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# Entrepreneurial activity in an environment of digital transformation: an analysis of relevant factors in the euro area

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The main feature of the current business reality is the speed of the changes in the environment and the uncertainty they generate. Among these changes, those which stand out for their importance are the ones related to the current digital revolution, which is changing, in a very short period of time, the companies' business models. From this perspective, and based on panel data for the 2009–2020 period, the study seeks to examine in depth the technological and innovative factors which are related to the entrepreneurial density in euro area countries, with special emphasis on self-employed entrepreneurs. The results obtained show that greater robotization of industrial activities generates entrepreneurial opportunities, while investment in R&D by companies is negatively related to entrepreneurial activity. It is also noteworthy that public investment in R&D and the greater volume of employment in scientific-technological sectors has not been significant in the generation of entrepreneurial opportunities. These conclusions make it possible to identify economic policies to promote entrepreneurial activity, such as training and the generation of a favorable environment for digital innovation and artificial intelligence, but also the incentive for intrapreneurial activity in companies that invest in R&D.

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## Introduction

The digital revolution that is currently unfolding, and which promises to radically shape the coming decades, is at the heart of the change and the resulting uncertainty. There is no doubt that society is becoming more and more digital every day. Proof of this is the change in consumer habits that has been developing since the end of the 20th century, with the democratization of the Internet, and which has intensified with the exponential development of computer processing and devices that are closer to consumers, such as smartphones.

However, digitalization brings not only benefits but also important disadvantages. The most relevant, although not the only ones. On the one hand, the digital disconnection of part of society, which is not able to adapt to new technologies at the speed demanded by the environment. On the other hand, as has happened in the industrial revolutions that preceded the current digital revolution, new technologies contribute to the destruction of the jobs most liable to automation, affecting vulnerable social groups, as has been studied in recent years in the case of the current digital revolution in Europe (see, among others, the work of Carbonero et al., 2018; Chiacchio et al., 2018; Firlej and Zbozień, 2020, and Klenert et al., 2023).

However, as the economic changes that have taken place throughout history have also shown, such an important revolution as the digital transformation not only entails threats but also great opportunities for economic agents who know how to adapt to the new environmental circumstances.

In fact, digital transformation is developing not only new jobs but entire economic sectors based on new concepts that are changing consumer behavior and the business models of companies that carry out more traditional activities. Concepts such as artificial intelligence, robotics, Big Data, the Internet of Things, the metaverse and blockchain are just a few examples of terms that are generating new entrepreneurial opportunities in new and more traditional sectors (Ben-Youssef et al., 2021; Kollmann et al., 2022).

In this sense, Nambisan (2017) points out how new digital technologies are transforming the uncertainty inherent in the entrepreneurial process, while other authors, such as Von-Briel et al. (2018) or Chalmers et al. (2021), theoretically develop the role of digital technologies within the entrepreneurial process. In fact, Satalkina and Steiner (2020) do not hesitate to qualify digital entrepreneurship as an essential factor within the innovative system, pointing out the importance of the entrepreneur, the entrepreneurial process and the entrepreneurial ecosystem. Likewise, Baig et al. (2022) point to six streams in digital entrepreneurship research: business models, entrepreneurship process, strategic platform, ecosystem, training and digital social entrepreneurship.

New business models and the products they generate mean greater consumer choice. Thanks to the ideas derived from entrepreneurship in the digital environment, consumers not only have greater product alternatives, but also services that improve the customer experience. This is undoubtedly one of the greatest consequences of entrepreneurial activity in a digitally transformed environment. As Leimeister, Österle, and Alter (2014) point out, mobile technologies, high-speed communications and the Internet of Things make it possible to increase the services available through devices, changing the way of life and posing a challenge for companies, but also for consumers.

Therefore, compared to the development of digital technologies and their impact on consumption, the development of entrepreneurial activity enables new quality consumer services that help to strengthen the long-term relationship, under a service convenience perspective (Dai and Salam, 2014). Indeed, as Silalahi and Rufaidah (2018) point out, consumers' digital experience is determined by factors such as digital service experience, digital image experience, digital touchpoint experience and digital broad banking experience.

Within the process of digital transformation, the robotization of the economy is taking on a leading role. The European Union is no stranger to this automation trend, as shown by the evolution of the stock of industrial robots in the member countries. In fact, from 2000 to 2020, the stock of industrial robots in the largest European economies has increased by 153% in Germany, 117% in France, 99% in Italy and 189% in Spain. However, in other smaller but increasingly important economies, the increases have been more significant, since they started from a smaller base. This is the case, for example, in the Czech Republic (with an increase of 2148%), Hungary (with an increase of 3762%) or Poland (with an increase of 3491%). In relation to its impact on the economy (and employment in particular), authors such as Carbonero et al. (2018) estimate that the robotization of the economy has a negative impact on global employment, although less in developed countries. However, recently, authors such as Klenert et al. (2023) conclude from their analysis that there is no evidence that robots reduce the share of low-skilled workers in Europe. At the enterprise level, there is no doubt about the importance that robots are gaining in sectors such as tourism (Callarisa-Fiol et al., 2023) or industry (Landscheidt et al., 2018).

