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ENTREPRENEURSHIP AND DIGITALISATION IN EU: TWINNING INSIGHTS THROUGH A PANEL THRESHOLD REGRESSION

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Abstract. The study methodologically employs, in a novel perspective, the panel threshold analysis, considering the time frame 2006–2020, to capture the relationship between new business density rate, as a proxy for entrepreneurship, and individuals' digital inclusion, as a proxy for digitalisation in EU countries. Based on the human capital theory, the results indicated a strong single threshold effect between individuals' digital inclusion and new business creation, confirming that entrepreneurship is influenced by the skills, knowledge, and experience of the entrepreneurs, including their education, training, and work history. For EU countries, individuals' digital inclusion boosts business creation only after reaching a certain level. When separating the EU countries from the perspective of their Innovation Index performance, the threshold effect was statistically evidenced in all categories but with different values. The strongest positive influence from digitalisation towards entrepreneurship was visible in emerging countries, while the lowest was for countries classified as moderate innovators. The research provides an original framework for understanding the complex factors that drive entrepreneurship and can help researchers and practitioners develop strategies for promoting entrepreneurial activity. Digitalisation's opportunities are significant, and entrepreneurial individuals and organisations able to adapt and innovate are more likely to be successful.

Keywords: digitalisation, entrepreneurship, innovation, human capital, EU countries, panel threshold.

JEL Classification: F69, L26, O30, J24, O52, C24.

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1. Introduction

Our research aims to gain a deeper understanding of how digital technologies influence entrepreneurial activities and outcomes, providing an original framework for understanding the complex factors that drive entrepreneurship. The article explores the relationship between new business density rate, as a proxy for entrepreneurship, and individuals' digital inclusion, as a proxy for digitalisation in EU countries. Studying this relationship is crucial since it provides valuable knowledge to support the development of more innovative, inclusive, and prosperous societies.

Following the results of Zhao et al. (2022), we grounded our research on human capital theory, suggesting that entrepreneurship is influenced by the skills, knowledge, and experience of the entrepreneur, including their education, training, and work history. Human Capital Theory is an economic concept that focuses on the importance of investment in individuals as

a key factor in driving economic growth and productivity (Schultz, 1961, 1963; Becker, 1964; Topel, 1991). Andersson et al. (2021) discovered that the average employee age is negatively related to innovation since older employees might be less motivated to utilise and adapt to new technologies. In contrast, younger employees are more inclined to adopt and adjust to modern technological skills or join firms with higher innovation potential. Likewise, Ivanová et al. (2021) discussed the need for continuous skill development and education to ensure that workers can adapt to the changing demands of the digital age. They emphasise the importance of developing digital literacy and thinking critically, solving complex problems, and working collaboratively in the digital environment. Notably, the research of Carbó-Valverde et al. (2022) suggested that a combination of entrepreneurial, institutional, and financial strategies is essential for achieving profitability in the FinTech sector.

In terms of gender diversity, Lopez-Nicolas et al. (2020) found that female employees positively impact business model experimentation, especially in innovative industries. Rajahonka and Villman (2019) highlighted that while digitalisation offers significant opportunities for women in leadership and entrepreneurship, it also presents various challenges, such as work-life balance and the need to update their skills.

Well-being and digital skills are closely linked in the modern digital era, with technological integration highlighting the significance of digital proficiency for individual well-being. Huđek et al. (2021a, 2021b) explored how social and cultural norms, government initiatives, and digitalisation affect freelancers' job satisfaction and career growth. Their research indicates that policies encouraging supportive social norms, government programs, and improved digital infrastructure enhance freelancers' well-being and professional success, benefiting the economy and society at large.

Our study investigated the relationship between digitalisation and entrepreneurship in EU countries from 2006–2020. The contributions of this paper lie in four key aspects: the comprehensive analysis of the existing literature, the foundational theory, the employment of the panel threshold regression model at the EU countries level and the separation of EU countries from the perspective of their innovation performance, according to EU Commission's Summary Innovation Index (SII). Our methodology is new to the existing literature by accounting for non-linear attribution and resulting in more accurate outcomes by capturing the non-linear relationship between digitalisation and entrepreneurship in EU countries. Following Lobonț et al. (2022), we acknowledged the performance heterogeneity across EU countries. We have divided EU countries from the perspective of their innovation performance into Innovation leaders, Strong innovators, Moderate innovators, and Emerging innovator countries (European Commission, 2023).

The results reveal a strong single threshold effect between individuals' digital inclusion, as a proxy for digitalisation and new business density rate, as a proxy for entrepreneurship, confirming that the entrepreneurs' skills, knowledge, and experience influence entrepreneurship. When separating the EU countries from the perspective of their Innovation Index performance, the threshold effect was statistically evidenced in all categories but with different values. The strongest positive influence from digitalisation towards entrepreneurship was visible in emerging countries, while the lowest was for countries classified as moderate innovators. In terms of recommendations, the results indicate that policymakers should consider the optimal level of digitalisation to maximise benefits while minimising potential drawbacks. This approach will help create a balanced, inclusive, and sustainable entrepreneurial ecosystem.

The paper is organised as follows: the introduction places our study within the realm of examining the relationship between digitalisation and entrepreneurship in EU countries,

primarily grounded on the human capital theory. The first section analyses the existing scientific research. The second section presents two primary hypotheses, elaborating on the panel threshold regression model (Hansen, 1999) with four equations, establishing the relationship between digitalisation and entrepreneurship. The third section is devoted to summarising and interpreting the findings. The conclusions provide policy recommendations towards adopting a balanced approach to digitalisation and creating a conducive environment for digital entrepreneurship.

