codes and programs that jointly sustain the operationalization of hardware components, such as computers or similar infrastructures (O'Brien & Marakas, 2010), but its existence is inexorably dependent on these same hardware devices (i.e., software and hardware become valuable when put together). At a technical level, there are two main types of software[2]: system software (i.e., controls and supports the computer system, functioning as an interface between hardware and software) and application software (i.e., performs information processing activities, closely connected with the end-user)(UNCTAD, 2012).

Altogether, these systems provide the necessary instructions for different types of hardware to perform specifically designed tasks, that can range, for example, from the control of production lines to the rendering of a browser's web page, or, even, the functioning of smart devices. Consequently, software is commonly characterized as the "brain of ICT devices" (UNCTAD, 2012, p. xvi) or "the medium through which IT expresses itself" (National Research Council, 2006, p. 36), as it critically affects the functionality of different types of devices and their capacity to respond to an array of diversified user needs. Software's recent high value profile results, then, from the role it assumes in harnessing the potential of a broad array of goods and services across sectors, but also from its own economic nature.

The question remains, however, on how the software activity should be measured and what dimensions constitute the industry. Despite its significant growth, measurement standardization attempts have tended to result in dispersing approaches across countries, which may partially explain the scarcity of consistent academic and statistical literature. Factors such as the relatively immature industry life cycle stage, the quickly evolving roles of software, as well as the intangible nature and "context-dependent value" generated by this activity (National Research Council, 2006, p. 4), have all contributed to the challenge of studying this business field. Most studies have either focused on the software industry as an

[2] These two product dimensions can be further branched down, in accordance with the particular software activities performed.

integrating element of the ICT sector and the digital economy, lacking to isolate its independent activity, or have defined context-specific definitions, failing to use internationally comparable measures.

One of the most thorough efforts to approach this classification and measurability conundrum was developed by the OECD (2009), whose work aimed at providing a statistically comparable definition for the industry and at setting accounting standards recommendations. Hence, departing from the abovementioned software definition by the United Nations (2009), the most recent revision developed by the OECD distinguished specific industry subcategories, in a total of seven software-related classification codes (i.e., four-digits)[3]. The subsectors included capture the core and direct activity of the industry, concerning, for instance, software publishing, computer programming or data processing, hosting, and related services. In subsequent chapters of this dissertation, the same set of industry codes will be used, to facilitate the statistical analysis that will follow, but also to provide results that may, in the future, be more easily comparable with other studies.

Also, although the general industry classification systems used in both Europe and the United States (i.e., NACE and NAICS, respectively) have become progressively compatible with the International System of Industry Classification (ISIC), other countries, such as Israel and India, have tended to use their own statistical methodologies for industry studies, hindering the access to comparable and official international data on the industry. Additionally, it should also be mentioned that, given the industry's growing ubiquitous nature, much of the value generated by software has had effects that spillover to other industries, and has become growingly embedded in the activity of firms beyond the software industry. Hence, definitions such as those presented above, inevitably fail to capture all the value that is being created outside the industry's boundaries (Stryszowski, 2009).

2.2.2. The Economics of Software: Supply and Demand

The software industry's significant growth, witnessed mostly over the last two decades, has been strongly anchored by the specific nature of these goods and services, which have, ultimately, shaped the industry's unique supply and demand dynamics. In general,

[3] The detailed industry classification codes used and the respective description are presented in Table 1, shown in Section 3.2. of this dissertation.

software firms tend to have a high dependence on knowledge and innovation-based capabilities, which is reflected in an imperative role of qualified human capital for the prosecution of the industry's activity (Giarratana & Fosfuri, 2007). As so, contrarily to most hardware production subsectors, the software industry has been remarkedly characterized by stronger levels of labor intensiveness, which has been reinforced by the quick obsoletion associated with these technologies.

In theory, virtually any individual with technical programming skills can, at least initially, develop its own software code using a limited number of resources and without facing significant entry requirements (Li et al., 2010). Hence, while software activity may involve some level of up-front entry investments (e.g., computer infrastructure) and posterior fixed production costs (e.g., labor costs or R&D investments), the industry's overall entry and exit barriers tend to be low, which comes as a natural facilitator for firm creation. Additionally, due to its information-based activity, software distribution tends to resemble a "copy and paste" operation (i.e., near-zero additional input costs needed to replicate the initial code), pushing marginal costs to levels that are typically close to zero (OECD, 2020a).

In this scenario, the paradigm of scale economies has shifted from conventional production standards, in the sense that, once software is ready for release, firms can achieve exponential output levels without significant increases to the level of production inputs or diffusion costs required to release an additional "unit"[4] of software (Johansson et al., 2006). Thus, after absorbing initial fixed and software development costs, firms can achieve scaling without mass inputs, incurring in significantly low marginal costs (OECD, 2020a). In essence, this implies that even traditional pricing options have tended to shift. If unitary marginal costs are close to zero, then the price of these information-based products must be based on alternative approaches, such as that of the perceived value of the good or service for users, rather than the unitary production costs *per se* (Shapiro & Varian, 1998).

Software has also been characterized by the potential of scope economies, as the complementarity of the baseline development process (e.g., cross-use of software codes) and the shared use of existing resources (e.g., infrastructures, workforce, data) may act as a facilitating and cost-offsetting element for the expansion of businesses' product range

[4] Typically, software is distributed via licenses to use or reproduce the software, under the terms of the respective licensing agreement. In some cases, an original software may also be directly sold to the user (e.g., custom-made software for particular use purposes).

(Besanko et al., 2017; National Research Council, 2006). Through the complementarity of knowledge and resources, firms in the industry can more easily offer a vaster array of features in a same software environment, but also crossover traditional industry boundaries with little additional costs. This sectoral permeability has reinforced the blurring of traditional industry boundaries, leading to the creation of novel business models and to the reshaping of previously established sectors (Johansson et al., 2006).

In recent decades, the industry's scalability potential has expanded due to the growth of digitized and internet-based technologies, namely because, today, firms can reach and interact with global audiences, at the distance of a click (UNCTAD, 2019). Indeed, in the digital world, the notion of scale gained a virtual dimension, that has forced the development of new business models and reshaped the competitive structure of different markets. Concurrently, the value of today's software technologies also relies in the capacity to decrease transaction costs (i.e., costs of using the market, such as of searching or communicating information)(Coase, 1937; Guellec & Paunov, 2018) for millions of its users, by enabling the ubiquitous availability of information and reducing information asymmetries (Garicano & Kaplan, 2001), but also in the ability to generate new knowledge from existing data.

Growing digitalization trends have, consequently, reinforced the need to collect, transform, and extract value out of a large amount of digital data flows, sometimes characterized as the "lifeblood" of the digital economy's development (UNCTAD, 2021a, p. 65). This "big data" paradigm has become an economic resource for most organizations, whose value grows with the new knowledge that software applications can derive from it. Resultingly, there has been an emerging focus on data monetization strategies and data-based business models (UNCTAD, 2021a), through which organizations try to transform data's intangible value into quantifiable economic gains, for example by using personalized price discrimination and advertisement strategies (Baecker et al., 2020; Esteves & Resende, 2019).

The evolution of high-speed digital networks has, then, progressively transformed the modes through which software is delivered, going from generally on premises and licenses-based software applications to web and services-based solutions. It is in this context that the notion of "digital servitisation" arises, referring to the transformation from product-centric to services-centric business models using digital technologies (Kowalkowski et al., 2022), and whose value creation is rooted in the interplay between software, products, and services systems across industries (Kohtamäki et al., 2021). Consequently, software-as-a-service (SaaS) business models, that typically follow a "pay-as-you-go" revenue model, are proliferating in the industry, due to the cost-effectiveness and mass-scalability potential of web-based solutions (Stryszowski, 2009).

This tertiarization of the industry has been sustained by the underlying expansion of a "platformization" phenomenon across markets. In a general accession, digital platforms can be described as multi-sided, software-based platforms where different user groups, or sides of the market, interact by using the platform as an intermediary (Rochet & Tirole, 2003). These multi-sided markets are leveraged, then, on the positive cross-group externalities that stem from the co-creation of value by the supply and demand agents, and its usage has recently expanded to an increasing number of industries (Armstrong, 2006; Hagiu, 2009). This common platform can assume different shapes in accordance with the specific digital-related intermediation offered (e.g., social media, marketplaces, or payment systems).

In the interaction that occurs between the sides of digital platforms, there is a common display of network effects, which occur when the incentive for platform use is positively affected by the number of users that enter the same and/or opposing sides of the platform (i.e., direct and indirect network effects, respectively)(Garcia & Resende, 2011). For example, while the value of a videogame console grows with the number of users who purchase the console, increases in the number of users also attract the development of more games that are compatible with that console, expanding the expected returns of both sides (Rochet & Tirole, 2003). Thus, the interdependent relationship between software users and publishers is frequently reinforced in a dependent loop, that has only been strengthened by ever-evolving technologies like cloud computing, AI, or big data analysis (Hagiu, 2012).

These dynamics of supply and demand are, then, mutually reinforcing and have jointly contributed to the growing public and private interest for the industry. If in the 90's the industry was already considered the fastest growing component of the ICT sector (OECD, 2002), the recent advancements in digital and web-based technologies have only emphasized the sector's economic growth potential for developed and developing countries, bolstering software's increasingly engrained role in the day-to-day life of consumers, businesses, and public institutions (Johansson et al., 2006). Simultaneously, in a scenario where data-based economies of scope and scale, and network effects have a prevalent weight, the competitive dynamic of the industry has itself also been reshaped due to digitalization.

2.2.3. Competitive Structure

The advent of the software industry can be traced back to the mid-1940's, with the appearance of the first modern computers. In this era, software acted mostly as a "hardware-driven" technology, whose development was only guided by the specific demands of the equipment (Yrjönkoski et al., 2019). Accordingly, as software was incorporated in the scope of hardware manufacturing, there was mostly no direct software competition. It was only with the arrival of the first personal computers, around the late 70's, that the industry started to be recognized as an independent technological sector, that could respond to market needs in an unbundled way (Campbell-Kelly, 1995). From then onwards, progressive decreases in hardware pricing and the development of new infrastructures have been shaping the industry's competitive structure.

With the expansion of internet-based competition, the software industry was gradually faced with fundamental changes in its market structure and competitive dynamic, owing to elements such as the scalability of data-based business models (Hakkarainen, 2021), the generally quick obsolescence of these technologies (OECD, 2002), the relatively low entry and exit barriers, and the increased demand for specialized software services (OECD, 2020a). Consequently, recent studies (e.g., UNCTAD (2019)) have pointed towards a growing and accentuated market share concentration in the industry, that has been reflected in the reinforcement of monopolistic and oligopolistic market structures (Besanko et al., 2017). These "winner-takes-all" or "winner-takes-most" tendencies have appeared mostly as a reflection of the industry's characteristics explored in the previous subsection.

Firstly, data-centered businesses have been potentiating the premise that "size begets size" in the software industry. Incumbent digital platforms have usually assumed favorable positions for the extraction, processing, and analysis of large amounts of data, which can sustain the creation of knowledge that improves strategic and business acumen, in a way that data-sparse competitors cannot usually match (Mazzei, 2020). This can be further expanded by the prevalence of network effects: the existence of fewer rivals leads more users to the incumbent platforms, more users imply more data, typically leading to more market power, and again back to fewer competitors, in a looped path (e.g., Armstrong (2006) or Hagiu (2009)). As so, these snowball effects, brought on by the digital platforms' typical network effects, have tended to partially strengthen industry consolidation trends, as the market tips favorably towards a small number of large players, which sustain extensive data processing activities that support dominant market positions.

The small *versus* big software players polarization has been further sustained by data-based economies of scope. Thus, because incumbent digital platforms can use their big data advantages to monetize on the data collected or cross-share it into other business lines, there is an incentive for firms to leverage on the potential of larger, integrated datasets while increasing market efficiencies (UNCTAD, 2019). Also, offering more services in a single environment can, at least up to a certain point, improve the expected returns *per* feature added to the platform, as users will have more incentives to stay connected and the costs to switch to other platforms may simultaneously increase (OECD, 2020a). Through this, software firms also have incentives to incorporate secondary services, such as client support, because data gives them an increased awareness regarding user pain points and quicker response mechanisms (Stuckenberg et al., 2011).