In this context, this paper seeks to examine in depth the factors in the digital and technological sphere that are related, at an aggregate level, to entrepreneurial activity in general and to the entrepreneurial activity of self-employed entrepreneurs in particular,

Therefore, the underlying hypothesis of this paper is that the digital revolution generates opportunities in all sectors of the economy, not only in those immediately affected by technologies derived from digitalization.

First, therefore, a review of the literature relating entrepreneurial activity to the digitalization of the economy is carried out in order to properly contextualize the framework of the study. Secondly, the study hypotheses are defined in the paper followed by a third step consisting of the definition of the data sample used and the analysis methodology. Fourthly, the variables used in order to test the specified hypotheses are described. Fifthly, the main results obtained from the study are presented. Finally, the main conclusions, limitations and future lines of work derived from the study are presented.

## Entrepreneurship in a digitally transformed environment: a literature review

Digital transformation is a process that is significantly conditioning both the general economy and business activity. In this respect, Małkowska et al. (2021) study the digital transformation of European countries based on three dimensions: the digitization of society, the ability of economies to meet the challenges of digital transformation, and the ability of firms to take advantage of digital technologies. Indeed, Łobejko (2020) points out that companies that want to innovate must take advantage of the opportunities offered by digital transformation. Similarly, Bharadwaj et al. (2013) identify four areas of digital business strategy: scope of digital strategy, scale and speed of digital business strategy, the sources of business and the added value of digital strategy.

Beyond the ability of established firms to take advantage of digital transformation, the opportunities that a continuously changing environment creates for entrepreneurs are numerous, and the digital revolution is one of the greatest examples that can be found, as the academic literature makes clear. In this sense,

Hull et al. (2007) differentiate between digital entrepreneurship and traditional entrepreneurship, pointing out that entrepreneurship is a subcategory of entrepreneurship in which everything that is physical in a traditional organization becomes digital. They also show, as major differences, the marketing techniques and the product and service itself. In fact, Steininger (2019) points out that information technologies play the role of facilitator and mediator of entrepreneurs' operations, but also of result and ubiquity, becoming a business model in itself. On the other hand, Steininger and Gatzemeier (2019) show that the ability to manage the uncertainty implicit in digital technologies has reduced the time and effort needed to generate and evaluate new business ideas.

Sussan and Acs (2017) introduce a conceptual framework in the study of entrepreneurship in the digital age by integrating the concepts of digital ecosystem (which in turn incorporates aspects of digital infrastructure governance, digital users, digital entrepreneurship and digital market) and entrepreneurial ecosystem, in order to better understand the interaction between users and agents and to incorporate the social and individual behavior of consumers.

On the other hand, Sahut et al. (2021) classify the literature definitions of digital entrepreneurship into two blocks: on the one hand, research on whether and how digitalization is transforming entrepreneurial activity and, on the other hand, research on the entrepreneurial opportunities generated by digital innovation and its technologies. Finally, these authors define digital entrepreneurship as "the process of entrepreneurial creation of digital value through the use of various socio-technical digital enablers to support effective acquisition, processing, distribution, and consumption of digital information" (Sahut et al., 2021: 1162).

More than 20 years ago, Joshi and Yermish (2000) studied, within the framework of the Internet revolution, the necessary skills for digital entrepreneurs. More recently, Kraus et al. (2019) have analyzed various aspects related to digital entrepreneurship, such as digital business models, the digital entrepreneurship process, platform strategies, the digital ecosystem, entrepreneurship education and digital social entrepreneurship. Lekhanya (2018) focuses on how understanding and knowledge of digitalization in rural entrepreneurship can help rural industries survive and grow.

Likewise, Balocco et al. (2019) focus their analysis on the processes of change in the business model, especially relevant in new business projects that are created in dynamic environments, as is the case in the digital industries. On the other hand, Battisti (2019) analyzes projects developed and managed by public-private initiatives, pointing out that the social entrepreneur acts as a link between innovative managers and people reflective on technological issues, while Finkle (2019) analyzes the different business models available to potential entrepreneurs who want to develop their projects within the online sphere.

Galindo-Martín et al. (2019) find evidence that there is a relationship between digital transformations and entrepreneurial activity, though with limitations in terms of financing, since in countries with more inefficient credit markets, this limits access to credit and, therefore, the entrepreneurial process.

Focusing on one of the major reflections of the digital age, the methods of payments, Yin et al. (2019) conclude that in the case of China, mobile payments significantly increase the probability of entrepreneurship. Likewise, from a global perspective, Torres and Augusto (2020) point out that digitalization can increase a country's well-being if it has an adequate education system, governance institutions and a financial system oriented towards philanthropy. They also point out that social entrepreneurship has a positive impact on national welfare if institutions are weak, and this is the same in both developed and less developed countries.