2. Literature review

The debate on whether entrepreneurship and digitalisation synergise for success has been notable for forty years, primarily through the lens of EU countries' innovation performance. This involves analysing the link between entrepreneurship, indicated by new business density, and digital inclusion, reflecting digitalisation in EU countries. The significance of this connection grew with the Internet in the 1990s, gained prominence in the early 2000s, and surged in the 2010s due to the rise of digital technologies and entrepreneurial ventures. Digitalisation, transforming services or processes into digital formats, differs from digital disruption, which implies a radical industry change, a concept that became widespread with the advent of e-commerce in the late 1990s and early 2000s. Since then, digital disruption, a consequence of digitalisation, has influenced all sectors, leading companies to adopt new technologies for business innovation and model creation.

In the early 2000s, the research on entrepreneurship-digitalisation tandem was mainly concerned with the impact on traditional entrepreneurship models, such as developing new business models and using digital marketing. Gradually, research on digital entrepreneurship and the use of digital technologies has accelerated, considering studies on the role of digital platforms in the entrepreneurial process, such as crowdfunding, as well as the impact of digital technologies on entrepreneurial ecosystems and the emergence of new forms of digital entrepreneurship. In this regard, Nambisan (2017) introduced a digital technology perspective on entrepreneurship, emphasising the inadequacy of traditional views to capture the complexities of digital entrepreneurship fully. The concept includes digital technologies, platforms, affordances, and infrastructures as core elements. Diener and Špaček (2020, 2021) highlighted that poor IT infrastructure impedes digital transformation. Andersson et al. (2021) found that software development boosts innovation in Swedish firms, particularly in less software-intensive sectors, suggesting broad benefits for firms incorporating software development into their innovation strategies. This research supports the idea that diverse industries should invest in software development to stay competitive in the digital era. Bouwman et al. (2019) found that business model innovation positively affects SMEs' performance during digitalisation. Pelikánová (2019) highlighted the link between R&D spending and innovation in the EU, showing that higher R&D investments boost innovation output, essential for economic growth. Ghazy et al. (2022) discovered a positive relationship between entrepreneurship, productivity, and digitalisation in the EU, suggesting that digitalisation policies could enhance productivity and entrepreneurial activities, aiding economic growth. Baranauskas and Raišienė (2022) emphasised the integration of sustainability with digital entrepreneurship, noting that digital technologies, opportunities, and sustainable development can yield broader social, economic, and environmental benefits.

The previous studies mainly explore the multiple benefits digitalisation has provided entrepreneurs, including the ability to access new markets, reduce costs, and increase business

efficiency. However, digital disruption presents various challenges for businesses, industries, and individuals. As technology continued to evolve rapidly, it forced organisations to adapt to new ways of working, thinking, and delivering value. The digital environment also poses unique challenges that entrepreneurs must overcome to establish and grow their ventures successfully, such as competition in the digital landscape, continuous innovation and adaptation, ensuring adequate cybersecurity, attracting funds for their digital ventures, and attracting and must-have digitally proficient employees. Christensen (1997) highlighted the challenges companies face when confronted with disruptive innovations, emphasising the importance of recognising, adapting to, and investing in new technologies and business models to remain competitive in an ever-changing landscape. Later, Nambisan et al. (2019) examined the digital transformation of innovation and entrepreneurship, focusing on the progress made, challenges faced, and emerging key themes. The authors spotlighted the opportunities digital technologies and platforms provide for developing new products, services, and business models and the growth and scaling of start-ups and small and medium-sized enterprises (SMEs). Despite these opportunities, the authors also discussed the challenges of digital transformation, such as data privacy and security concerns, the digital divide, the need for upskilling and reskilling, and potential job loss due to automation. The study by Wulff (2022) emphasised the importance of adaptability and resilience, particularly in the Swedish fashion industry, in the face of exogenous shocks and suggested that embracing digital transformation and sustainable practices can help businesses navigate such challenges more effectively. Companies that could quickly respond to the changing market conditions, pivot their business models, and embrace digitalisation were better positioned to weather the challenges posed by the pandemic. Ogrean and Herciu (2021) analysed Romanian SMEs' adaptation to the EU's digital and sustainable transitions, noting progress but also highlighting challenges such as limited finance, poor infrastructure, and insufficient digital skills. To overcome these challenges, the authors recommend targeted policy interventions and support mechanisms to promote digitalisation and sustainability among Romania's SMEs. Poandl (2019) investigated the digitalisation in academic start-ups at the Gruendungsgarage, a joint initiative by the Graz University of Technology and the University of Graz. The study revealed that start-ups face various challenges based on their level of digitalisation, contributing to the understanding of digitalisation's impact on start-ups.

Generally, digital transformation, supported by effective governance, can lead to significant economic growth. Effective public governance is crucial in steering digital transformation, fostering an environment where entrepreneurship thrives, and economic development flourishes through innovative and sustainable digital solutions. Sussan and Acs (2017) highlighted the relationship between digital platforms, entrepreneurship, and market dynamics, suggesting that public policy should reflect the nuances of digital entrepreneurship. Crăciun et al. (2023) stressed the role of effective public governance in digital transformation for economic and social benefits. Rietmann (2023) observed that rural areas could boost competitiveness and community value through specialised knowledge, local supply chains, and policies that enable global market access. Lasi et al. (2014) pointed to the necessity of collaboration across academia, industry, and policymakers to navigate Industry 4.0 challenges and opportunities. Iancu et al. (2022) advocated policies aiding vulnerable businesses and SME recovery post-COVID-19 in Romania. Pirtea et al. (2019) discussed combating corruption as crucial for fostering innovation, R&D investment, and economic growth.