Additionally, the industry has been witnessing growing competitive pressure and business dynamics as a result of the rapid technological innovation and short product life cycle that are associated with software technologies in the digital era (OECD, 2020a). To fuel software innovation, larger incumbents have been growingly dependent on intensive and extensive research and development (R&D) efforts, to sustain consolidated competitive positions (Stryszowski, 2009). Contrary to smaller firms, incumbents in the industry tend to have a greater financial capacity to sustain these costs, but also a large scale that facilitates the quicker amortization of high R&D investments (Tidd & Bessant, 2005).

In this regard, reports have shown that incumbents in the software industry have growingly sought new ways to improve innovative capacity and sustain the competitive position against both small and large rivals, namely through mergers and acquisitions (M&A). M&A levels in the industry have tended, then, to surpass those of most other sectors in the USA and Europe (Schief et al., 2013). In this scenario, entrants serve frequently as sources of innovation, acting as "pilot fishes" in the development and testing of innovative technologies, new markets, or, even, business models (Guellec & Paunov, 2018, p. 17). If successful, then incumbents might have an incentive to incorporate the activity of these young software competitors, acquiring innovation competencies directly from the market, rather than pursuing potentially more expensive and less agile in-house solutions.

However, incumbents may also target innovating firms with the aim of diminishing the competitive threat that they represent, incurring in the designated "killer acquisitions". In general, incumbents may have an incentive to halt the market's open flow of creative destruction mechanisms when there is some level of substitutability between the products or services offered, that can threaten the incumbent's competitive position (Cunningham et al., 2020). While these pursuits have been doomed as anticompetitive behavior, large companies in the software industry, such as Microsoft Corporation or Alphabet Inc, have been formally targeted by competition authorities for alleged misconduct (e.g., FTC (2020)).

Altogether, the mentioned competition-influencing elements make it an exemplary "Schumpeterian" industry, wherein entry rates have tended to be relatively high, but survival is "usually a challenge" for entrants (Li et al., 2010, p. 632). This doesn't, however, mean that software entrants do not have prime importance for the industry's dynamic. Indeed, software's competitive landscape has been marked by the coexistence of high consolidation and entrepreneurship levels (Guellec & Paunov, 2018), wherein there are usually a few large, incumbent firms and a longer tail of niche-focused young ventures (Giarratana & Fosfuri, 2007). Hence, more than just a gateway for the innovation of incumbents, new entrants in the industry have aimed at serving specific niches in technological sectors, while also catalyzing software's innovation potential across other unrelated industries (OECD, 2020a).

2.2.4. The Portuguese Software Industry in a Global Landscape

In an era where more than half of the world population has gained access to the internet, the competitive landscape of the software industry has become ever more globalized. Despite the paucity of international statistical reporting on the software industry, some reports have pointed towards the lasting concentration of output and trade in more developed countries in Northern America, Europe, and Asia, although particular country rankings differ across reports. Indeed, the existing related data seems to point towards a higher technological readiness level of these regions, that appear to be leading the international deployment and use of digital technologies (e.g., OECD (2020a) or UNCTAD (2021a)).

However, the growth of the digital economy has been altering the perception regarding traditional determinants of optimal business geographic choices, for technological firms. In the age of digital information, locational factors that were once prioritized, such as the access to raw materials or transportation networks, for example, have given place to an intensive quest for "skills, technology, and knowledge" (Johansson et al., 2006, p. 8). This implies, then, that firms in these high-tech areas may proactively seek knowledge agglomeration locations, that are not only rich in highly-specialized workers in technologic fields but wherein the potential clustering of businesses, universities, and research centers may offer a competitive path to foment knowledge, innovation, and entrepreneurial spillovers (Arauzo-Carod, 2021).

These preference shifts have opened the door for the development of smaller and increasingly specialized technological hubs. Thus, even developing countries, like India, Philippines, Vietnam, or China, have been able to gain a relevant global role in the development of the software industry and outperform many developed countries that have a higher GDP *per capita*, by focusing on its ecosystem's comparative advantages (UNCTAD, 2021b). Similarly, even medium and small-sized regions in developed countries, such as small municipalities in Europe, have also been able to leverage on its locally based expertise to attain globally attractive positions in the industry. This is also sustained by the fact that the industry presents overall low entry barriers and maintains a high-growth and high-value nature, that have enhanced business entry flows (UNCTAD, 2012).

In line with the European growth scenario, Portugal has, in the last decade, been progressively assuming a relevant role as a high-level technological ecosystem within the European and Global landscapes, establishing a generally positive reputation for its software and technology-focused hubs (AICEP, 2021). Consequently, certain studies have pointed the software industry and other specific ICT sectors (e.g., telecommunications) as some of the most relevant competitiveness sources for the country's growth, in coming decades (EY, 2021). Indeed, Portugal placed relatively well in the UN's recent Readiness for Frontier Technologies index, reaching the 32nd position (i.e., high-level score group) amongst 158 countries, mostly supported by the relative quality of the workforce, infrastructures, and innovation capabilities of its technological ecosystems (UNCTAD, 2021b).

Through the DESI index (i.e., Digital Economy and Society Index), computed by the Eurostat (2022a) to track the European Union's (EU27) digital performance, it is also possible to perceive that Portugal seems to be progressively improving its relative level of digital competitiveness, climbing from the 19th to the 16th position, between 2020 and 2021. However, despite some improvements, the country still presents a below-average performance at a European level, which may be partially affecting the overall development of the software industry. While the performance of the country in metrics such as the integration of digital public services are above European average, the country's performance has fallen short in dimensions such as the level of the population's basic digital literacy or the integration of digital technologies in businesses.

At a financial level, recent data has shown that, from 2017 to 2021, Portugal had one of the lowest *per capita* levels of cumulative invested capital in the overall technological sector (i.e., 23rd position), across Europe. According to the same report, Europe has shown a geographical funding gap across countries, that has favored the most developed countries and technological hubs (Atomico, 2022). Nonetheless, other reports have recently pointed towards rising and significant levels of direct foreign investment captured by Portuguese technological firms, namely in the Northern and Lisbon Metropolitan Area (LMA) regions, when compared with other European countries (EY, 2021). Studies have also pointed to increasing venture capital investments directed to the Portuguese IT and ICT sectors (e.g., CMVM (2021) or European Startups (2022)).

Although the data available does not allow for a more granular analysis on the software industry, its growing relevance can be observed through the type of startups that are being created in the country. Recent reports by Startup Portugal et al. (2021) have shown that most startups created in the country, in 2020, occupied tech-related activities. Additionally, it might be interesting to note that all the seven Portuguese unicorns (i.e., startups that have scaled-up and reached a valuation of one billion dollars or more) created in the last years are directly or indirectly dependent on software development for the prosecution of its baseline activity.

Hence, the 21st century has seen the rise of the Portuguese software industry as a competitive player in the international technological landscape, assuming a growing part in the ICT sectors' contribution for national GDP. This growth has been pushed by comparative competitive advantages in dimensions such as human capital qualifications and innovation efforts (i.e., namely through the three folded connection between stakeholders in private firms, the public sector, and the academia)(FCT, 2013). The relative paucity of literature on the particular activity of the software industry opens, however, the need for a more detailed analysis on the industry's typical characteristics and recent developments, as will be seen subsequently.

3. Data Description

3.1. Quadros de Pessoal

To achieve its objectives, this dissertation will use selected data retrieved from the Quadros de Pessoal (QP, herein) micro-database, collected by the Portuguese Ministry of Labor, Solidarity and Social Security. The QP data is collected through a legally mandatory employment survey, filled annually by all the Portuguese private firms who employ at least one wage-earning employee. The data may be characterized at three levels - firms, establishments, and workers (Gabinete de Estratégia e Planeamento [GEP], 2019b) - for the sectors included in the CAE-Rev. 3.

For this analysis, only the firm and employee files were used. The firm-level dataset includes information on the industry, location, firm age, employment, ownership, and sales volume, among other variables. The employee-level dataset includes information such as the workers' age, sex, nationality, education, qualification, occupation, and wages, among other variables. Each firm and employee included in QP has a unique identification code (ID), assigned at the moment of first registry in the database, that enables their tracing overtime.

The comprehensive and reliable nature of the QP dataset makes it an adequate source for this dissertation's main purpose. This may be justified by the existence of a longitudinal type of data that allows for the yearly matching and tracking of firms and employees, and by the large representativeness of the survey, covering virtually all firms in the private sector with at least one wage-earner. These advantages have also been approached in noteworthy studies developed on the topics of business entry and exit in the Portuguese economy (e.g., Mata and Portugal (1994) or Geroski et al. (2010)).

3.2. Sample Construction

The following sections will primarily grasp the activity of the software industry by using the definition provided by the OECD (2009), whose respective industry classification codes and description can be seen in Table 1. The ISIC classification codes used by the OECD have an identical correspondence to those of NACE, which then derive in the Portuguese classification of economic activities (i.e., CAE). Overall, our sample is restricted to firms in the software industry from 2010 to 2019, and their workforce (including workers aged between 18 and 67 years-old, who are either business-owners or wage-earners).

Table 1
Software Industry Classification Codes (CAE Rev.3)

CAE Rev.3	Code Label	Code Description
5820	Software Publishing	Design, development, adaptation, and publishing services of non-customized packaged, downloadable, online, or licensed services of computer games (for all platforms), and of other general systems or application software.
6201	Computer Programming Activities	Design, development, testing and implementation of on-demand and original systems, application, database, or webpages, among other types of specially designed software.
6202	Computer Consultancy	Provision of consultancy services, regarding equipment, programming, and other related IT technologies, as well as the provision of necessary technical support and training services.
6203	Computer Facilities Management Services	Management and monitoring of IT equipment and network systems, with the purpose of providing services such as network problems diagnosis or security systems management.
6209	Other Information Technology (IT) and Computer Services Activities	Provision of other IT-related services, not else-where classified in the remaining subdivisions, such as computer disaster recovery or software installation services.
6311	Data Processing, Hosting, and Related Activities	Provision of data processing services and infrastructures for diverse hosting activities, such as web, data, streaming, or applications hosting, and other types of hosting and provisioning services, such as data storage and management services.
6312	Web Portals	Development and operation of websites that use a search engine to manage and maintain databases of Internet addresses and content, as well as other types of websites that act as a portal to the Internet.

Note. Industry classification codes' description based on the definitions by the OECD (2009) and INE (2007).

For comparison purposes, and whenever relevant, we consider a sample that contains data on firms in the remaining knowledge intensive services (KIS) sectors in the 2010-2019 period, and their workforce, following the classification developed by the Eurostat (2022b), presented in Table 2. The choice for this comparative group may be justified by the overall recent spur of interest concerning the role of knowledge intensive business activities for economic growth and development (i.e., knowledge economies), but also due to the software industry's very nature as a core KIS business area.

Table 2
Knowledge Intensive Services Classification Codes (CAE Rev.3)

CAE Rev.3	Classification Label	Classification Description
50-51 69-71; 73-74; 78; 80	Market KIS	Includes water and air transport, specialized management, engineering, accounting, legal, and other related services. Also includes employment, security, and investigation services.
64-66	Financial KIS	Includes specialized financial and insurance services activities.
59-63; 72	Other High-tech KIS (Excluding Software)	Includes telecommunication, broadcasting, and media-related activities, as well as scientific research and development.
58; 75; 84-93	Other KIS	Includes publishing activities (excluding software), veterinary, public administration and social security, human health, education, and arts and entertainment activities, among others.

Note. Industry classification codes' description based on the definitions provided by the Eurostat (2022b).

Additionally, missing values in the variables of interest were dropped on both datasets, which was the case of the sales volume and number of hours worked variables. Observations which were duplicated for all variables and for which the same worker appeared more than once in each year were dropped, which accounted for only a relatively small portion of the initial observations (i.e., around 4%). Observations that did not match in the employee and firm datasets were also dropped (i.e., around 0.02%).

Overall, this study will use employer and employee-level data from 2010 to 2019. The employer dataset includes 31,686 (YearsxFirms) observations for the software industry and 518,444 (YearsxFirms) observations for the comparison group, while the matched employer-employee dataset includes 462,878 (YearsxEmployees) observations for the software industry and 6,963,228 (YearsxEmployees) observations for the comparison group.