From an environmental point of view, Elia et al. (2020) focus their attention on the concept of the digital entrepreneurship ecosystem, pointing out the importance of four dimensions: digital actors, digital activities, motivations and digital organizations. Jafari-Sadeghi et al. (2021) study the effects of digital transformation on value creation through the study of technological entrepreneurship.

On the other hand, and from the perspective of labor market transitions, Fossen and Sorgner (2021) investigate, in the case of the United States, the impact of the new wave of digitization of occupations on the different types of entrepreneurship, including digital entrepreneurship. They conclude that workers with higher levels of skills and abilities or who work in ICT sectors with greater potential for destructive digitization are more likely to become entrepreneurs, which does not seem to be the case for workers with lower levels of skills and abilities.

Likewise, digital transformation not only allows competitive advantages to be achieved in terms of innovation, but also becomes a fundamental tool for the sustainable development of European companies, affecting business activity, business models, business processes and products (Bednarčíková and Repiská, 2021).

On the other hand, from an entrepreneurial characteristics perspective, Ferreira et al. (2019) conclude that age and gender are factors to consider, since older entrepreneurs put more obstacles in the way of their adoption of new digital processes, while younger entrepreneurs and women are more likely to implement innovative digital processes. The authors also highlight regional and sectoral factors as important for innovativeness.

One of the main manifestations of the digital transformation in which the economy is immersed is the evolution of robotics applied to business processes, mainly industrial, but also in services, which leads to the replacement of human work with advanced software robots (Sobczak, 2022). This fact is nothing but a consequence of innovation, a factor directly related to digital transformation. In fact, investment in R&D has become a factor studied in the literature to understand the current digitization environment (Chen and Kim, 2023).

Finally, a fundamental perspective should not be forgotten: how entrepreneurial activity in a digitalized environment improves customer service. In this sense, Baig et al. (2022) point out that a basic characteristic of the sharing economy is that the consumer and the business owner do not have a hierarchy, but rather they both benefit, while indicating how entrepreneurs use technology to study the most innovative demands of consumers. In fact, as an advantage over traditional entrepreneurs, access to information technology is what helps digital entrepreneurs to analyze potential customers (Hair et al., 2012).

In turn, Srinivasan and Venkatraman (2018) study how entrepreneurial success is connected to the movements of other entrepreneurs and to the coordination within and across platforms. In fact, they indicate that both entrepreneurs and customers work on digital platforms to build the digital ecosystem and generate value in the digital network.

Finally, authors such as Barinua and Nwajiubah (2022) point out the relationship between social entrepreneurship and service quality, highlighting that the most empathetic and responsive organizations tend to develop personalized services that meet the needs of the customer, who feels valued.

## Hypothesis of the study

The main hypothesis of the paper is that the digital revolution enables entrepreneurs to find business opportunities. In

particular, it studies the case of self-employed entrepreneurs without employees. The reason for the decision to focus on the segment of entrepreneurs rather than the self-employed is two-fold. On the one hand, their importance within the European business structure is evident, where they account for 63% of the active business population and 84% of the new companies created. On the other hand, the comparative analysis of this segment within the total helps to understand the growth factors that allow these companies to transform themselves and generate employment, with a positive impact as a result of that transformation.

In the first place, as indicated in the literature review, the robotization of business processes has become one of the greatest exponents of digital transformation. The new opportunities that digitization and robotics are generating for the entire economy and society have implications for the entrepreneurial sphere. Authors such as Dirican (2015), Wang et al. (2021) or Callarisa-Fiol et al., 2023 highlight the impact of robotics and artificial intelligence on economies and companies in different sectors, so the first hypothesis of the paper is the possible influence of robotics on entrepreneurial activity.

- H1: Higher robot density in all industrial sectors generates greater opportunities for entrepreneurship in the economy.

On the other hand, investment in R&D is the seed for the generation of knowledge and ideas that allow the development of technologies that characterize the current digitization environment, becoming a link between this digital environment and entrepreneurial activity. In fact, the literature has studied the relationship between R&D investment and entrepreneurial activity (Abellán et al., 2015; Acs et al., 2015; García-Tabuenca et al., 2008; García-Tabuenca et al., 2012; Aarstad et al., 2022). On the one hand, Babina and Howell (2018) note that entrepreneurship is a source of knowledge spillover from corporate R&D, with the result that other authors such as Łobejko (2020) point out that thanks to digital transformation, companies can become more innovative and their employees more entrepreneurial. Therefore, the next two hypotheses of the paper are based on studying whether investment in R&D (public and private) is related to entrepreneurial activity:

- H2: Private sector R&D investment generates greater opportunities for entrepreneurship in the economy.
- H3: Public sector R&D investment generates greater opportunities for entrepreneurship in the economy.