Research on entrepreneurship and digitalisation has continued to evolve in recent years, with a growing focus on other areas such as sustainability, social entrepreneurship, and

innovation. Studies also indicated that firms must be agile and adaptive to changes brought about by digitalisation to achieve success. Pirtea et al. (2021) highlighted the benefits of integrating ESG principles into corporate strategies for assessing sustainability and risk. Sklavos et al. (2022) called for more research on green entrepreneurship and digital transformation in the SME food industry, emphasising the need to include sustainability in growth strategies for long-term success. The literature also underscores the importance of collaboration, knowledge sharing, and adaptability in the digital era. Bostan et al. (2022) noted that companies effectively adapt communication practices to meet external challenges. Witschel et al. (2022) explored how manufacturing firms succeed in digitalisation by focusing on dynamic capabilities, organisational factors, and environmental turbulence. Ferreira et al. (2022) found a significant link between entrepreneurial attitudes, abilities, and aspirations in environmental and digital transitions, suggesting that these elements are crucial for strategising effective transitions, with dynamic panel data analysis offering deep insights into these interactions.

In summary, research highlights the interplay between entrepreneurship and digitalisation, emphasising the role of digital technologies in transforming business operations and governance. This synergy creates new opportunities and challenges, with digital advancements driving innovation, growth, and competitiveness in the entrepreneurial landscape. The impact of digitalisation on entrepreneurship includes opening new markets, streamlining processes, and fostering growth and innovation in a globally connected environment. Graphically, Figure 1 mind maps the complex relationship between entrepreneurship and digitalisation, considering both historical perspectives and current trends.

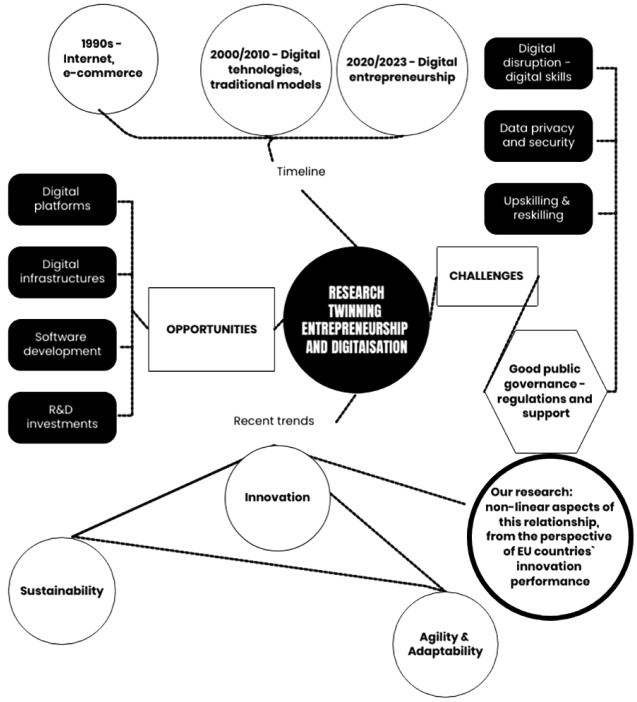


Figure 1. Mind mapping the entrepreneurship – digitalisation relationship: historical perspectives and current trends (source: authors' processing)

The present research seeks to investigate the relationship between digitalisation and entrepreneurship by delving into critical themes, advantages, challenges, and potential consequences for subsequent research and the business landscape through a comprehensive literature review. The novelty of this study is underscored by its unique approach to examining the dynamic interplay between entrepreneurship and digitalisation. While existing research has broadly acknowledged the benefits, opportunities, and challenges of digital business environments, the article brings a fresh perspective, in line with current research approaches, by focusing on the nuanced and non-linear aspects of this relationship, particularly within the context of European Union countries. Practically, our methodology is new to the existing literature by accounting for non-linear attribution, resulting in more accurate outcomes by capturing the non-linear relationship between digitalisation and entrepreneurship in EU countries. Withal, this paper fills this research gap by exploring the relationship between digitalisation and entrepreneurship from the perspective of EU countries' innovation performance. We have acknowledged the performance heterogeneity across EU countries (Lobonț et al., 2022), dividing them into Innovation leaders, Strong innovators, Moderate innovators, and Emerging innovator countries (European Commission, 2023). Our study delves into the specific context of EU countries by acknowledging their diverse innovation performance, generating a more tailored understanding of how digitalisation influences entrepreneurship across different innovation maturity levels.

3. Data and methodology

3.1. Theoretical assumptions

In the modern digital era, the realm of entrepreneurship is continually evolving, and individuals with robust digital skills often transition into entrepreneurship through a multifaceted process. Firstly, their digital proficiency facilitates access to online resources and networks, enhancing entrepreneurial readiness. Digital inclusion, in this context, directly impacts entrepreneurial dynamics by lowering entry barriers, enabling global market reach, and fostering innovative business models. Consequently, regions with higher digital inclusion often witness a surge in the new business density rate, as digitally skilled individuals are better poised to initiate and sustain entrepreneurial ventures.

One intriguing prospect is the role of digital inclusion in shaping entrepreneurial dynamics. This article delves into the intricate process of how individuals with strong digital skills transition into entrepreneurship.

In our pursuit to elucidate the relationship between digitalisation and entrepreneurship, we have delineated several pivotal research questions that aim to systematically deconstruct the hypothesised relationships and potential threshold effects, respectively:

Research Question 1: How does digitalisation influence entrepreneurship, and can a positive correlation be identified between these two variables?

Research Question 2: Considering the potential non-linear effect, at what specific points or levels of digitalisation does the influence on entrepreneurship change in magnitude or direction?

Research Question 3: How can individual digital inclusion be used as an accurate proxy to measure the broader concept of digitalisation in the context of its relationship to entrepreneurship?

Research Question 4: Is there a specific threshold or critical point in individual digital inclusion that significantly alters its relationship with the new business density rate?

Research Question 5: How does the new business density rate respond before and after this identified threshold of individual digital inclusion, if the case?

According to the vast literature, we assume a significant relationship between digitalisation and entrepreneurship and propose two hypotheses that will be tested through econometric analysis.

Hypothesis 1: There is a positive relationship between digitalisation and entrepreneurship.