4. Firm and Worker Dynamics Over 2010-2019 [5]

4.1. Firm Characteristics

Table 3

Total Number of Firms by KIS Sector, Portugal, 2010-2019

	Software Industry	Market KIS	Financial KIS	Other High-tech KIS	Other KIS
2010	2,391	21,088	3,145	1,173	22,482
2011	2,580	21,467	3,463	1,260	23,286
2012	2,676	21,379	3,568	1,202	23,302
2013	2,881	21,533	3,694	1,287	23,782
2014	3,110	22,164	3,786	1,354	24,464
2015	3,273	22,388	3,787	1,329	25,004
2016	3,420	22,704	3,771	1,350	25,305
2017	3,633	23,164	3,797	1,424	25,804
2018	3,813	23,777	3,790	1,449	26,136
2019	3,909	23,548	3,744	1,441	25,853

Table 3 shows the absolute number of firms in the software industry and the comparison KIS groups, over the 2010-2019 period. Although the total number of firms across all industries has mostly grown, the software industry had one of the largest relative increases in the number of firms across the period studied, growing from 2,391 in 2010 to 3,909 firms in 2019. This trend is reinforced by the data shown in Figures 1 and 2.

[5] All the tables and graphical representations included in this section have been developed by the author, based on the data available in the QP database.

Figure 1

Distribution of Total Number of Firms by KIS Sector (%), Portugal, 2010 and 2019

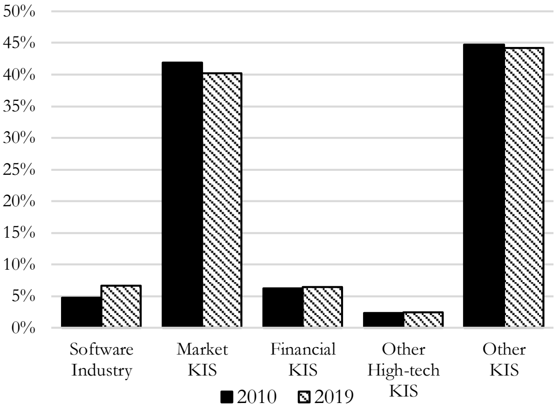
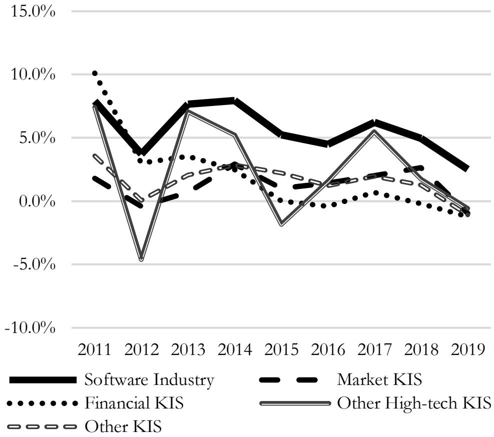


Figure 2

Annual Growth Rate in the Total Number of Firms by KIS Sector (%), Portugal, 2010-2019



As can be seen in Figure 1, the weight of the software industry on the total number of firms analyzed increased by around two percentage points between 2010 and 2019. Hence, despite its relatively reduced size (i.e., in terms of total number of firms), the industry has tended to show greater or equal growth trends when compared to other KIS sectors. Software was, across the period, the only industry with a persistently positive annual growth rate in the total number of firms[6], as presented in Figure 2.

Figure 3

Distribution of Total Number of Firms of the Software Industry by Sub-Sector (%), Portugal, 2010 and 2019

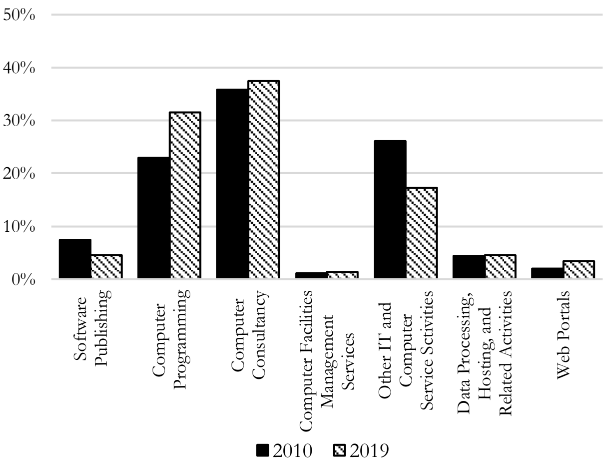
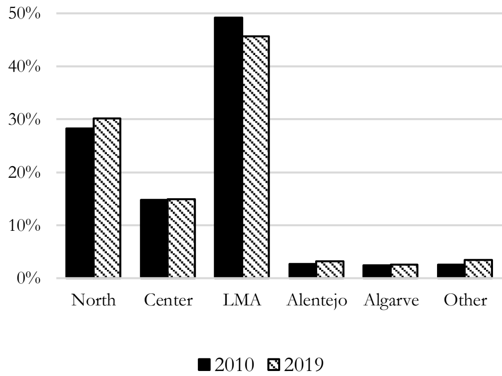


Figure 4

Distribution of Total Number of Firms of the Software Industry by NUTS (%), Portugal, 2010 and 2019



[6] Measured as the percent growth in total number of firms between the period t and t+1, for the whole period.

Figure 3 details the distribution of the total number of firms across software's subsectors, for 2010 and 2019. "Computer Programming Activities" (6201) observed the highest relative increase in the total number of firms, followed by "Computer Consultancy" (6202). This was accompanied by the reduction of subsectors such as "Other IT and Computer Services Activities" (6209) and "Software Publishing" (5820). While increases in technological consultancy fit well with the narrative of a rising digitalization trend (Portugal Gov, 2021), the relative growth of the 6201 subsector may be potentially justified by the growing demand for personalized IT services (Sunikka & Bragge, 2009), in detriment of the mostly standardized solutions offered in the 5820 subsector. The relative decrease in the number of firms in the 6209 subsector may be justified by the inclusion of these services in the activity of firms with other industry classification codes (e.g., IT consultancy).

Figure 4 displays the geographical distribution of software firms, for 2010 and 2019, by NUTS[7]. As may be seen, the industry's activity is significantly concentrated in the Lisbon Metropolitan Area (LMA), followed by the North and Center regions of Portugal, in both analyzed years. The most relevant increase in the total number of firms' distribution comes from the North region, a trend which would be expected given the recent growth of the region as a strategic innovation and tech-hub (EY & Invest Porto, 2019; fDi Intelligence, 2020). In contrast, note that the LMA region shows the highest relative decrease in the analyzed period, which is in line with the idea that the region is "losing ground" in terms of relative regional attractiveness, in Portugal (EY & Invest Porto, 2019, p. 27).

Table 4
Firm Size and Age by KIS Sector (Average), Portugal, 2010-2019

	Software Industry	**Market KIS**	**Financial KIS**	**Other High-tech KIS**	**Other KIS**
Size (Nr Employees)	14	12	23	21	14
Age (Years)	8.14	12.24	13.28	11.46	18.72

[7] NUTS stands for "Nomenclature of Territorial Units for Statistics", as defined by the Eurostat.

Table 4 presents the average size and age of firms in the industries considered[8]. The software industry is comprised by relatively young firms, a characteristic that is reinforced when compared with other KIS sectors that present a higher average firm age across the analyzed period. Similarly, firms in the industry tend to employ a relatively reduced number of workers, pointing to the prevalence of micro and small firms. This size and age gap may be explained by the comparatively high entrepreneurial dynamism that is typically associated with this technological area, as explored in previous chapters of this dissertation.

Figure 5

Distribution of Total Number of Firms of the Software Industry by Size (%), Portugal, 2010 and 2019

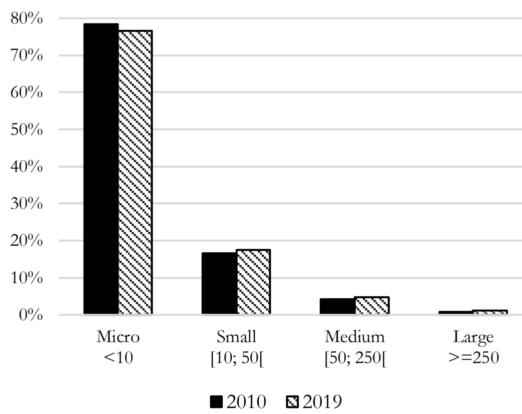
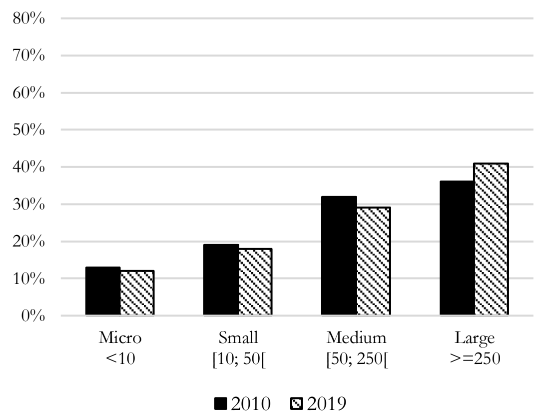


Figure 6

Distribution of Market Share (in terms of Gross Sales) of Firms of the Software Industry by Size (%), Portugal, 2010 and 2019



Note. Size groups were defined in accordance with INE's definition (INE, n.d.)

Through the firm size data showed in Figure 5, it is possible to observe that the industry's business structure has a relevant weight of micro and small firms, a tendency which is persistent across the analyzed period and that is aligned with the overall demography of the Portuguese economy. Thus, firms with a medium and large size have a lower expression in the industry. It is, however, worth observing that there seems to be a tendency for an overall rise in size of software firms, as the proportion of micro firms reduced and that of small, medium, and large firms increased over the period considered.

Despite the prevalence of micro and small businesses in the total number of firms, the overall software industry is commonly characterized by a big *versus* small players dynamic

[8] Measured as the simple average of each sectors' average firm size and age, across the period.

in terms of output concentration, as mentioned previously. The analysis of the industry's market share distribution by size[9], displayed in Figure 6, shows that medium and large firms concentrated around 70% of the gross sales generated in the industry, which contrasts with the reduced total number of firms within these size groups. Between the years of 2010 and 2019 this output concentration trend was reinforced, particularly through the output concentration in large firms.

Figure 7

Real Gross Sales per Employee by KIS Sector (Millions, Euros), Portugal, 2010 and 2019

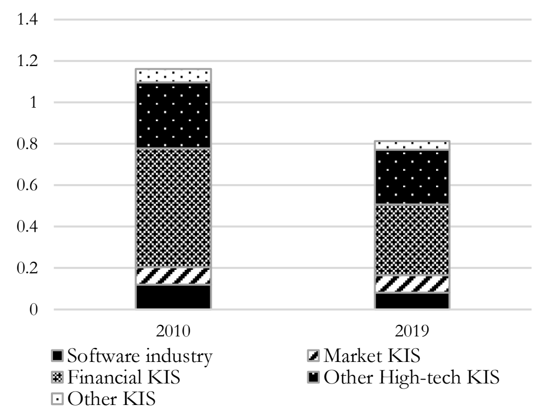


Figure 8

Real Gross Sales, Real Gross Sales per Employee and Total Employees Evolution of the Software Industry (Log, Euros), Portugal, 2010-2019

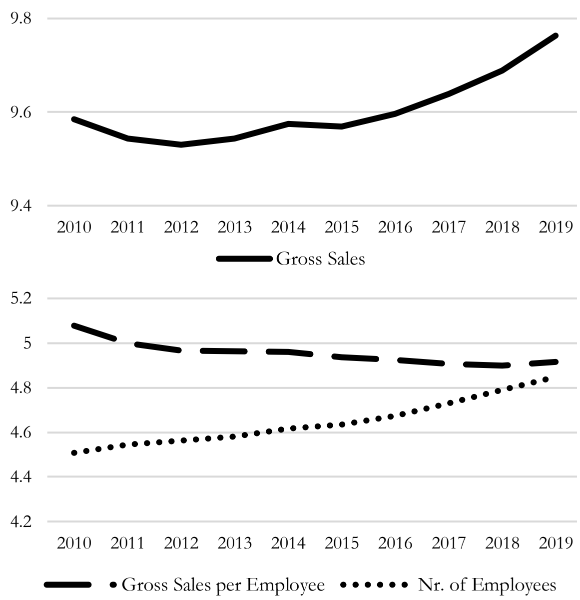


Figure 7 displays the level of gross sales generated per employee by sector, a measure that is commonly used to analyze labor productivity. Data seem to point to a productivity reduction across the period, with the most significant decreases coming from the software industry and the Financial KIS sector. This declining trend is, however, aligned with the productivity growth deceleration of the Portuguese economy in the last decade (GEE, 2019a), namely as the services sector has been pointed as the main source of this productivity evolution.