Finally, the importance of R&D (public or private) is complemented by the existence of professionals with adequate training that allows them to face the digitization environment but also to generate and find entrepreneurial opportunities. On the one hand, companies develop profiles with their investments in accordance with their needs for adaptation to the environment. On the other hand, public investment in R&D generates specialized professionals who, from institutions such as universities or laboratories, have the necessary skills and knowledge to take advantage of the opportunities generated by the environment and become entrepreneurs. Given the importance that jobs in the science and technology sectors have taken on in recent years, the relationship between the growth of this job profile and entrepreneurial activity is widely studied. In fact, authors such as Wang et al. (2013) point out that professional efficiency, prior knowledge, social networks and perception of professionals' environment have positive effects on the recognition of entrepreneurial opportunities:

- H4: More employment in science and technology-intensive sectors generates greater opportunities for entrepreneurship in the economy.

## Analysis sample and methodology

The sample consists of panel data for euro area countries over the 2009–2020 period. The cases of Malta, Greece and Ireland have been filtered out of the sample as they do not contain complete data during the period mentioned for entrepreneurial density. Therefore, the countries included in the study are: Belgium, Bulgaria, Estonia, France, Germany, Italy, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Lithuania, Latvia, Austria and Romania.

We chose the sample for analysis for several reasons. On the one hand, and from a political perspective, the European Union has developed a series of digital goals for 2030 (Europe's Digital Decade: digital targets for 2030: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en), marking the previous decade as Europe's Digital Decade. These measures are based on four pillars, among which the digital transformation of companies stands out, placing special emphasis on the level of digital intensity of SMEs.

On the other hand, focusing the study on the countries of the Eurozone, within the European Union, is based on the fact that all companies in these countries are subject to the same Monetary Policy, which makes it possible to focus the study on other variables in which the decisions of each country condition their entrepreneurial strategy.

In relation to the methodology, given the nature of the data, we have chosen to apply a panel data methodology, which is a methodology widely used in the literature for the analysis of entrepreneurial activity and the digital economy (Ferreira et al., 2022; Zhou et al., 2022, among others). The advantage of this methodology is that it combines cross-sections (information from several countries) over several time periods. This makes it possible to reflect the heterogeneity that exists between countries. In a simplified way, these estimates can be represented as follows:

$$y_{it} = a_i + \beta X_{it} + u_{it}$$

where $i$ represents the country and $t$ the year of analysis.

## Variables

Given the objective of the work and the hypotheses specified, variables are required to contract the assumptions defined. In this sense, this section describes the variables that have been used, indicating the definition, the source of information and the main descriptive characteristics.

**Dependent variable: entrepreneurial activity**. The dependent variable used in this paper has been constructed as the ratio between the population of new firms created in the year of analysis t and the active population of the economy in year t. However, under this perspective, two dependent variables have been developed: one referring to the total entrepreneurial activity and the other to self-employed entrepreneurs without employees.

This distinction is made because of the importance of these small enterprises in the economic structure of the euro area, so that in 2020 the percentage of these enterprises without employees reached 83% of the total number of enterprises created that year, maintaining a growing trend (in 2014, it reached 80.4%).

Table 1 shows the definition and data sources used, while Table 2 shows the distribution of both variables.

It can be seen from the data shown in Table 2 that there is dispersion across euro area countries for both of the metrics used. Thus, it is interesting to note that the mean is approximately twice the median, while there is a significant difference between the maximum and minimum of the distribution. This is

**Table 1 Dependent variables: definition and sources.**

| Variable | Definition | Source |
|---|---|---|
| Density of entrepreneurial activity | Ratio of the volume of new enterprises created in year t for Business economy except activities of holding companies to the labor force of year t | Eurostat |
| Density of entrepreneurial activity (companies without employees) | Ratio of the volume of new enterprises without employees created in year t for Business economy activities except activities of holding companies to the labor force of year t | Eurostat |

Source: Eurostat.

**Table 2 Distribution of the number of start-ups in the panel data.**

| | Density of entrepreneurial activity | Density of entrepreneurial activity (without employees) |
|---|---|---|
| Media | 121,473.8 | 96,601.9 |
| Standard error | 8354.0 | 7096.7 |
| Medium | 64,558.5 | 45,059.0 |
| Standard deviation | 115,756.4 | 98,334.2 |
| Minimum | 7229.0 | 4977.0 |
| Maximum | 513,382.0 | 489,352.0 |

Source: Data from Eurostat.

**Table 3 Independent variables: definition and sources.**

| Variable | Definition | Source |
|---|---|---|
| Relative change in GDP | Year-on-year change in GDP in chain-linked volumes (base 2010), calculated as a difference of neperian logarithms. | Eurostat |
| Unemployment rate | Unemployment rate, calculated as the unemployed population divided by the active population | World Bank |
| Bank credit | Domestic credit granted by banks to the private sector as a percentage of GDP | World Bank |
| Density of industrial robots | Number of industrial robots installed in relation to the active population | The International Federation of Robotics |
| Private sector R&D investment | R&D investment by the private sector as a share of GDP | Eurostat |
| Public sector R&D investment | Public sector R&D investment as a share of GDP | Eurostat |
| Employment in science- and technology-intensive sectors | People employed in science and technology sectors | Eurostat |

Source: Eurostat, World Bank and The International Federation of Robotics.

indicative of the heterogeneity among the countries analyzed, which entail different characteristics in terms of size and economic and sectoral structure.