We expect a non-linear effect on the relationship between digitalisation and entrepreneurship, assuming threshold values influence the relationship sign. Studies employed various digitalisation and entrepreneurship proxies. The model for our database indicated more statistical significance for the indicator of digital inclusion – individuals, related to the frequency of internet access, than for the DESI index (Digital Economy and Society Index). For entrepreneurship, we choose the number of new businesses with limited liability registered over the year, with information gathered from the national business registries of the countries.

Hypothesis 2: There is a threshold effect between individuals' digital inclusion, as a proxy for digitalisation, and new business density rate, as a proxy for entrepreneurship.

In addition, we anticipate different results based on countries' level of innovation since previous research emphasised how digitalisation and digital technologies are embraced to foster innovation in products and services, leading to performance improvements and innovation is key for start-ups and the development of an entrepreneurial environment, ensuring efficiency, productivity, and competitiveness (Bouwman et al., 2019; Blichfeldt & Faullant, 2021; Centobelli et al., 2022).

3.2. Data

Following Ghazy et al. (2022), we considered the new business density rate as the dependent variable to proxy entrepreneurship. The new business density rate represents the number of newly registered businesses per 1,000 working-age individuals within a specific region or country. This metric provides valuable insights into entrepreneurial activity, reflecting the frequency of new business creation. This indicator is accessible and offers several advantages, such as comparability across different regions and countries, capturing the most recent trends in entrepreneurship; it is sensitive to changes in the entrepreneurial environment, such as regulatory, economic, or cultural factors, enabling a better understanding of the factors influencing entrepreneurship.

The threshold variable is represented by digital inclusion, the proxy for digitalisation. It reflects the extent to which individuals, businesses, and communities have equitable access to and use of digital technologies, such as the Internet, computers, and mobile devices. While using digital inclusion as a proxy for digitalisation offers several advantages, capturing the social impact, economic development, and policy relevance, it is, however, essential to consider the limitations of the metric. Digital inclusion does not fully capture the extent of technological advancements, the adoption of technologies by businesses, or the pace of digital transformation within industries.

To address the model's limitations, we employed the abovementioned metrics in conjunction with other indicators to obtain a more comprehensive picture of entrepreneurial activity and understanding of digitalisation. Hence, we include up to four control variables: the Economic Complexity Index (ECI), educational attainment through school enrolment – secondary level (inspired by the research of Lobonț et al., 2022, who overviewed the relationship between public policy and entrepreneurship through threshold models), the gender parity index (GPI) and the Economic Sentiment Indicator (ESI).

Data were collected annually from various independent sources, as indicated in Table 1, with sample periods ranging from 2006 to 2020 for the 27 members of the European Union. Following the results from Lobonț et al. (2022), we acknowledged the performance heterogeneity across EU countries and segmented the EU27 countries based on Innovation Index performance to ensure a more detailed and accurate understanding of how digitalisation interacts with entrepreneurship across varying innovation landscapes.

Table 1. Indicators' description (source: authors' processing)

Indicator	Comment	Description	Source/Statistical database
Entrepreneurship – New Business Density Rate (NewBusRate)	Dependent variable, proxy for entrepreneurship	The number of newly registered firms with limited liability per 1,000 working-age people (ages 15–64) per calendar year	World Bank's Entrepreneurship Database (World Bank, n.d.)
Digitalisation – Digital inclusion – individuals (DigIncl)	Threshold variable, proxy for digitalisation	Frequency of internet access: once a week (including every day)	Eurostat (2022a, 2022b)
Economic Complexity Index (ECI)	Control variable	A measure of capabilities and know-how of a given country determined by the diversity, ubiquity, and complexity of the products it exports	Growth Lab Harvard University (2020)
School enrolment, secondary – % gross (Educ.att.)	Control variable	The ratio of total enrolment, regardless of age, to the population of the age group	World Bank (2023)
School enrolment, primary and secondary (gross), gender parity index (GPI)	Control variable	The ratio of girls to boys enrolled at primary and secondary levels in public and private schools	World Bank (2022)
EU Economic sentiment indicator (ESI)	Control variable	A composite indicator made up of five sectoral confidence indicators with different weights: - industrial confidence (40 %); - construction confidence (5 %); - services confidence (30 %); - consumer confidence (20 %); - retail trade confidence (5 %)	Eurostat (2022a, 2022b)
Summary Innovation Index (SII)	Indicator used for separating the UE27 panel into 4 separate sub-panels (4), from the perspective of Innovation Index performance: Innovation leader, Strong innovator, Moderate innovator and Emerging innovator countries.	A measure of the innovation performance of a country	European Commission, European Innovation Scoreboard and Regional Innovation Scoreboard (European Commission, 2023)

3.3. The panel threshold regression model

The panel data consists of one dependent and one independent variable and, in the second stage of the analysis, control variables. It was set as a single threshold model based on Hansen's (1999) threshold regression model. The general equations are presented below:

$$NewBusRate_{it} = \begin{cases} \mu_i + \beta_1 DigIncl_{it} + \varepsilon_{it}, & if\ DigIncl_{it} \le \gamma \\ \mu_i + \beta_2 DigIncl_{it} + \varepsilon_{it}, & if\ DigIncl_{it} > \gamma \end{cases}; \quad (1)$$

$$NewBusRate_{it} = \begin{cases} \mu_i + \beta_1 DigIncl_{it} + \alpha_1 x_{1it} + \alpha_2 x_{2it} + \alpha_3 x_{3it} + \alpha_4 x_{4it} + \varepsilon_{it}, & if\ DigIncl_{it} \le \gamma \\ \mu_i + \beta_2 DigIncl_{it} + \alpha_1 x_{1it} + \alpha_2 x_{2it} + \alpha_3 x_{3it} + \alpha_4 x_{4it} + \varepsilon_{it}, & if\ DigIncl_{it} > \gamma \end{cases}; \quad (2)$$