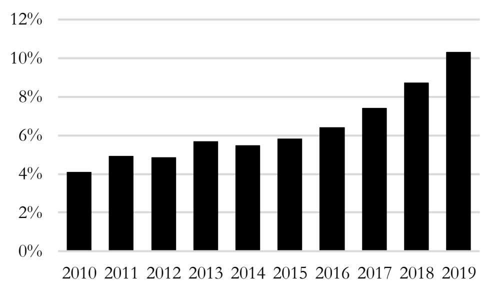
[9] Measured as the ratio between the total sales output of size group i and the total industry sales output.

Figure 8 details the labor productivity scenario of the software industry. Given that both gross sales and the total number of employees mostly grew, the overall decrease in productivity seems to point towards a difficulty in generating a level of gross sales growth that is proportional to the growth in the total number of employees. Indeed, despite the economic advancements brought in by ICT technologies, there seems to be some productivity paradox of the digital economy even at an international level, namely pushed by the relatively immature phases of these industries and by measurement difficulties (van Ark, 2016).

Table 5
Proportion of Foreign Social Capital in the Total Social Capital by KIS Sector (Average, %), Portugal, 2010 and 2019

	Software Industry	**Market KIS**	**Financial KIS**	**Other High-tech KIS**	**Other KIS**
2010	3.94%	1.61%	3.65%	3.27%	0.29%
2019	10.06%	3.73%	4.81%	5.84%	0.81%

Figure 9
Proportion of Firms with at least 50% Foreign Social Capital in the Total Social Capital of the Software Industry (%), Portugal, 2010-2019



It is also worth noting, according to Table 5, that the average level of foreign social capital within the industry has significantly increased, namely when compared with remaining KIS sectors. Particularly, the proportion of firms in the Portuguese software industry with 50% or more foreign social capital in the total social capital structure has more than doubled over the analyzed period, as can be seen in Figure 9. This is in line with the idea that Foreign Direct Investments (FDI) projects directed towards software and IT services have some of the highest relative growth, in Portugal, in the last years (EY, 2021).

4.2. Entry and Exit Flows (2011-2018)

Following the procedures used in similar studies with the QP database (e.g., Mata and Portugal (1994)), a firm was identified as an entrant if it appeared for the first time in the QP files in year t over the 2010-2019 period (i.e., based on the firm's unique identification code) and if it exhibited a firm age lower than three years. A firm was classified as an "exiter" in t if it was present in the QP files in t-1 but there was no survey registry for the same firm in the two subsequent years (i.e., in t and t+1). This implies that there is no exit data for 2010 and 2019 [10,11].

Table 6
Gross Number of Firm Entry and Exit by KIS Sector, Portugal, 2011-2018

	Software Industry		**Market KIS**		**Financial KIS**		**Other High-tech KIS**		**Other KIS**	
	Entry	Exit	Entry	Exit	Entry	Exit	Entry	Exit	Entry	Exit
2011	313	274	1,589	2,268	479	307	162	140	1,559	1,890
2012	311	310	1,457	2,465	311	331	100	190	1,397	2,123
2013	427	319	1,588	2,301	322	330	165	134	1,661	2,149
2014	412	303	1,706	2,141	245	319	142	155	1,597	1,860
2015	425	381	1,740	2,313	244	371	114	184	1,605	2,084
2016	414	387	1,578	2,140	215	343	141	170	1,473	2,064
2017	483	394	1,651	2,092	188	310	142	158	1,576	1,978
2018	488	437	1,638	2,135	195	345	125	174	1,562	2,109

Table 6 presents the total number of entering and exiting firms of the software industry and remaining KIS sectors, from 2011 to 2018. In the software industry, both gross entry and exit increased in the analyzed period. Comparatively, the growth[12] in entries and exits between 2011 and 2018 were highest for the software industry. Although the number of exiting firms in the industry grew relatively more when compared with the growth in the number of its entering firms, absolute numbers still consistently pointed towards more entries than exits in the analyzed period, for the same industry.

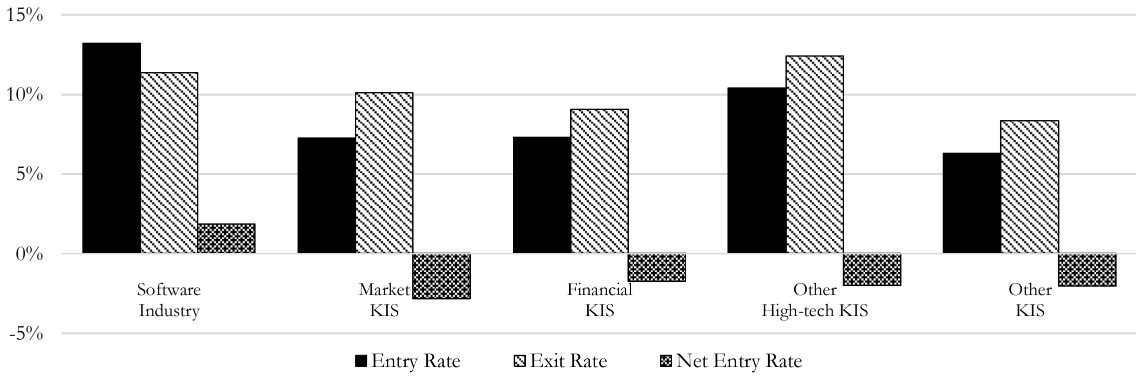
[10] The nature of the QP database does not allow for a straightforward distinction between different types of exits. Thus, the absence of a firm for a certain period may, besides the possibility of permanent closure, be a mere consequence of the failure to submit the survey, a temporary exit, or shifts in business activity (e.g., due to M&A activity).

[11] For coherence, entry data for 2010 and 2019 were suppressed, as there was no matching exit data.

[12] Measured as the percent growth in total number of entries and exits between 2010 and 2019.

Figure 10

Entry, Exit, and Net Entry Rates by KIS Sector (Average, %), Portugal, 2011-2018



An isolated analysis of gross entry may, however, result in an inflated sense that entry is quantitatively more substantial than what it may really be, while it might also present greater sensitivity to an industry's relative size (Geroski, 1991; Siegfried & Evans, 1994). Thus, studies have showed that net entry rates tend to constitute a small portion of gross entry and exit (e.g., Brandt (2004)). Figure 10 shows the entry, exit, and net entry rates for the software industry and remaining KIS sectors[13], obtained as an average from 2011 to 2018. Across the period, the software industry showed the highest entry and exit rates and was the only to consistently display positive net entry rates. The remaining KIS sectors presented mostly negative net entry rates across the years[14].

Table 7

Correlation Between Entry and Exit Rates by KIS Sector, Portugal, 2011-2018

	Software Industry		**Market KIS**		**Financial KIS**		**Other High-tech KIS**		**Other KIS**	
	Entry	Exit	Entry	Exit	Entry	Exit	Entry	Exit	Entry	Exit
Entry	1.00		1.00		1.00		1.00		1.00	
Exit	-0.06	1.00	0.57	1.00	0.47	1.00	0.32	1.00	0.34	1.00

13 Entry and exit rates were, respectively, measured through the ratio between total entry and exit, over the average between the total number of firms in t and t-1 (i.e., this implies that no entry rates are presented for 2010). Net entry rates were obtained through the difference between entry and exit rates.

14 More detailed values for entry, exit, and net entry rates by KIS sector, software subsector and location of software firms, for Portugal, in the 2011-2018 period, can be seen in Appendix B.

Following the conclusions of existing literature (e.g., Baldwin and Gorecki (1991)), most of the sectors that presented higher entry rates also tended to present higher exit rates, reinforcing the premise that firm entry and exit follow similar patterns and may be positively correlated. Indeed, as shown in Table 7, almost all sectors showed a positive correlation between firm entry and exit, except for the software industry. Positive correlations between entry and exit rates seem to defy the pre-existing notion that firm turnover comes as a response to potential sub or super-normal profits (i.e., which would cause a negative correlation)(Geroski, 1995). Software's diverging values could, if statistically significant, be a consequence of the industry's current high growth phase, wherein the expected profitability is still attractive for potential entrants, contributing to a net expansion of the industry supply.

Figure 11

Entry, Exit, and Net Entry Rates of the Software Industry (%), Portugal, 2011-2018

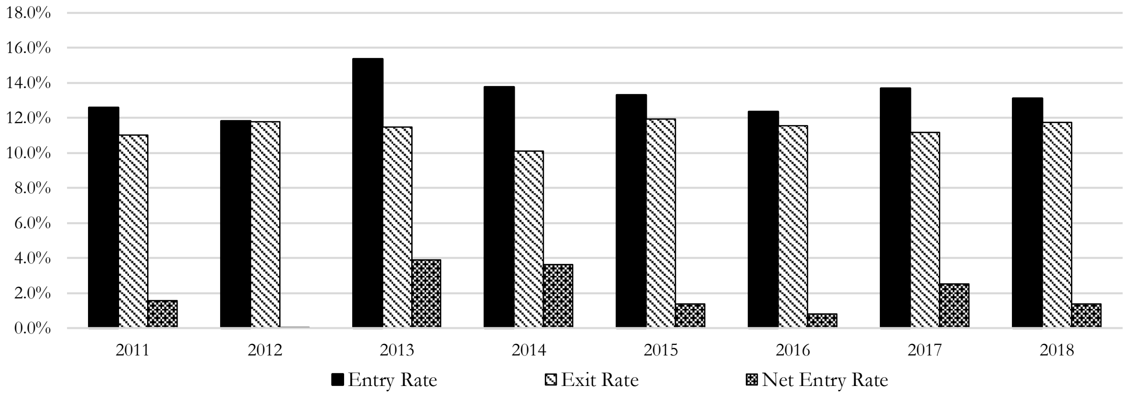


Figure 11 displays the entry, exit, and net entry rates of the Portuguese software industry, between 2011 and 2018. Throughout the period studied, there were only positive net entry rates, which was met with relatively stable entry and exit rates. However, in 2012 the net entry rate reached a near-zero level, and entry rates had its lowest value across the period. This may be a consequence of the Sovereign debt crisis that hit the country between 2011 and 2013 (Fundação Francisco Manuel dos Santos, 2022), although effects shown in the entry and exit data are not clear in the years previous and subsequent to 2012.

Figure 12

Entry, Exit, and Net Entry Rates of the Software Industry by Sub-sector (Average, %), Portugal, 2011-2018

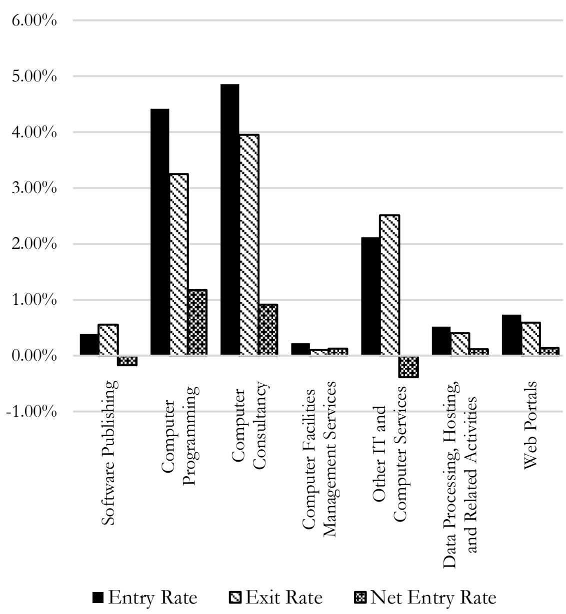


Figure 13

Entry, Exit, and Net Entry Rates of the Software Industry by NUTS (Average, %), Portugal, 2011-2018

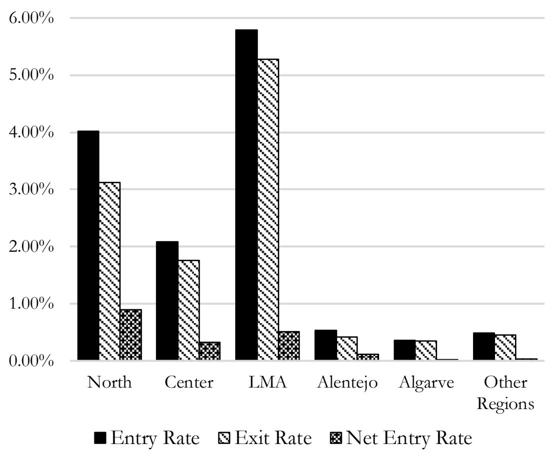


Figure 12 presents the entry, exit, and net entry rates by software subsector, as an average from 2011 to 2018. Across subsectors, some types of software activities seem to display a comparatively higher entry and exit dynamic. In line with the results analyzed on the total number of firms, "Computer Programming Activities" (6201) and "Computer Consultancy" (6202) displayed a comparatively higher firm dynamic, showing, on average, the highest entry and exit rates in the industry and displaying persistently positive net entry rates. Contrastingly, the "Other IT and Computer Services Activities" (6209) and "Software Publishing" (5820) subsectors consistently presented below or near-zero net entry levels, between 2011 and 2018.