**Independent variables**. Secondly, the estimated models are based on a number of countries that share common values, institutions and a common currency, but which also have heterogeneity in their economic structures, which inevitably leads to differences in terms of growth and employment.

Likewise, the importance of bank credit in the financing of entrepreneurial activity and the heterogeneity observed in the different financial systems leads to the need to consider this variable within the scope of entrepreneurial activity.

In this way, and in line with the literature (Del Olmo-García and Crecente, 2020; Fuentelsaz et al., 2015; Fuentelsaz et al., 2019), the year-on-year change in GDP, the unemployment rate, and the weight of credit to the private sector in GDP have been defined as macroeconomic control variables.

Likewise, in order to test the hypotheses put forward in the paper, the independent variables studied were the density of industrial robots, private sector R&D investment, public sector R&D investment, and employment in science- and technology-intensive sectors.

Table 3 shows the definition and data sources of these independent variables, while Table 4 shows the distribution of the sample studied.

As can be seen in Table 4, the average growth rate of the euro area countries over the period mentioned was 0.8%, although the median is practically 2%. It should be noted, however, that the study sample includes both the period of economic crisis and the crisis resulting from the COVID-19 pandemic, whose impact on economic growth in 2020 was very significant.

Also noteworthy is the fact that the trough was −16% for Lithuania in 2009, reflecting the strong impact of the 2008 crisis on the Baltic republics. Likewise, the maximum of the distribution (7%) corresponds to Romania's growth in 2017.

With regard to the unemployment rate, the distribution implies strong heterogeneity shown by the euro area countries in terms of labor market characteristics, with geographies such as Germany, which had the minimum distribution in 2019, coexisting with Spain, which showed the maximum distribution in 2013, as a result of the strong impact of the 2008 crisis on this country. It should also be noted that the average for the euro area over the

**Table 4 Macroeconomic variables: descriptive analysis.**

| | Change in GDP (%) | Unemployment rate (%) | Bank credit (%) | Density of industrial robots | Private sector R&D investment (%GDP) | Public sector R&D investment (% GDP) | Employment in science- and technology-intensive sectors (thousands of persons) |
|---|---|---|---|---|---|---|---|
| Media | 0.8 | 9.0 | 76.1 | 1.3 | 0.2 | 0.9 | 3451.5 |
| Standard error | 0.3 | 0.3 | 2.3 | 0.1 | 0.0 | 0.0 | 303.0 |
| Medium | 1.8 | 8.1 | 71.2 | 1.1 | 0.2 | 0.7 | 1611.4 |
| Standard deviation | 3.8 | 4.4 | 31.6 | 1.2 | 0.1 | 0.7 | 4198.4 |
| Minimum | −16.1 | 3.1 | 24.7 | 0.0 | 0.0 | 0.1 | 178.5 |
| Maximum | 7.1 | 26.1 | 174.0 | 5.6 | 0.5 | 2.5 | 17,399.7 |

Source: Data from Eurostat, World Bank and The International Federation of Robotics.

period in question was 9%, compared to 8.1% for the median value.

On the other hand, in relation to credit to GDP, less dispersion is observed in terms of mean (76%) and median (71%), although if the maximum and minimum of the distribution are analyzed, disparity can be observed between countries such as Spain in 2009 (maximum of the distribution) and Romania in 2019 (minimum of the distribution).

Likewise, there is heterogeneity between the countries analyzed over the period analyzed for all the independent variables. In the case of robot density, the mean is 1.3 robots per thousand active persons, with the median falling to 1.1. Likewise, the minimum distribution reaches 0.006 robots per thousand active people, corresponding to Lithuania in 2009, reaching its maximum in Germany in 2019.

On the other hand, the differences observed in R&D investment from the private sector stand out compared to the public sector. In fact, while the average private investment reaches 0.90% of GDP (0.70% in the case of the median), public investment barely reaches 0.20% of GDP on average and at the median.

Finally, for employment in science- and technology-intensive sectors, the average is 3.4 million people, although the median falls to 1.6 million people. This is reflected in the peaks and troughs of the distribution. On the one hand, the minimum is 178,000 people, corresponding to Estonia in 2010, compared to the maximum of 17 million people in Germany in 2019.

## Results

As noted above, the aim of the estimates presented in this section is to understand which factors representative of the digital economy are related to entrepreneurial activity, with particular emphasis on the entrepreneurial activity of the self-employed.

It should be noted that, on the one hand, the variables have been included in the models on the basis of their logarithmic transformation, except for the case of the relative change in GDP. On the other hand, panel data models with fixed effects have been estimated given the result shown by the Hausman test, from which it is concluded that this is the best estimate compared to a model with random effects.

Likewise, in order to obtain the estimation of the variances and covariances matrix robust to autocorrelation and heteroscedasticity, the estimations have been carried out with robust standard deviations (HAC).