$$\left\{ NewBusRate_{it}, DigIncl_{it}, x_{1it}, x_{2it}, x_{3it}, x_{4it} : 1 \le i \le n, 1 \le t \le T, \right\},$$

where μ_i represents the heterogeneity of countries involving fixed effects. $NewBusRate_{it}$ is the dependent variable, the proxy for entrepreneurship, and the new business density rate. $DigIncl_{it}$ represents the digitalisation proxy, i.e., Digital inclusion – individuals, as the threshold variable, β_1 and β_2 represent the threshold coefficients estimated for various threshold values, and γ is the estimated value of the threshold and the base of comparison for the change in the independent variable, DigIncl. The control variables (ECI, Educ.att., GPI, and ESI) are reflected by $x_{1it}, x_{2it}, x_{3it}, x_{4it}$ while α_1, α_2, α_3 and α_4 represent the estimated coefficients of the control variables. ε_{it} is the error term, and i refers to the country (i=1...27, EU countries), while t to the annual base of the period analysed (2006–2020).

According to the threshold model, once the independent variable, $DigIncl_{it}$, exceeds the threshold value (γ), the dependent variable, $NewBusRate_{it}$, changes with β_2 units while $DigIncl$ changes one unit.

The advanced single threshold model can be rewritten as follows:

$$NewBusRate_{it} = \mu_i + \beta_1 DigIncl_{it} \left(DigIncl_{it} \le \gamma \right) + \beta_2 DigIncl_{it} \ (DigIncl_{it} > \gamma) + \varepsilon_{it} \quad (3)$$

or with control variables:

$$NewBusRate_{it} = \mu_i + \beta_1 DigIncl_{it} \left(DigIncl_{it} \le \gamma \right) + \beta_2 DigIncl_{it} \ (DigIncl_{it} > \gamma) + \alpha_1 x_{1it} + \alpha_2 x_{2it} + \alpha_3 x_{3it} + \alpha_4 x_{4it} + \varepsilon_{it}. \quad (4)$$

Generally, the threshold analysis might return numerous threshold values. However, we will not develop the equations above further into a double-threshold regression model because our database returned statistically significant results only for the single-threshold models.

4. Results and discussion

Our paper focuses on identifying the relationship between digitalisation and entrepreneurship through threshold model analysis. First, we test the stationarity of the variables employed in the analysis in Stata software through the Levin–Lin–Chu unit-root test (Levin et al., 2002). All considered variables are stationary (Table 2).

Table 3 includes the descriptive statistics for the overall database. The EU-27 countries' average new business density rate is 5.64, varying from 0.31 to 39.04. Digital inclusion is between 18 and 97, with an average of 69. ECI has an average of approximately 1.1, reaching 2.3, and the ESI is, on average, 99, varying from 70 to 119. For the secondary school enrolment,

the average is 108% (from 83.8 to 163.9%), and for gender parity, the ratio of girls to boys enrolled at primary and secondary levels is, on average, 1, varying from 0.9 to approximately 1.1.

Table 2. Unit root tests for stationarity of the variables (source: authors' processing)

Variables	Levin-Lin-Chu test (H0: Panels contain unit roots)	
	t-stat	p-value
NewBusRate (dependent)	–1.6673**	0.0477
DigIncl (threshold)	–10.1234***	0.0000
ECI	–2.8075***	0.0000
Educ.att.	–2.6311***	0.0043
GPI	–3.0179***	0.0013
ESI	–9.4751***	0.0000

Table 3. Descriptive statistics (source: authors' processing)

Variables	Obs	Mean	Std. dev.	Min	Max
NewBusRate	405	5.6416	5.3530	0.31	39.04
DigIncl	405	69.3255	17.5414	18.36	96.75
ECI	405	1.0975	0.5417	0.0065	2.3074
Educ.att.	405	108.4753	15.9351	83.8186	163.9347
GPI	405	1.0023	0.0272	0.9352	1.0982
ESI	405	98.9198	9.3855	69.9666	119.0833

Figure 2 illustrates the relationship between new business density rate and digital inclusion. For lower values of digitalisation, up to 55, we expect to negatively influence the number of newly registered firms. However, the new business density rate is positively influenced when digital inclusion crosses this level. Considering that the average new business rate is 69.32, we expect that for most EU countries, digitalisation supports entrepreneurship expressed through newly registered firms.

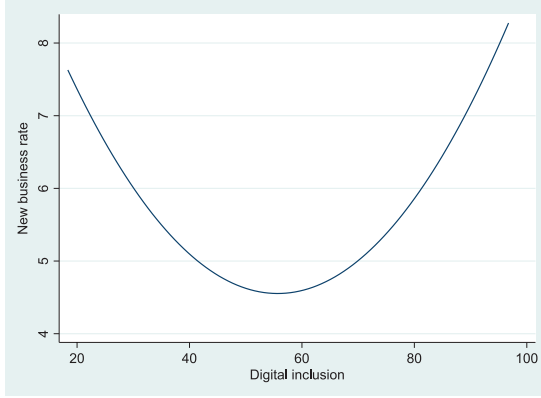


Figure 2. The relationship between individual digital inclusion and new business density rate for the overall database (EU-27, 2006–2020) (source: authors' processing)

Table 4 presents the panel threshold regression between digital inclusion and new business density rate in the EU countries. Results initially evidenced a non-linear relationship and a threshold effect for the single threshold model under the 1% significance level, from which the relationship between digitalisation and entrepreneurship might become opposite. The threshold was 58.36 for the simple model, with a larger coefficient associated with the lagged new business rate before the threshold. Accordingly, for the EU-27 countries, digital inclusion is expected to support newly registered firms with limited liability. Also, the entrepreneurship proxy is related to the previous new business density rate (regression coefficient of 0.7315 for the lagged dependent variable). However, when digital inclusion exceeds 58.36, we expect the previous density rate to slightly discourage the current rate of newly registered firms (regression coefficient of –0.0877 for the lagged dependent variable). When the model considers control variables, the threshold increases to 74, proving that digitalisation becomes even more critical for supporting newly registered firms under the influence of capabilities, know-how, education, or confidence in the economy. Again, we mention the average individual digital inclusion, which is 69.33 for the EU-27 database.