Figure 13 presents the entry, exit, and net entry rates by geographical location (NUTS) of firms in the software industry. While all locations showed, on average, positive net entry rates, the North, Center, and LMA regions presented a comparatively higher firm dynamic across the period. Herein, the premise that the software industry in the North of Portugal seems to be growing is reinforced, as the region displayed the highest net entry rate levels across most of the analyzed years, although the LMA region presented consistently superior entry and exit rate levels.

Table 8
Entrant Characteristics by KIS Sector (Average), Portugal, 2011-2018

	Software Industry	Market KIS	Financial KIS	Other High-tech KIS	Other KIS
Size (Nr Employees)	3.87	3.63	6.27	2.72	3.74
Market Share (%)	1.74%	1.38%	0.92%	0.32%	1.55%

Table 8 presents some of the main characteristics of entrant firms in the software industry and the remaining KIS sectors, obtained as an average in the 2011-2018 period. Entering firms tended to be smaller than incumbent firms, an expected trend given that studies have shown that most entrants enter via "denovo"(i.e., greenfield firms, that did not have any type of activity, in previous periods) and small-scale entry (e.g., Mata (1993) or Baldwin and Gorecki (1991)). Also, although many firms attempted entry each year, the average market penetration[15] obtained by software's entrants and the remaining comparison group tended to be relatively small and to have a diminished effect on total industry output (i.e., which is aligned with the study, for e.g., by Dunne et al. (1988)).

Table 9
"Exiter" Characteristics by KIS Sector (Average), Portugal, 2011-2018

	Software Industry	Market KIS	Financial KIS	Other High-tech KIS	Other KIS
Size (Nr Employees)	4.32	4.95	5.34	5.32	4.78
Age (Years)	5.73	9.18	10.16	7.67	11.30
Market Share (%)	2.42%	2.43%	1.37%	6.29%	3.77%

Table 9 presents some of the main characteristics of exiting firms, obtained as an average from 2011 to 2018. Looking at the average size of "exiters", data show that firms exiting the software industry are, on average, smaller and younger than firms leaving the remaining KIS group. This trend, together with the relatively diminished exit market shares, may point to the idea that firms exiting the market tend to have exited due to the inability to

[15] Measured as the entrants' gross sales divided by the industry's total gross sales.

actively reach a sufficient size or market penetration to survive, or to a potentially intense M&A activity conducted by larger firms on younger and/or smaller software firms.

4.3. Worker Characteristics

Table 10

Total Number of Workers by KIS Sector, Portugal, 2010-2019

	Software Industry	Market KIS	Financial KIS	Other High-tech KIS	Other KIS
2010	32,445	231,242	90,394	26,702	299,202
2011	35,421	235,804	88,784	27,371	311,199
2012	36,852	216,671	85,920	26,350	311,141
2013	38,322	224,796	83,408	26,527	315,372
2014	41,539	241,172	82,216	26,598	319,002
2015	43,375	243,176	81,177	27,037	335,960
2016	47,523	252,846	79,048	27,128	352,037
2017	54,291	266,467	77,532	27,478	363,743
2018	62,134	274,664	78,445	27,795	375,610
2019	70,976	277,544	71,573	27,997	387,185

Table 10 presents the total number of employees by sector, from 2010 to 2019. Although the workforce across all industries has mostly grown across the period (i.e., except for Financial KIS sector), the software industry experienced one of the largest relative increases in the analyzed period, from 32,445 employees in 2010 to 70,976 in 2019.

Figure 14
Distribution of Total Number of Workers by KIS Sector, Portugal, 2010 and 2019

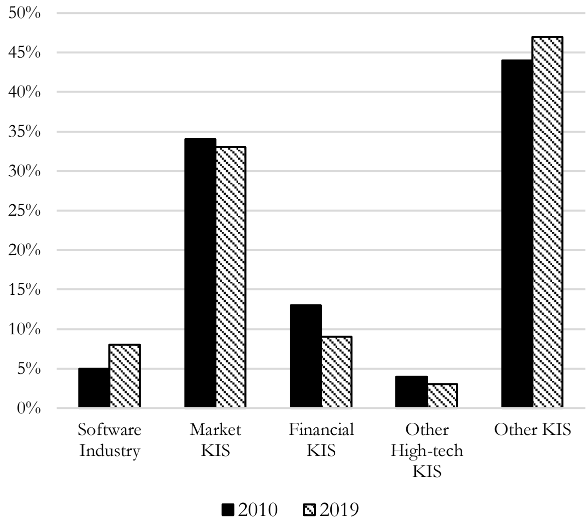
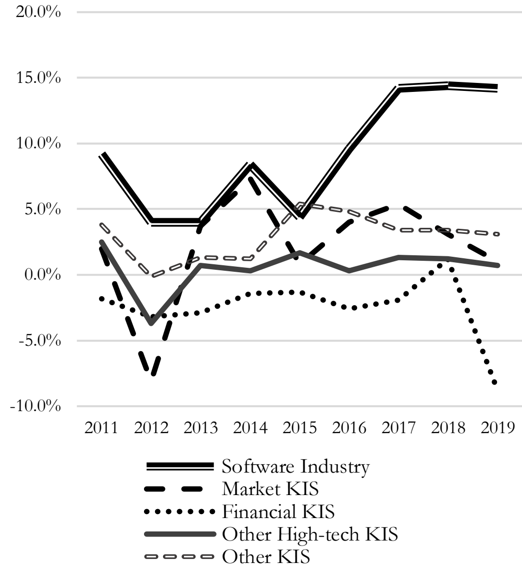


Figure 15
Annual Growth Rate in the Total Number of Workers by KIS Sector, Portugal, 2010-2019



Indeed, as may be seen in Figure 14, the weight of the software industry on the total workforce of the comparative KIS group increased by around three percentage points between 2010 and 2019. The software industry was the only exhibiting a persistently positive annual workforce growth rate[16], showing mostly greater or equal growth trends when compared to the remaining KIS sectors, as detailed in Figure 15.

Table 11
Workers Characteristics by KIS Sector (Average), Portugal, 2010-2019

	Software Industry	Market KIS	Financial KIS	Other High-tech KIS	Other KIS
Age (Years)	35	37	42	41	41
Sex (Male)	70.84%	56.71%	50.64%	59.77%	21.56%
Nationality (Portuguese)	95.83%	94.60%	98.70%	97.77%	96.87%
Education					
9th Grade or Less	4.68%	35.95%	9.06%	12.87%	39.80%

Continues in the next page.

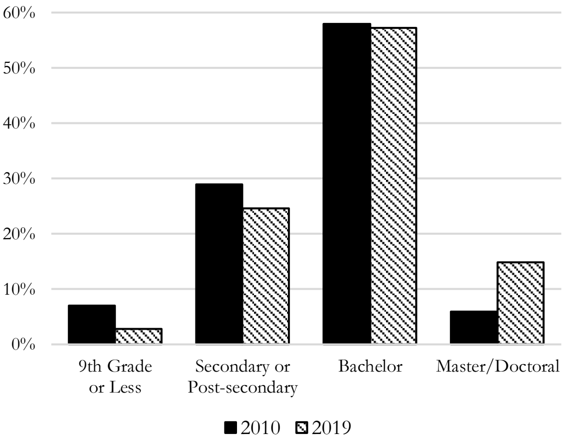
[16] Measured as the percent growth in total number of employees between the period t and t-1.

	Software Industry	Market KIS	Financial KIS	Other High-tech KIS	Other KIS
Education					
Secondary or post-secondary degree	28.45%	34.35%	38.80%	35.99%	23.95%
Bachelor's degree	56.19%	26.29%	47.38%	43.79%	31.98%
Master/Doctoral degree	10.50%	3.09%	3.95%	6.47%	3.00%
Other	0.19%	0.32%	0.06%	0.15%	0.15%

Table 11 shows some of the characteristics of the workforce by sector, obtained as an average from 2010 to 2019. The software industry employed workers that were, on average, younger than those of the comparative KIS sectors, also employing a larger proportion of male individuals (i.e., contrasting with the more gender-balanced employment of the remaining KIS sectors). Due to its nature, software firms tend to significantly rely on workers from STEM fields, areas which are more likely to have an under representativeness of women (Hammond et al., 2020).

Figure 16

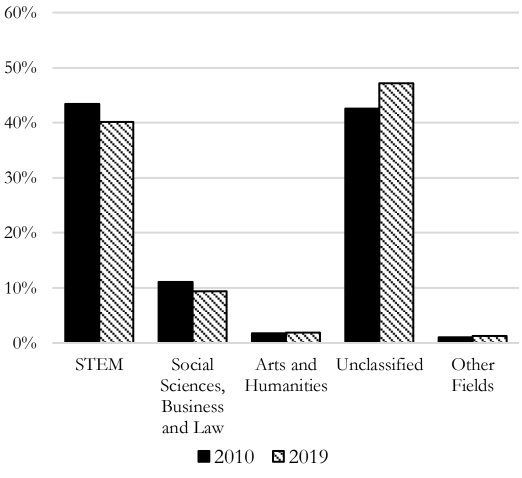
Distribution of Workers of the Software Industry by Education Level, Portugal, 2010 and 2019



Note. A 5th category ("Other responses") was omitted from the figure because, for both years, it represented a near-zero percentage level.

Figure 17

Distribution of Workers of the Software Industry by Field of Study, Portugal, 2010 and 2019



Note. "Other Fields" includes Education, Construction, Transformation, Environment and Agriculture, Health, Social Services, and Services.

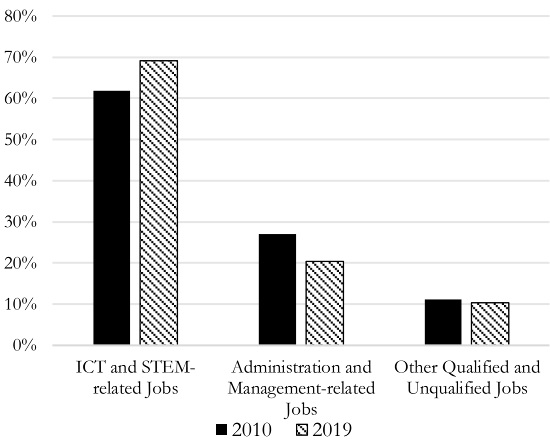
Figure 16 displays the distribution of employees from the software industry by level of study, for 2010 and 2019. The software industry's workforce seems to have improved its average qualification levels, namely as the proportion of workers without a college degree decrease around eight percentage points (i.e., considering workers with the 9th grade or less, and those with a secondary or post-secondary degree). Comparing with data shown in Table 11, the software industry employed a larger proportion of college graduates than the remaining KIS sectors. Within the industry, the level of employees with a Master or Doctoral degree exhibited the highest increase between 2010 and 2019.

Figure 17 shows the distribution of workers from the software industry by field of study, for 2010 and 2019. Workers in the industry have mostly come from unclassified fields[17], STEM, or Social Sciences, Business and Law academic backgrounds. However, these two latter fields of study have decreased its relative representativeness, which has been mostly counterweighted by increases in the unclassified group (DGES, n.d.).

Table 12
Top 10 Occupations of the Software Industry, Portugal, 2019

Rank	Occupations Classification and Code
1	ICT Specialists (25)
2	ICT Technicians (35)
3	Finance, Accounting, Administration, Public Relations, and Commercial Specialists (24)
4	STEM Specialists (21)
5	Office Workers, General Secretariats, and Data Processing Operators (41)
6	Finance, Administration, and Business Intermediate Level Technicians (33)
7	Direct Client Support Workers (42)
8	Commercial and Administration Services Directors (12)
9	Sciences and Engineering Intermediate Level Technicians, and Professionals (31)
10	Hotel, Restaurant, Commerce, and Other Services Directors (14)

Figure 18
Distribution of Workers of the Software Industry by Occupations (%), Portugal, 2010 and 2019



[17] Following the categorization used by DGES (n.d.), the "Unclassified" field refers to other fields of study that have not been specified, are unknown or do not fit any of the remaining categories.