As can be seen in Table 5, two models have been developed: one representative of general entrepreneurial activity, and the other of the entrepreneurial activity of self-employed entrepreneurs. Thus, of the three control variables that capture economic behavior, only the relative change in GDP (with a positive sign) is significant, while the unemployment rate and the relationship between bank lending and GDP are not statistically significant.

On the one hand, in relation to the control variables included, the lack of statistical significance of the unemployment rate suggests that entrepreneurship in the euro area does not have a necessity component when analyzing factors related to the digital economy. This suggests that the digital revolution is a source of opportunities for entrepreneurs, beyond the labor market situation, even when talking about self-employed entrepreneurs. This result would confirm the existence of indirect effects of the digital transformation on the economy through entrepreneurial activity (McKinsey, 2020). In this sense, authors such as Fouskas (2019) study the entrepreneurial process in the case of digitally oriented entrepreneurs, concluding that these people have a relevant motivation regarding the process of exploring opportunities. Other authors, such as Wang et al. (2013), point out that recognition of entrepreneurial opportunities comes from the entrepreneurs' prior knowledge, but also from their efficiency, social networks and recognition of the opportunities provided by the environment.

On the other hand, the results show that the ratio of credit to GDP is not statistically significant when entrepreneurial activity is related to factors characteristic of the digital economy. Likewise, the importance of the financing function in entrepreneurial activity is undeniable (Crecente, 2011). However, this fact is not incompatible with the results shown, in the sense that within the European reality there are financial systems that have a greater market component compared to others with a greater banking component (Del Olmo-García et al., 2022). In this way, the flow of bank credit is fundamental in economies with a higher degree of bankarization, while in other geographies other forms of financing for entrepreneurial activity take center stage, either based on markets or on new ways of raising funds based, in turn, on the digital revolution itself, such as crowdfunding, family offices or debt funds (Block et al., 2018; Nguyen et al., 2019; Kolokas et al., 2022; Graham, 2022; Vásquez-Ordóñez et al., 2022; Porras González et al., 2022). In fact, as Garrigos-Simon et al., (2021) points out, companies suffer the consequences of the lack of credit information from financial institutions, so alternatives such as venture capital and crowdsourcing are necessary. Likewise, Lynn and Rosati (2021) point out that Internet-based financing mechanisms, such as crowdfunding or token offerings, have the potential to transform the financing of entrepreneurial activity. Authors such as Cavallo et al. (2019) point out that the growth of digital entrepreneurship projects depends on external funding, which leads to the importance of venture capital funds, so they find positive correlation between growth trajectory and

**Table 5 Estimated models.**

| | Model 1 (Total companies) | | Model 2 (Self-employed entrepreneurs) | |
|---|---|---|---|---|
| **Variable** | **Coefficient** | ***P* value** | **Coefficient** | ***P* value** |
| Constant | −50.6266 (36.6724) | 0.1674 | −32.0713 (36.1753) | 0.3753 |
| Change in real GDP | 0.1422 (0.0460) | 0.0020*** | 0.0916 (0.0490) | 0.0617* |
| Unemployment rate | −0.0099 (0.8493) | 0.9907 | −0.7056 (0.9579) | 0.4614 |
| Bank credit/GDP | 2.7594 (1.7125) | 0.1071 | 3.2239 (2.8179) | 0.2526 |
| Robot density | 1.8440 (0.6743) | 0.0062*** | 2.1258 (0.7995) | 0.0078*** |
| Business R&D investment | −3.1837 (1.0723) | 0.0030*** | −2.5178 (1.4776) | 0.0884* |
| Public R&D investment | 0.1057 (0.4987) | 0.8322 | 0.7467 (0.5473) | 0.1725 |
| Population employed in science and technology | 7.1157 (4.4548) | 0.1102 | 4.3178 (4.3960) | 0.3260 |
| *N* | 190 | | 190 | |
| Hausman contrast (*P* value) | 0.0036 | | 0.0856 | |
| CD test (Pesaran) (*P* value) | 0.9682 | | 0.9798 | |
| Wooldridge test (*P* value) | 0.1353 | | 0.1179 | |

Standard deviations in parentheses (*$p < 0.10$; **$p < 0.05$; ***$p < 0.01$).
Source: Own elaboration.

venture capital funding. For their part, Colombo, D'Adda and Quas (2019) note that firms have a greater propensity to seek external capital when the local availability of venture capital is higher.

Finally, the results related to the hypotheses to be contrasted are shown. In relation to the density of robots, the results show a statistically significant positive relationship with entrepreneurial activity, both in general and among self-employed entrepreneurs. This allows us not to reject the first hypothesis of the paper, concluding that the expansion of automated and robot-developed activities increases the business opportunities that entrepreneurs observe in the market. This result confirms the conclusions of authors such as Dirican (2015), Wang et al. (2021) or Callarisa-Fiol et al. (2023), who highlight the impact of robotics and artificial intelligence on economies and companies.