Therefore, since the model with all control variables returns a threshold of 74, meaning that, for the overall database, there are only a few cases (Sweden, Denmark, the Netherlands) that exceed the average value of the digitalisation proxy, expecting, in general, a positive influence from digitalisation towards entrepreneurship.

Table 4. Panel threshold regression results for the effects between digitalisation and entrepreneurship within the EU-27 countries (source: authors' processing)

	Threshold Value	Coefficient	Z	p-value
Threshold variable: DigIncl				
Single threshold effect test	58.3665***		48.46	0.000
No. of moment conditions	104			
Lag_NewBusRate_b		0.7315***	313.84	0.000
Lag_NewBusRate_d		–0.0877***	–13.83	0.000
cons_d		0.0807	0.94	0.347
Threshold variable: DigIncl; Control variables: ECI, Educ.att.				
Single threshold effect test	65.9095***		9.90	0.000
No. of moment conditions	130			
Lag_NewBusRate_b		0.5719***	31.13	0.000
ECI_b Educ.att._b		1.3972*** –0.05153**	3.85 –2.21	0.000 0.027
Lag_NewBusRate_d ECI_d Educ.att._d		–0.0482 –1.2388*** 0.0438*	–1.04 –3.46 1.79	0.297 0.001 0.073
cons_d		–4.4817	–1.51	0.131
Threshold variable: DigIncl; Control variables: ECI, Educ.att., GPI, ESI				
Single threshold effect test	74.0812***		9.68	0.000
No. of moment conditions	156			
Lag_NewBusRate_b		0.7133***	8.02	0.000

End of Table 4

	Threshold Value	Coefficient	Z	p-value
ECI_b		2.2564***	4.70	0.000
Educ.att._b		–0.252***	–4.63	0.000
GPI_b		35.5061	1.53	0.127
ESI_b		0.0167*	1.92	0.055
Lag_NewBusRate_d		0.3168***	3.31	0.001
ECI_d		–0.7538	–0.82	0.413
Educ.att._d		0.3288***	3.50	0.000
GPI_d		–43.1428*	–1.88	0.061
ESI_d		–0.0338	–1.15	0.248
cons_d		7.8613	0.37	0.714

Note: *, **, *** – significance at the 10%, 5% and 1% levels, respectively.

While the decision to start a business may be an individual one, the success of a business often depends on external factors, like economic, political, legal, technological, social, and cultural factors. Favourable macroeconomic conditions, such as economic growth, low inflation, and stable interest rates, can provide a supportive environment for entrepreneurs by fostering consumer demand, improving access to finance, and increasing business confidence. Therefore, based on the database gathered for this study, we tested the model with several (economic complexity, educational attainment) or all control variables (economic complexity, educational attainment, gender parity, economic sentiment) to observe the differences between results.

A country's economic structure affects entrepreneurial activities in various ways, including industry composition, the level of economic development, the regulatory environment, access to finance, human capital, and cultural and social factors. Overall, the threshold regressions evidenced a statistically significant positive influence from ECI towards the new business density rate; for the values below the threshold and digital inclusion values higher than the threshold, a negative impact from ECI on the new business density rate. Generally, higher ECI values are associated with a more diverse and innovative economic environment that fosters entrepreneurial activities (Tok, 2020; Zhu & Li, 2017; Koch, 2021; Growth Lab Harvard University, 2020). However, some scholars (Goldschlag & Tabarrok, 2018; Naudé, 2022) found that a shared characteristic among countries experiencing a decline in entrepreneurship is the presence of high GDP per capita and high economic complexity. More complex countries endowed with different types of more sophisticated production capabilities generate a decline in entrepreneurship. Investing in human capital through education, training, and skill development can foster a more entrepreneurial mindset (Marvel et al., 2016; Estrin et al., 2016; Dutta & Sobel, 2018; Madriz et al., 2018; Chitsaz et al., 2019). Although we expected a better-educated workforce to boost entrepreneurship, our statistically significant results prove that educational attainment negatively influences the new business rate up to the threshold value of the digitalisation proxy and a positive one on the new business rate upwards of the threshold.

Female entrepreneurial activity can be positively impacted by reducing the gender gap in education (Khalid et al., 2022; Schneider, 2022). We expected that reducing the gender gap would boost entrepreneurship. From our analysis, the gender parity index – GPI seems to influence NewBusRate up to the threshold positively and negatively afterwards. However, the results were statistically significant only for the regression model that included all four control variables and only for the GPI coefficient associated with values higher than the threshold. Cardella et al. (2020) emphasised the significance of women's

entrepreneurship in contributing to a country's economic growth. Women encounter more challenges when launching a business due to various barriers, like cultural and industry biases, lack of access to financing or limited networks. Therefore, a non-linear effect from gender parity towards new business density rate is expected, especially from the overall sample of all the EU countries.

Finally, statistically significant results only proved its positive influence on new business rates up to the ESI threshold value. This composite index measures the overall confidence level in a region or country's economy based on surveys of consumers and businesses across various sectors (Eurostat, 2022a, 2022b). We expect a high level of ESI to encourage entrepreneurship since it reflects a positive outlook on the overall economic climate. When the ESI is high, businesses and consumers have confidence in the economy, fostering entrepreneurial activities.

Following the results from Lobonț et al. (2022), we acknowledged the performance heterogeneity across EU countries and separated them from the perspective of their innovation performance into Innovation leaders, Strong innovators, Moderate innovators, and Emerging innovators (European Commission, 2023), (Table 5) and reapplied the threshold model to overview its significance across different types of countries.