Table 12 shows the top 10 jobs in the software industry, in 2019, which are all either from the STEM or ICT, or Finance, Accounting, Business and Commercial areas, representing close to 90% of the industry's total workforce. The top 10 jobs were ranked based on the jobs with a higher employee representativeness in the software industry, in 2019, and the respective classifications are based on INE's Portuguese Classification of Occupations. Figure 18 displays the distribution of workers from the software industry by occupation, for 2010 and 2019. As can be seen, most workers in the industry had ICT and STEM-related roles followed by Administration and Managerial-related roles. The proportion of Administration and Managerial-related roles decreased throughout the period, which was mostly compensated by increases in ICT and STEM-related jobs.

Figure 19

Real Monthly Wages by KIS Sector (Average, Euros), Portugal, 2010-2019

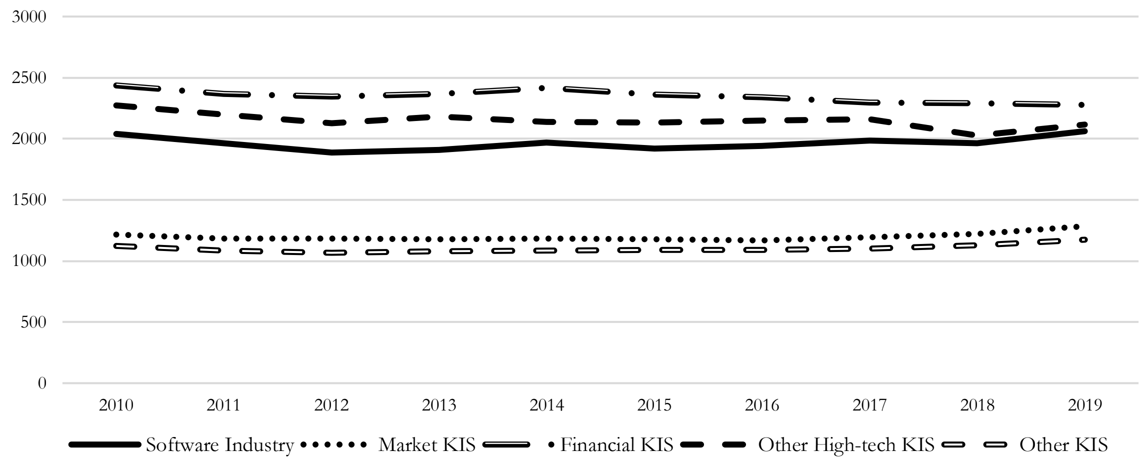


Figure 19 presents the average real monthly wages by sector, between 2010 and 2019. Software was consistently the third sector with the highest average wage levels, following Financial KIS and other High-tech KIS. In the industry, real wages decreased more significantly during the years of the Portuguese Sovereign crisis (2010-2013), displaying progressive recovery signs since then. Data show that the real average wages in the industry seem to have only fully recovered to its pre-2010-2013 crisis level between the years of 2018 and 2019. In these last years, there seems to be a convergence trend with the wage levels of the sectors with the top two highest wage levels.

5. Empirical Model

5.1. The Logit Model

The process of firm exit is considered a central topic in the academic and economic literature, having been the focus of a wide variety of authors throughout the last decade (Cefis et al., 2021). More concretely, most of the existing literature has focused on the impact of macro (e.g., Agarwal and Gort (1996) or Deltas et al. (2014)) and micro (e.g., Dunne et al. (1988) or Li et al. (2010)) level determinants on firm survival. A relatively more recent stream of research has also explored how some individual characteristics of managers and entrepreneurs could impact the firm survival and exit outcome (e.g., Backman and Karlsson (2020) or Rocha et al. (2015)).

Despite this, literature on the specific business dynamics of emerging technological industries remains rather scarce at all levels. Hence, the present chapter will be focused on the study of the determinants of exit of the Portuguese software industry. To study these potential relations, the following sections will use a discrete binary choice model, based on the maximum likelihood estimator. Therefore, the aim will be to study which factors may (or not) be associated with the probability of a firm exiting the industry (*j*=1). We define *i* as

$$y_i = \begin{cases} 1\ if\ the\ firm\ is\ exiting\ the\ market\ in\ period\ t, \\ 0\ otherwise \end{cases} \tag{1}$$

Accordingly, we estimate a binomial logit model, with a dependent variable that represents the predicted probability that the outcome of a software firm *i* is *j*, during period *t*, conditional on a set of chosen variables X*i*. This is given by:

$$P_{ij} = \exp\left(X'_i\, \beta_j\right) \Big/ \sum_{l=0}^{1} \exp\left(X'_i\, \beta_l\right), \quad j = 0{,}1 \tag{2}$$

A detailed description of the variables included in the vector X_i is provided in the Appendix C. The model and corresponding variables used have been selected following some of the previously mentioned seminal literature on the topic of firm entry and exit. To study the probability of a firm exiting the industry, the chosen firm-level explanatory variables control for dimensions like firm age, size, geographical location, software subsector, labor productivity level, and foreign social capital, and the employee-level variables include workforce characteristics, such as the sex, age, formal education level, and job occupation.

5.2. Determinants of Exit

Table 13

Binary Logit Estimation Results (Dependent Variable=1 if Firm Exited)

	Coef.	Marginal Effect
Firm-level		
Age	-0. 0331***	-0.0023***
	(0.0040)	(0.0003)
Size (omitted category: large)		
Micro firm	1.4413***	0.0989***
	(0.5099)	(0.0350)
Small firm	0.6067	0.0416
	(0.5137)	(0.0353)
Medium firm	0.0669	0.0046
	(0.5542)	(0.0380)
Location (omitted category: LMA)		
North	-0.2513***	-0.0172***
	(0.0548)	(0.0038)
Center	-0.2252***	-0.0155***
	(0.0669)	(0.0046)
Alentejo	-0.1303	-0.0089
	(0.1224)	(0.0084)
Algarve	0.0015	0.0001
	(0.1340)	(0.0092)
Other regions	-0.0286	-0.0020
	(0.1401)	(0.0096)
Software subsectors (omitted category: computer consultancy)		
Software Publishing	0.0103	0.0010
	(0.1062)	(0.0073)
Computer Programming Activities	0.0779	0.0053
	(0.0571)	(0.0039)

Continues in the next page.

	Coef.	Marginal Effect
Firm-level		
Software subsectors (omitted category: computer consultancy)		
Computer Facilities Management Services	-0.3810*	-0.0261*
	(0.2271)	(0.0156)
Other IT and Computer Service Activities	0.1675***	0.0115***
	(0.0616)	(0.0042)
Data Processing, Hosting, and Related Activities	-0.1543	-0.0106
	(0.1287)	(0.0088)
Web Portals	0.3940***	0.0270***
	(0.1201)	(0.0082)
Foreign firm	0.0283	0.0019
	(0.1173)	(0.0080)
Labor productivity (log)	-0.2552***	-0.0175***
	(0.0255)	(0.0018)
Employee-level		
Females (%)	-0.0752	-0.0052
	(0.0765)	(0.0053)
Age (omitted category: 55-67 years)		
<35 years (%)	-0.2345*	-0.0161*
	(0.1214)	(0.0083)
35-44 years (%)	-0. 1456	-0.0100
	(0.1184)	(0.0081)
45-54 years (%)	-0.1007	-0.0700
	(0.1277)	(0.0088)
Education (omitted category: master or doctoral degree)		
No college (%)	0. 4728***	0.0324***
	(0.1257)	(0.0086)
Bachelor (%)	0.3441***	0.0236***
	(0.1277)	(0.0088)
Other education (%)	-0.2754	-0.0190
	(0.5810)	(0.0399)
ICT-related job (%)	-0.4416***	-0.0303***
	(0.0654)	(0.0045)

Continues in the next page.

Year dummies (omitted category: 2010)	Yes
Constant	-1.930
N	29,460
Log likelihood	-7,388.1588
Pseudo R^2	0.0843

Note. *,** and *** denote significant at 10, 5 and 1% level, respectively. Values in parentheses correspond to robust standard errors.

Table 13 reports the coefficients and average marginal effects[18] estimates obtained from the estimation of the binary logit model (i.e., including all the variables shown in the Appendix C). Non-exiting firms are used as the reference group for the dependent variable, for each year. Year dummies for the 2010-2017 period were also introduced but the corresponding results are not showcased as the corresponding coefficients do not typically present a perceptible pattern (Mata et al., 1995).

In general, firm-level results show that older and larger firms, as well as those with higher labor productivity levels, have a lower probability of becoming an "exiting" firm. Firstly, results suggest that the older the firm, the lower the probability of exiting (i.e., *ceteris paribus*, the probability of exit decreases by 0.23 percentage points with one additional year of existence). Similarly, larger firms seem to be less likely to exit the market, when compared with smaller firms. Hence, results suggest that having a micro-sized firm significantly increases the probability of having an exit outcome in the software industry

This may be justified by the fact that older, established players have mostly already gone through the "learning and selection" process that is necessary to adapt "expectations of success" (Mata & Portugal, 1994, p. 242), which usually only comes with market experience and know-how accumulation. Younger and smaller firms may also have greater financial constraints, that make any necessary efficiency adjustments more challenging (Besanko et al., 2017; Geroski, 1991). Results seem, then, to be reasonable and are in line with the studies conducted on the survival and exit determinants for different industries (e.g., Honjo (1998) and Raz and Gloor (2007), for the Japanese and Israeli software industry, respectively, or Mata and Portugal (1994) and Bartelsman et al. (2005), for other industries).

[18] Alternatively, as a robustness check, the marginal effects at the means were also calculated. The results are shown in Appendix D.

Also, results show that an increasing level of labor productivity seems to significantly reduce the probability of having an exit outcome. Hence, the general premise that firm exit acts as a market selection process is reinforced (Geroski, 1989), especially because exit tends to be associated with a below-average productivity that inhibits a firm's capacity to competitively survive (Cefis et al., 2021). The results from our model are, then, in line with those found in the general literature (e.g., Carreira and Teixeira (2011), on the Portuguese manufacturing industry, or Blanchard et al. (2012), on the French food industry).

Firm-level results also suggest that belonging to the North or Center regions of Portugal seems to significantly reduce the probability of exiting the market, when compared with the LMA region. Despite statistically insignificant, effects across the remaining regions presented both positive and negative effects, reinforcing the idea that each region may have locational advantages or disadvantages that affect firm performance. Following previous literature, firm geographic locational choices are expected to have some impact on this probability, due to the potential presence of performance-influencing agglomeration economies and regional comparative advantages (e.g., Boschma and Weterings (2005) or Deltas et al. (2014), for the Dutch and American software industry, respectively).

Concerning software's subsectors, results suggest that the subsector to which a firm belongs seems to influence the probability of the exit outcome differently. For instance, when compared with "Computer Consultancy" (6202), firms in the "Other IT and Computer Service Activities" (6209) and the "Web Portals" (6312) subsectors seem to be significantly more likely of becoming an "exiting" firm. Also, belonging to the "Computer Facilities Management Services" (6203) subsector seems to significantly reduce this same exit outcome. Notice, however, that the different software subsectors present quite dissimilar sizes, which makes direct interpretations and comparisons more challenging.

Employee-level results suggest that firms which employ a younger and more qualified workforce, with a higher proportion of ICT workers, present a lower probability of exiting the market. Firstly, the likelihood of becoming an "exiting" firm in the industry seems to diminish when the workforce has a larger proportion of employees between 18 and 35 years old, comparatively to the older age group. Hence, *ceteris paribus*, the probability of becoming an "exiting" firm reduces by 1.61 percentage points when the proportion of employees in the youngest group age increases by one percentage point. Results found in other industries have tended to show both positive and negative influences on performance. For instance, some studies have found that the proportion of older managers may positively influence the performance and survival potential of firms (e.g., Backman and Karlsson (2020)).

The results obtained with our model could translate the fact that younger workforces are typically associated with a higher propensity and openness towards new technologies, and innovation-based competitive strategies, when compared with older human capital (e.g., Aubert et al. (2006) or Colovic et al. (2019)). Also, because software and IT are relatively novel fields of study, there may be an increased hiring reliance on young graduates with STEM-related academic backgrounds within the industry (UNCTAD, 2012). This proximity with younger workers may also be influenced by the overall shortage of ICT-skilled workers, that has pushed many businesses to try to capture younger talent (Shapiro et al., 2015). Thus, it seems reasonable that employing an increasing proportion of younger employees could decrease the likelihood of becoming an "exiting" firm in the software industry.