An interesting result is shown by the two variables relating to R&D investment in the economy. On the one hand, it appears that public investment has no statistically significant effect on entrepreneurial activity (rejecting Hypothesis 3). In this sense, authors such as Guellec, van Pottelsberghe (2000) point out that civil research financed by the public sector is neutral in relation to business R&D, which seems to have consequences in terms of entrepreneurial activity. On the other hand, R&D investment by the business sector does show a statistically significant effect, but with a negative sign, which would lead to the conclusion that the more business investment in R&D, the less entrepreneurial initiative is shown by economies (thus rejecting Hypothesis 2). This result could be explained by the fact that firms invest in order to improve the productivity of their activities and sectors, which does not necessarily lead to an increase in market opportunities for entrepreneurs in the economy as a whole. In fact, investment by companies is itself a factor in boosting employment, which would ultimately lead to the most qualified professionals having no incentive to start up a business project if they find salaried jobs that meet their expectations. Indeed, as Babina and Howell (2018) point out, R&D investment can reduce the propensity to undertake if it increases business growth or generates greater job interest. Conversely, entrepreneurship would be increased if R&D investment generates new ideas that employees can take ownership of or if it incentivizes entrepreneurship itself.

This result and interpretation are also linked to the last variable in the model, employment in activities of a scientific or technological nature, which was found to be non-significant. Thus, it is concluded that the most highly educated professionals oriented towards activities with a strong technological and digital component have no incentive to undertake business projects if they find paid employment that meets their expectations (rejecting Hypothesis 4). Therefore, the increase in employment in more technology-intensive activities, far from encouraging the business opportunities that professionals in the sector may see, discourages them from leaving their jobs and shows no relationship with entrepreneurial activity.

These findings are consistent with the results of authors such as Klarner et al. (2013), who point out that companies can retain, through innovation, high-profile workers with entrepreneurial skills. In fact, senior management plays a crucial role in attracting and retaining this talent through policies that combine security and flexibility.

## Discussions and conclusions

Digital transformation is a basic feature of the digital revolution that countries around the world are experiencing, but with particular importance in the euro area. This revolution has consequences in all areas of life, affecting the labor market in particular, but also consumer habits and corporate business models.

The main hypothesis of this study is that the digitalization of the economy has a direct influence on entrepreneurial activity. And not only does it influence sectors directly related to digitization or technology, but the influence extends indirectly to the economy as a whole.

This paper seeks to understand the main factors of the digital economy that are related to entrepreneurial activity, both in general and among self-employed entrepreneurs, who are a key group in euro area economies. From an empirical perspective, entrepreneurial density (new companies created in relation to the active population) has been related to factors related to the digital revolution: density of industrial robots (in relation to the active population), investment in R&D of public and private origin and employment generated in the most science- and technology-intensive sectors. In this way, and based on a panel of data for the euro area countries and for the period 2009–2019, econometric models have been estimated to understand the relationships between the entrepreneurial density of the economy as a whole and of self-employed entrepreneurs and the factors mentioned above.

Firstly, it is important to note that, from an economic perspective, the level of unemployment and the importance of bank credit on GDP have been shown not to be statistically significant when analyzing factors related to the digital economy. On the one hand, these results allow us to conclude that entrepreneurship in the euro area has an opportunity character when related to digital transformation factors (Wang et al., 2013; Fouskas, 2019; McKinsey, 2020). On the other hand, companies do not only look to the banking sector for financing, but are turning to alternative sources that are becoming increasingly important in an environment of digital transformation (Nguyen et al., 2019; Kolokas et al., 2022; Garrigos-Simon et al., (2021); Lynn and Rosati, 2021;

Graham, 2022; Vásquez-Ordóñez et al., 2022; Porras González et al., 2022).

The results have also shown that the density of industrial robots generates opportunities of an entrepreneurial nature. In this way, and beyond the consequences that the increase in automated tasks carried out by robots may have on the labor market, the entrepreneurial opportunities arising from the technologies accompanying this digital revolution are growing significantly, both in technological sectors and in the economy as a whole, as a result of the multiple applications in all sectors and fields. These conclusions are consistent with contributions such as that of Dirican (2015), who highlights the impact of robotics and artificial intelligence on the economic and business structure of the main economies.

On the other hand, the results derived from the analysis based on R&D investment are mixed. On the one hand, public investment in this area has been shown not to be statistically significant, which should lead public authorities to reflect on R&D investment policies and their impact, as well as to favor public-private partnerships (Loukil, 2018).

As far as investment within the private sector is concerned, it seems to have a negative relationship with entrepreneurship opportunities. This may be due to the fact that companies make these investments in order to improve the productivity of their processes, generating knowledge among their workers that they apply directly in paid jobs that meet their job expectations, which reduces the incentive to seek opportunities in the market in order to undertake an entrepreneurial project.

This is also the case with the result on employment in the technology sectors, which shows a negative relationship with entrepreneurial density. It should come as no surprise, if the labor market promotes the right incentives, that highly trained and prepared professionals with a paid job that meets their expectations do not have direct incentives to undertake a business idea in an environment as uncertain as the current one.