Table 5. EU countries categorised depending on innovation performance (sourceEuropean Commission, 2023)

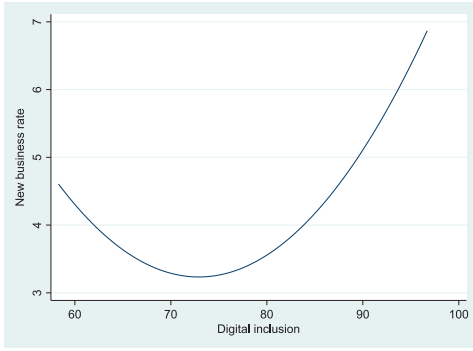
Innovating leaders	Strong innovators	Moderate innovators	Emerging innovators
Belgium	Austria	Czech Republic	Bulgaria
Denmark	Cyprus	Greece	Croatia
Finland	Estonia	Italy	Hungary
Netherlands	France	Lithuania	Latvia
Sweden	Germany	Malta	Poland
	Ireland	Portugal	Romania
	Luxembourg	Slovenia	Slovak Republic
		Spain	

Table 6 includes the descriptive statistics of the variables for every country category. The highest new business density is in the strong innovators, being, on average, double (the mean is 9) than the average value of the other three country categories (4.79, 4.36 or 4.34). The digitalisation proxy is the highest in innovation leaders (86.2), followed by strong innovators (74.88) and moderate and emerging innovators (with approximately 62 and 60, respectively). The highest capabilities and know-how are observed in strong innovators (average of 1.27) and innovation leaders (1.22), followed by the moderate and emerging countries (average of 1 and 0.94, respectively). Differences between country categories are significant in educational attainment: innovation leaders present an average of 130, while strong and moderate innovators 105–106%, and emerging innovators 98%. Therefore, education seems to have a relevant impact on the level of innovation. The gender parity index, as well as the ESI, are variables that have the lowest differences across country categories. Therefore, we do not expect these control variables to strongly impact the threshold analysis applied to review the effect of digitalisation on entrepreneurship in terms of country innovation classification.

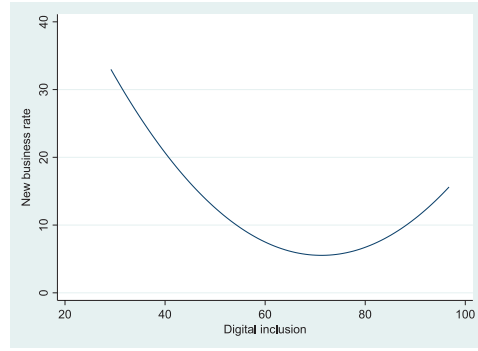
Table 6. Descriptive statistics for each sub-sample (source: authors' processing)

	Innov. Leaders	Strong innov.	Moderate innov.	Emerging innov.
NewBusRate	75 obs.	105 obs.	120 obs.	105 obs.
Mean	4.7966	9.0045	4.3617	4.3451
Std. dev.	2.1828	8.3146	3.7923	2.6105
Min	2.62	0.48	0.31	0.47
Max	10.02	39.04	18.02	12.14
DigIncl	75 obs.	105 obs.	120 obs.	105 obs.
Mean	86.231	74.8826	61.8844	60.1971
Std. dev.	8.1839	14.5829	15.6242	16.4427
Min	58.3	29.18	22.69	18.36
Max	96.7	96.75	91.25	88.17
ECI	75 obs.	105 obs.	120 obs.	105 obs.
Mean	1.2225	1.2718	1.004	0.9407
Std. dev.	0.4916	0.5635	0.5527	0.4732
Min	0.1064	0.0086	0.0184	0.0065
Max	1.9214	2.3074	1.8495	1.7135
Educ.att.	75 obs.	105 obs.	120 obs.	105 obs.
Mean	130.6794	105.0763	106.3624	98.4288
Std. dev.	20.2623	9.2336	8.6482	7.0136
Min	96.9797	91.4408	93.3061	83.8186
Max	163.934	154.9083	126.1905	115.2444
GPI	75 obs.	105 obs.	120 obs.	105 obs.
Mean	1.0317	0.9968	0.9939	0.9963
Std. dev.	0.0361	0.0213	0.0189	0.0174
Min	0.9804	0.9576	0.9352	0.9663
Max	1.0982	1.0602	1.04	1.0494
ESI	75 obs.	105 obs.	120 obs.	105 obs.
Mean	99.401	99.0043	98.5994	98.8578
Std. dev.	8.789	9.0673	9.5489	10.0189
Min	80.4	75.2	70.275	69.9666
Max	114.225	116.425	114.0333	119.0833

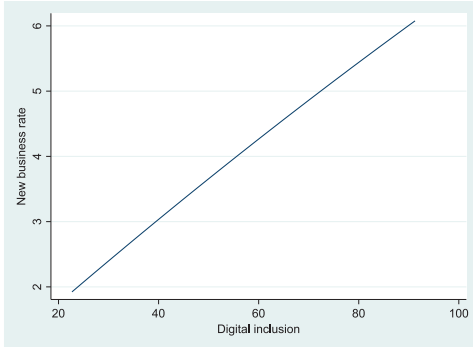
Figure 3 exhibits the relationship between the new business density rate and digital inclusion for every sub-sample. The non-linear relationship between digitalisation and entrepreneurship is evidenced by the graphical analysis in three sub-samples (innovating leaders, strong and emerging innovators). Although the threshold values (from which the relationship changes) are different for the three country categories (approximately 73 for innovating leaders, 70 for strong and 45 for emerging innovators), lower digitalisation values negatively influence new business density rates. However, higher ones are inducing a direct influence on entrepreneurship. The graph does not indicate a threshold for moderate innovators but a direct relationship between digitalisation and entrepreneurship. These values will be further confirmed or not by the threshold analysis applied to every sub-sample.