In line with this, results also suggest that the level of education of employees has a significant effect on the firm's exit likelihood. When compared with the option of employing a larger proportion of workers with a masters or doctoral degree, the probability of exiting significantly increases at lower education levels (i.e., no college or bachelor's degree). The results obtained seem reasonable given that the level of education of the human capital tends to play a role in the performance and survival of firms (e.g., Bates (1990) or Saridakis et al. (2008)), but also because formal education levels tend to be lower across groups of older employees (Backman & Karlsson, 2020).

Lastly, results show that employing a higher proportion of ICT-based workers, when compared to other occupations, has a significantly negative effect on the probability of becoming an "exiting" firm. Thus, all other things constant, an increase in one percentage point on the proportion of ICT workers in the total workforce seems to reduce the exit probability by 3.03 percentage points. Here again, the premise that the activity of the industry seems to be highly dependent on specialized ICT skills is reinforced.

5.3. Robustness Checks

As a robustness check, particular subsamples of the previously estimated model were analyzed, by looking at some of the predicted values after estimation, given a set of chosen constraints ($E(y_j|x_j)$). In line with some of the results analyzed previously and considering the top three locations with more software firms, the predicted probability of exit is lowest in the North region, followed by the Center and LMA regions. Considering the top three subsectors with more firms, companies in the "Computer Consultancy" (6202) and "Computer Programming" (6201) business areas showed the lowest predicted probability of exiting, followed by "Other IT and Computer Service" (6209). Across the three regions, the "Computer Consultancy" subsector (6202) consistently displayed the lowest exit probability. These results are in line with what was obtained in previous sections of this dissertation.

Additionally, as an exploratory study, the initial model was re-estimated using the entry rate as an explanatory variable. While the overall quality of the model decreased, increases in the entry rate seemed to significantly diminish the probability of becoming an "exiting" firm in the industry. Although these results may contradict some of the general literature (i.e., which shows that entry tends to induce exit, and vice versa), this is in line with the descriptive results analyzed in chapter four, wherein the entry and exit rates for the Portuguese software industry showed a negative correlation.

The model was also estimated for the high-tech sector (excluding the software industry), one of the sectors included in the comparative KIS group considered in previous chapters. The estimated coefficients and average marginal effects obtained with the estimation are shown in Appendix E. While the absolute results cannot be directly compared across models, it is still worth noting the sign of some of the resulting estimations obtained.

For instance, for the high-tech sector, employing an increasingly higher proportion of older employees (i.e., 35 to 44 and 45 to 54 years age groups) when compared to the oldest age group (i.e., 55 to 67 years age group), seems to significantly reduce the probability of becoming an "exiting" firm by more than the youngest age group (i.e., 18 to 34 years age group). This diverges slightly from the previous findings for the software industry, wherein results had suggested that employing a larger proportion of younger employees significantly reduced the mentioned probability by more than the two remaining, older groups. Herein, the fact that firms in the software industry are more dependent on the capabilities of younger employees (e.g., due to programming skills) to remain in the market seems to get reinforced.

6. Conclusion

This dissertation focused on the study of the Portuguese software industry, in the 2010-2019 period, providing both a detailed characterization of the industry and an empirical analysis focused on the determinants of exit of these firms. To achieve the proposed objective, the Quadros de Pessoal database was used for the mentioned period, including a sample with 31,686 (YearsxFirms) observations for the software industry. All in all, by presenting an overview of the state of the Portuguese software industry, the aim was to expectedly provide the basis and motivation for further detailed investigation into the characteristics of this business context and into the core dimensions that make it a potential source of economic competitiveness for Portugal.

Across the 2010-2019 period, Portuguese software firms were characterized by having a usually small size and a significantly younger firm age, when compared with the remaining KIS sectors. Despite the prevalence of small-sized firms, data confirmed that the industry's sales output is remarkedly concentrated amongst a relatively reduced number of firms with medium and large sizes. The industry's activity is mostly concentrated in the LMA, North, and Center regions of Portugal, and in the "Computer Programming Activities" (6201) and "Computer Consultancy" (6202) software subsectors. The software industry's workforce is mostly characterized by younger and predominantly male workers, with increasingly higher formal education levels. Results also confirmed an overall dependency on ICT-related occupations, which represented the highest proportion of the workforce.

At the business dynamics level, entrants presented a usually reduced size, and market penetration level, when compared with the industry's remaining players. Firms that exited the software industry in the 2011-2018 period were, on average, smaller and younger than those that left the remaining KIS sectors. While the LMA region showed superior entry and exit rate levels in Portugal across the same period, the North region was the only that presented consistently higher net entry rate levels across most of the analyzed years, for the software industry. Across software subsectors, firms in the "Computer Programming Activities" (6201) and "Computer Consultancy" (6202) sectors displayed, on average, the highest entry and exit rates in the industry and persistently positive net entry rates.

Results consistently confirmed the industry's widely reported growth and business dynamic throughout the 2010-2019 period, a trend which is particularly exacerbated when compared with the reality of the remaining KIS sectors. Thus, annual growth rates in the total number of firms and workforce employed were positive and comparatively higher for the software industry in the analyzed period. Software firms also attracted consistently larger proportions of foreign social capital, a trend which was reinforced between 2010 and 2019. At the business dynamics level, the industry presented, on average, the highest entry and exit rates across the KIS group and was the only to consistently display positive net entry rates.

Concerning the estimated logistic model, which included a sample of 29,460 observations, results suggested that the probability of becoming an "exiting" firm comparatively diminishes for firms with higher size, age, and labor productivity levels. Firms located in the North and Center regions of Portugal presented a lower probability of having an exit outcome, when compared with those in the LMA area. At the employee level, results showed that the employment of a larger proportion of younger, more educated, and ICT-based workers decreased the probability of exiting the Portuguese software industry. These employee-level results seem to characterize the particular case of the software industry, as robustness check procedures showed a different reality for the remaining high-tech industry.

In the envisioning of future research on the Portuguese software industry, it could be interesting to understand the potential effect of other variables in the industry's business dynamics. More concretely, while the QP database displayed some limitations at this level, in a market that is characterized by high innovation levels and an ever-globalized supply and demand dynamic, dimensions such as the innovation capacity (e.g., through the level of R&D investments), or the international trade (e.g., through the weight of exports on total sales) could be pertinent explanatory inputs to the analysis of software businesses' exit behavior.

Additionally, considering that the results obtained showed that the industry's workforce is mostly composed by ICT-based job occupations, it could be relevant to pursue further studies concerning the impact of managerial roles in the performance and business dynamics of the software firms. Thus, the presence of qualified managers, the quality of the management teams or, even, the existence of employee training in managerial areas could all be valuable inputs for future studies.

Constraints felt at the industry classification level, which difficulted the comparison of the Portuguese software industry's performance (i.e., *vis-à-vis* that of other countries), should also reinforce the imperative need for further collaboration amongst policymakers, namely in the promotion of internationally comparable industry categorizations and studies.

At a modelling level, the expectation is that this study's baseline econometric approach encourages the further pursuit of other modelling options (e.g., firm survival analysis) that could help understand and bring novel perspectives on the industry's entry, exit, and survival patterns. Hence, in a scenario of overall national and international literature scarcity, this study expectedly acts as a departing note for the further comprehension of an industry that is, and can even further be, a source of global competitiveness and growth for the Portuguese economy.

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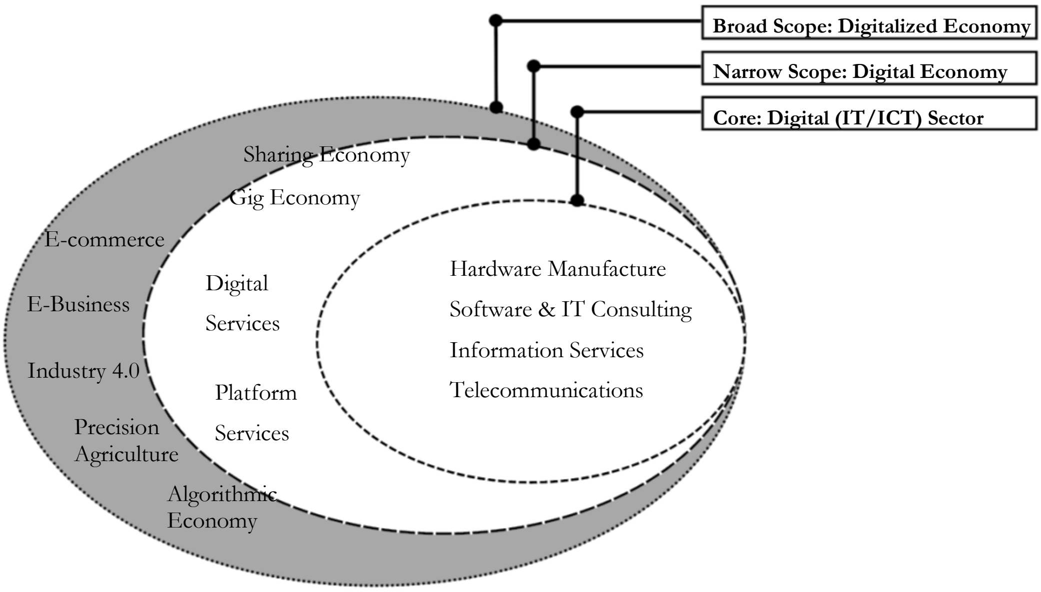
8. Appendix

Appendix A

Figure 20

Scope of the Digital Economy



Note. Adapted from *Defining, Conceptualising and Measuring the Digital Economy* (68)[Working paper], by Bukht and Heeks (2017), p.13, University of Manchester, Global Development Institute.

Appendix B

Table 14

Entry, Exit and Net Entry Rates by KIS Sector, Portugal, 2011-2018

	Software Industry			Market KIS			Financial KIS			Other High-tech KIS			Other KIS		
	Entry	Exit	Net Entry	Entry	Exit	Net Entry	Entry	Exit	Net Entry	Entry	Exit	Net Entry	Entry	Exit	Net Entry
2011	12.59%	11.02%	1.57%	7.47%	10.66%	-3.19%	14.50%	9.29%	5.21%	13.32%	11.51%	1.81%	6.81%	8.26%	-1.45%
2012	11.83%	11.80%	0.04%	6.80%	11.51%	-4.71%	8.85%	9.42%	-0.57%	8.12%	15.43%	-7.31%	6.00%	9.11%	-3.12%
2013	15.37%	11.48%	3.89%	7.40%	10.72%	-3.32%	8.87%	9.09%	-0.22%	13.26%	10.77%	2.49%	7.06%	9.13%	-2.07%
2014	13.75%	10.12%	3.64%	7.81%	9.80%	-1.99%	6.55%	8.53%	-1.98%	10.57%	11.74%	-0.98%	6.62%	7.71%	-1.09%
2015	13.32%	11.94%	1.38%	7.81%	10.38%	-2.57%	6.44%	9.80%	-3.35%	8.50%	13.72%	-5.22%	6.49%	8.43%	-1.94%
2016	12.37%	12.56%	0.81%	7.00%	9.49%	-2.49%	5.69%	9.08%	-3.39%	10.53%	12.69%	-2.16%	5.86%	8.21%	-2.35%
2017	13.70%	11.17%	2.52%	7.20%	9.12%	-1.92%	4.97%	8.19%	-3.22%	10.24%	11.39%	-1.15%	6.17%	7.74%	-1.57%
2018	13.11%	11.74%	1.37%	6.98%	9.10%	-2.12%	5.14%	9.09%	-3.95%	8.70%	12.11%	-3.41%	6.01%	8.12%	-2.11%

Table 15

Entry, Exit and Net Entry Rates by Geographic Region of the Software Industry, Portugal, 2011-2018