Both results show not only the importance of having entrepreneurial skills and motivations, but also the importance of business policies to attract and retain entrepreneurial talent in firms, so that, based on security and flexibility policies, entrepreneurial activity is discouraged by promoting innovation within firms (Klarner et al., 2013).

Finally, in terms of the implications of entrepreneurship in the digital era, several lines of discussion can be developed. From a theoretical perspective, the continuous advances in digital transformation and robotization make it necessary to continue with this line of research and understand the impact of these innovations on companies and entrepreneurial activity. Although the impact on employment needs to be measured, the conclusions obtained allow us to be optimistic and generate an incentive for further research into the impact on market opportunities discovered by entrepreneurs. It should not be forgotten that entrepreneurial activity can generate employment, so understanding the needs of entrepreneurs and the new professional profiles arising from digital transformation is necessary to understand the impact on the economy. Advantage should be taken, in this sense, of the growing availability of information in this area.

From an applied perspective, on the one hand, the conclusions obtained allow us to develop some economic policy proposals that could encourage entrepreneurial activity. On the one hand, the results obtained in relation to investment in R&D by the public sector should allow us to rethink this investment and look for ways in which greater investment in R&D could encourage entrepreneurship.

In this sense, greater public-private collaboration is required to invest public funds in high-impact projects based on the needs identified by entrepreneurs. To this end, a greater effort of collaboration between universities and companies is proposed, including the promotion of investment in entrepreneurial activity from the university. This effort would allow the development of companies without workers (self-employed) coming from the university environment and its researchers with a high potential for growth and employment generation, although this will probably require a reform of the university legal framework and, above all, of the values oriented to entrepreneurial activity. The creation of sandboxes in different areas (health, education, tourism, industry…) is also proposed, taking as an example the existing cases in the financial sector in countries such as Spain. All this would be under an effective regulatory framework that avoids problems of consumer and data protection. Finally, strategically, Europe and its member countries, in a coordinated manner, must become leaders in the generation of technologies and intra-structures aimed at boosting the digitalization and robotization of the economy.

On the other hand, improving incentives, aid and training related to entrepreneurship would allow employees who are especially prepared for the current digital revolution to have greater incentives to seek market opportunities and generate new business ideas that would allow society to advance further. In this sense, national talent should be promoted through training programmes based on public-private collaboration and aimed at teaching the most innovative technologies with direct application in entrepreneurial activity. The recipients of this training could be oriented, especially, to vulnerable groups such as the long-term unemployed or senior professionals. Both groups have important experience that, together with the appropriate training, would allow them to enhance their entrepreneurial skills and capture new market opportunities that would mean, for them, new professional opportunities.

Likewise, a great effort must be made to attract and retain specialized talent to increase the potential of Europe (and its member countries) as a leading region in digitization.

Moreover, the results obtained allow us to understand intra-entrepreneurial activity as an area to be promoted by companies. In fact, encouraging intrapreneurship would make it possible to take advantage of the opportunities of digital transformation and robotics without leaving the framework of the company, which would help to take advantage of the investment in R&D and the talent of the people working in the organization.

Likewise, the results obtained allow certain conclusions to be drawn in terms of customer service. Entrepreneurial activity based on digital factors and technology allows entrepreneurs to better understand customer needs and improve the service offered (Hair et al., 2012; Baig et al., 2022). This would result in an innovative offer, whose service to the consumer would be characterized by speed, consumer experience and comprehensiveness.

Furthermore, one of the most important results of the paper is the positive relationship between robot density in an economy and entrepreneurial activity. Indirectly, the literature has pointed out how robotics affects consumer experience and service (Huang et al., 2021; Lu et al., 2020; Xiao and Kumar, 2021), leading to increased compensatory consumption (Mende et al., 2019). Thus, the incentive that an economy's robot density places on entrepreneurial activity may come not only from the improvement in business processes, but also from their ability to influence customer services.

Therefore, the results of the study allow us to make progress in the knowledge of digital factors that foster entrepreneurial activity. As limitations, we highlight the lack of information on how the most representative technologies of the digital revolution, such as Blockchain or artificial intelligence, directly affect entrepreneurial activity. Likewise, future lines of research derived from the results obtained could be oriented towards overcoming these limitations and analyzing, in greater depth, how these digital

factors and the resulting entrepreneurial activity improve the perception of the quality of services among consumers in the Eurozone, investigating whether the density of robots encourages entrepreneurial activity due to their growing acceptance in services and customer experience.

## Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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## Author contributions

FdO-G: Conceptualization, Formal Analysis, Methodology, Writing Original Draft Preparation. FJC-R: Formal Analysis, Methodology, Writing – Review & Editing. MTdV-N: Writing – Review & Editing, Supervision. MS-A: Conceptualization, Writing – Review & Editing, Supervision.

## Competing interests

The authors declare no competing interests.

## Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

## Informed consent

This article does not contain any studies with human participants performed by any of the authors.

## Additional information

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