	North			Center			LMA			Alentejo			Algarve			Other Regions		
	Entry	Exit	Net Entry	Entry	Exit	Net Entry	Entry	Exit	Net Entry	Entry	Exit	Net Entry	Entry	Exit	Net Entry	Entry	Exit	Net Entry
2011	3.70%	3.02%	0.68%	2.49%	1.69%	0.80%	5.31%	5.19%	0.12%	0.36%	0.48%	-0.12%	0.32%	0.28%	0.04%	0.40%	0.36%	0.04%
2012	3.08%	3.20%	-0.11%	2.02%	1.75%	0.27%	5.90%	5.40%	0.49%	0.23%	0.46%	-0.23%	0.30%	0.42%	-0.11%	0.38%	0.57%	-0.19%
2013	4.25%	2.77%	1.48%	2.74%	2.02%	0.72%	6.62%	5.40%	1.22%	0.90%	0.50%	0.40%	0.40%	0.29%	0.11%	0.47%	0.50%	-0.04%
2014	4.44%	2.70%	1.74%	1.74%	1.37%	0.37%	6.01%	5.27%	0.73%	0.83%	0.23%	0.60%	0.47%	0.17%	0.30%	0.27%	0.43%	-0.17%
2015	4.48%	3.42%	1.07%	2.16%	1.88%	0.28%	5.30%	5.30%	0.00%	0.56%	0.34%	0.22%	0.34%	0.47%	-0.13%	0.47%	0.53%	-0.06%
2016	3.94%	2.96%	0.99%	2.12%	2.12%	0.00%	4.87%	5.41%	-0.54%	0.57%	0.30%	0.27%	0.30%	0.45%	-0.15%	0.57%	0.33%	0.24%
2017	4.08%	3.35%	0.74%	1.84%	1.79%	0.05%	6.30%	4.71%	1.59%	0.54%	0.54%	0.00%	0.26%	0.43%	-0.17%	0.68%	0.37%	0.31%
2018	4.14	3.55%	0.59%	1.56%	1.42%	0.13%	6.02%	5.56%	0.46%	0.27%	0.46%	-0.19	0.51%	0.27%	0.24%	0.62%	0.48%	0.13%

Table 16

Entry, Exit and Net Entry Rates by Subsector of the Software Industry, Portugal, 2011-2018

	Software publishing (5820)			**Computer programming activities (6201)**			**Computer consultancy (6202)**			**Computer facilities management services (6203)**		
	Entry	Exit	Net Entry	Entry	Exit	Net Entry	Entry	Exit	Net Entry	Entry	Exit	Net Entry
2011	0.20%	0.52%	-0.32%	3.90%	2.74%	1.17%	4.87%	4.22%	0.64%	0.24%	0.03%	0.16%
2012	0.34%	0.65%	-0.30%	4.19%	3.39%	0.80%	4.26%	3.88%	0.38%	0.23%	0.11%	0.11%
2013	0.40%	0.76%	-0.36%	5.11%	2.84%	2.27%	5.83%	3.82%	2.02%	0.11%	0.14%	-0.04%
2014	0.50%	0.43%	0.07%	3.84%	2.70%	1.14%	4.94%	3.44%	1.50%	0.27%	0.03%	0.23%
2015	0.50%	0.66%	-0.16%	4.70%	3.60%	1.10%	4.36%	4.17%	0.19%	0.16%	0.03%	0.13%
2016	0.30%	0.72%	-0.42%	4.33%	3.50%	0.84%	4.69%	3.91%	0.78%	0.12%	0.12%	0.00%
2017	0.45%	0.37%	0.09%	4.59%	3.40%	1.19%	5.42%	4.08%	1.33%	0.23%	0.11%	0.11%
2018	0.46%	0.38%	0.08%	4.67%	3.79%	0.89%	4.51%	4.08%	0.43%	0.43%	0.16%	0.27%

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Table 16

Entry, Exit and Net Entry Rates by Subsector of the Software Industry, Portugal, 2011-2018

	Other IT and computer service activities (6209)			**Data processing, hosting, and related activities (6311)**			**Web portals (6312)**		
	Entry	Exit	Net Entry	Entry	Exit	Net Entry	Entry	Exit	Net Entry
2011	2.37%	2.70%	-0.32%	0.36%	0.44%	-0.08%	0.64%	0.32%	0.32%
2012	2.02%	2.85%	-0.84%	0.34%	0.34%	0.00%	0.46%	0.57%	-0.11%
2013	2.23%	3.02%	-0.79%	0.72%	0.36%	0.36%	0.97%	0.54%	0.43%
2014	2.70%	2.70%	0.00%	0.47%	0.40%	0.07%	1.03%	0.40%	0.63%
2015	1.94%	2.19%	-0.25%	0.66%	0.38%	0.28%	1.00%	0.91%	0.09%
2016	1.70%	2.21%	-0.51%	0.42%	0.36%	0.06%	0.81%	0.75%	0.06%
2017	2.01%	2.07%	-0.06%	0.54%	0.43%	0.11%	0.45%	0.71%	-0.26%
2018	1.93%	2.28%	-0.35%	0.62%	0.54%	0.08	0.48%	0.54%	-0.05

Appendix C

Table 17

Description of Variables Included in the Empirical Model (Dependent Variable=1 if Firm Exited)

Category	Description
Firm-level	
Age	Firm age, in years.
Size	
Micro	Dummy=1 if the firm has less than 10 employees, 0 otherwise.
Small	Dummy=1 if the firm has at least 10 but less than 50 employees, 0 otherwise.
Medium	Dummy=1 if the firm has at least 50 but less than 250 employees, 0 otherwise.
Large	Dummy=1 if the firm has at least 250 employees, 0 otherwise.
Location	
North	Dummy=1 if the firm is in the North area of the country, 0 otherwise.
Center	Dummy=1 if the firm is in the Center area of the country, 0 otherwise.
LMA	Dummy=1 if the firm is the LMA area of the country, 0 otherwise.
Alentejo	Dummy=1 if the firm is the Alentejo area of the country, 0 otherwise.
Algarve	Dummy=1 if the firm is the Algarve area of the country, 0 otherwise.
Other Regions	Dummy=1 if the firm is one of the remaining areas of the country or is abroad, 0 otherwise.
Software subsectors	
Software Publishing	Dummy=1 if the firm belongs to the 5820 software subsector, 0 otherwise.
Computer Programming Activities	Dummy=1 if the firm belongs to the 6201 software subsector, 0 otherwise.
Computer Consultancy	Dummy=1 if the firm belongs to the 6202 software subsector, 0 otherwise.
Computer Facilities Management Services	Dummy=1 if the firm belongs to the 6203 software subsector, 0 otherwise.
Other IT and Computer Service Activities	Dummy=1 if the firm belongs to the 6209 software subsector, 0 otherwise.

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Category	Description
Firm-level	
Software subsectors	
Data Processing, Hosting, and Related Activities	Dummy=1 if the firm belongs to the 6311 software subsector, 0 otherwise.
Web Portals	Dummy=1 if the firm belongs to the 6312 software subsector, 0 otherwise.
Foreign firm	Dummy=1 if the firm has a weight of 50% or more foreign social capital in the total social capital, 0 otherwise.
Labor productivity (log)	Logarithm of the ratio between the total real firm sales volume and the total number of employees.
Employee-level	
Sex	Dummy=1 if the employee is a female, 0 if it is a male.
Age	
<35 years (%)	Dummy=1 if the employee is younger than 35 years old, 0 otherwise.
35-44 years (%)	Dummy=1 if the employee is between 35 and 44 years old, 0 otherwise.
45-54 years (%)	Dummy=1 if the employee is between 45 and 54 years old, 0 otherwise.
55-67 years (%)	Dummy=1 if the employee is between 55 and 67 years old, 0 otherwise.
Education	
No college	Dummy=1 if the worker has a basic, 9-grade, secondary, or a post-secondary education degree, 0 otherwise.
Bachelor	Dummy=1 if the worker has a bachelor's degree, 0 otherwise.
Master or doctoral	Dummy=1 if the worker has a master's or doctoral degree, 0 otherwise.
Other education	Dummy=1 if the worker has another type of unidentified degree, 0 otherwise.
Occupation	
ICT or STEM	Dummy=1 if the worker has the 21, 25, 31 or 35 job code, 0 otherwise.

Appendix D

Table 18

Alternative Marginal Effects Calculation

	Average	At Means
Firm-level		
Age	-0.0023***	-0.0017***
	(0.0003)	(0.0002)
Size (omitted category: large)		
Micro	0.0989***	0.0765***
	(0.0350)	(0.0269)
Small	0.0416	0.0322
	(0.0353)	(0.0272)
Medium	0.0046	0.0036
	(0.0380)	(0.0294)
Location (omitted category: LMA)		
North	-0.0172***	-0.0133***
	(0.0038)	(0.0029)
Center	-0.0155***	-0.0120***
	(0.0046)	(0.0036)
Alentejo	-0.0089	-0.0070
	(0.0084)	(0.0065)
Algarve	0.0001	0.0001
	(0.0092)	(0.0071)
Other regions	-0.0020	-0.0015
	(0.0096)	(0.0074)
Software subsectors (omitted category: computer consultancy)		
Software Publishing	0.0010	0.0005
	(0.0073)	(0.0056)
Computer Programming Activities	0.0053	0.0041
	(0.0039)	(0.0030)
Computer Facilities Management Services	-0.0261*	-0.0202*
	(0.0156)	(0.0120)
Other IT and Computer Service Activities	0.0115***	0.0089***
	(0.0042)	(0.0033)
Data Processing, Hosting, and Related Activities	-0.0106	-0.0082
	(0.0088)	(0.0068)

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	Average	At Means
Firm-level		
Software subsectors (omitted category: computer consultancy)		
Web Portals	0.0270***	0.0209***
	(0.0082)	(0.0064)
Foreign firm	0.0019	0.0015
	(0.0080)	(0.0062)
Labor productivity (log)	-0.2552***	-0.0135***
	(0.0255)	(0.0014)
Employee-level		
Females (%)	-0.0752	-0.0040
	(0.0765)	(0.0041)
Age (omitted category: 55-67 years)		
<35 years (%)	-0.0161*	-0.0124*
	(0.0083)	(0.0064)
35-44 years (%)	-0.0100	-0.0077
	(0.0081)	(0.0063)
45-54 years (%)	-0.0700	-0.0053
	(0.0088)	(0.0068)
Education (omitted category: master or doctoral degree)		
No college (%)	0.0324***	0.0251***
	(0.0086)	(0.0068)
Bachelor (%)	0.0236***	0.0183***
	(0.0088)	(0.0068)
Other education (%)	-0.0190	-0.0146
	(0.0399)	(0.0308)
ICT-related job (%)	-0.0303***	-0.0234***
	(0.0045)	(0.0035)
Year dummies (omitted category: 2010)	Yes	
N	29,460	

Note. *,** and *** denote significant at 10, 5 and 1% level, respectively. Values in parentheses correspond to robust standard errors.

Appendix E

Table 19

Binary Logit Estimation Results, High-tech KIS (Dependent Variable=1 if Firm Exited)

		Coef.	Marginal Effect
Firm-level			
Age		-0.0398***	-0.0031***
		(0.0044)	(0.0034)
Size (omitted category: large)			
	Micro firm	0.9108	0.0709
		(0.5943)	(0.0463)
	Small firm	0.1432	0.0111
		(0.6047)	(0.0470)
	Medium firm	-0.0217	-0.0017
		(0.6717)	(0.0523)
Location (omitted category: LMA)			
	North	-0.2592***	-0.0202***
		(0.0857)	(0.0067)
	Center	-0.1364	-0.0106
		(0.1013)	(0.0079)
	Alentejo	-0.1283	-0.0100
		(0.1523)	(0.0111)
	Algarve	0.1393	0.0108
		(0.1749)	(0.0136)
	Other regions	-0.0720	-0.0056
		(0.1767)	(0.0137)
Foreign firm		0.2098	0.0163
		(0.1889)	(0.0147)
Labor productivity (log)		-0.1717***	-0.0134***
		(0.0301)	(0.0023)
Employee-level			
Females (%)		-0.1419	-0.0110
		(0.0981)	(0.0076)
Age (omitted category: 55-67 years)			
	<35 years (%)	-0.2364	-0.0184
		(0.1656)	(0.0129)

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	Coef.	Marginal Effect
Employee-level		
35-44 years (%)	-0.3407**	-0.0265**
	(0.1609)	(0.0125)
45-54 years (%)	-0.4628***	-0.0360***
	(0.1764)	(0.0137)
Education (omitted category: master or doctoral degree)		
No college (%)	0.4588***	0.0357***
	(0.1770)	(0.0138)
Bachelor (%)	0.1335	0.0104
	(0.1898)	(0.0148)
Other education (%)	0.06219	0.0048
	(0.9775	(0.0760)
ICT-related job (%)	-0.3426***	-0.0267***
	(0.1171)	(0.0091)
Year dummies (omitted category: 2010)	Yes	
Constant	-1.8161	
N	11,991	
Log likelihood	-3,331.7018	
Pseudo R^2	0.0803	

Note. *,** and *** denote significant at 10, 5 and 1% level, respectively. Values in parentheses correspond to robust standard errors.

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