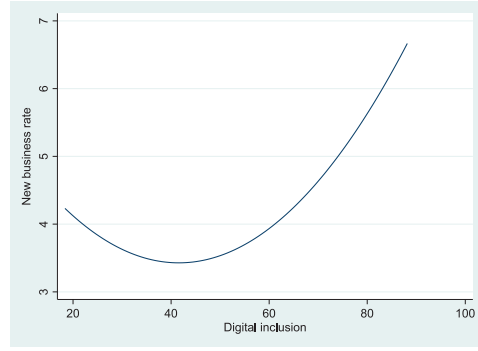
Innovating leaders



Strong innovators



Moderate innovators



Emerging innovators

Figure 3. The relationship between individual digital inclusion and new business density rate for EU countries categorised based on innovation performance (2006–2020) (source: authors' processing)

Table 7 presents the main results from the threshold regression models applied to the four sub-samples. When separating the EU countries from the perspective of their Innovation Index performance, for the simple threshold model (with dependent and threshold variable), the threshold effect was maintained in all categories but for strong innovators, for which the threshold value was significant only in the regression model that included ESI as a control variable.

Table 7. Panel threshold regression results for the effects between digitalisation and entrepreneurship within the EU countries categorised based on innovation (source: authors' processing)

	Threshold Value	Coefficient	Z	p-value
Category: Innovating Leaders *Threshold variable: DigIncl*				
Single threshold effect test	88.7861***		4.16	0.000
No. of moment conditions	104			
Lag_NewBusRate_b		–0.2613	–0.04	0.968
Lag_NewBusRate_d		3.5403	0.68	0.494
cons_d		–9.0329	–0.39	0.694

End of Table 7

	Threshold Value	Coefficient	Z	p-value
Category: Strong Innovators				
Threshold variable: DigIncl				
Single threshold effect test	84.6262		0.97	0.331
No. of moment conditions	104			
Lag_NewBusRate_b		0.4756	0.77	0.438
Lag_NewBusRate_d		–1.3402	–1.04	0.300
cons_d		22.3118	0.99	0.323
Threshold variable: DigIncl; Control variables: ESI				
Single threshold effect test	74.4474***		2.90	0.004
No. of moment conditions	117			
Lag_NewBusRate_b		–0.2101	–0.01	0.994
ESI_b		0.2848	0.82	0.413
Lag_NewBusRate_d ESI_d		4.1037 –0.7682	0.33 –0.92	0.745 0.359
cons_d		53.6509	1.05	0.296
Category: Moderate Innovators				
Threshold variable: DigIncII				
Single threshold effect test	52.7713***		8.84	0.004
No. of moment conditions	104			
Lag_NewBusRate_b		50.0933***	3.42	0.001
Lag_NewBusRate_d		–48.939***	–4.07	0.000
cons_d		89.6055**	1.97	0.049
Category: Emerging Innovators				
Threshold variable: DigIncII				
Single threshold effect test	74.6511*		1.92	0.055
No. of moment conditions	104			
Lag_NewBusRate_b		–0.7281	–0.18	0.860
Lag_NewBusRate_d		3.1256	1.27	0.205
cons_d		–27.0505**	–2.09	0.036

Note: *, **, *** – significance at the 10%, 5% and 1% levels, respectively.

Digitalisation has already been widely adopted by innovation leaders, and businesses have integrated digital technologies. The business environment in these countries is also subject to market saturation, higher competition and a strong focus on innovation and R&D. The threshold was evidenced at 88.78. With an average value of digital inclusion of 86.23, we expect innovation leaders to generally have a positive impact of digitalisation on entrepreneurship. After 2012, digital inclusion surpassed the threshold of 88.78 for most innovation leaders.

Strong innovators may have limited room for growth in developing infrastructure, skill development and digital adoption compared to leader innovators, where digital technologies have already been widely integrated. The threshold value is 74.45. Many of the strong innovators have a digital inclusion level higher than the threshold after 2010, for which we expect these countries to experience a positive impact from digitalisation towards entrepreneurship.

Moderate innovators may have limited resources for investing in digital infrastructure and supporting innovation, constraining the extent to which digital inclusion can boost new business rates. The threshold value is the lowest of all (52.77). Except for Greece, Italy, and Portugal, which reached a level higher than 52 after the financial crisis, the rest of the countries had a digital inclusion higher than 52 since 2008/2009, when the financial crisis began.

For emerging innovators, the threshold value is 74.65: Romania reached a digital inclusion higher than 70 (in 2019 and 2020), while Bulgaria was under 70 over the period analysed. The rest of the countries were set for digital inclusion higher than the threshold a little after 2014/2015, having overall significantly lower values than the rest of the sub-samples. Therefore, we expect the highest impact of digitalisation on entrepreneurship. Digital inclusion boosts the new business rate in emerging innovators by providing better access to digital tools and resources, enabling entrepreneurs to leverage technological advancements to create and grow businesses.

Regarding the lag of the dependent variable, only for the group of moderate innovators is the first lag of the new business density rate statistically significant for determining the current new business density rate. The relationship between the lag and the dependent variable is direct for the lower threshold and indirect for the upper threshold, similar to the statistically significant coefficients obtained from the threshold regression models applied to the overall EU-27 database.

The study found a positive correlation between digitalisation and entrepreneurship, confirming prior research (Dabbous et al., 2023) and introducing the novel finding of a threshold effect between digital inclusion and new business creation. This impact is particularly strong in emerging countries with lower innovation performance. Using digital inclusion as a proxy for digitalisation offers insights into socio-economic effects and policy implications but also has limitations, such as not fully capturing technological advancement, firm-level tech adoption, or sectoral digital evolution.

5. Conclusions

Our study sought to delve deeper into the relationship between digitalisation and entrepreneurship in EU countries from 2006 to 2020 by employing a panel threshold regression model. We considered the new business density rate as the dependent variable to proxy entrepreneurship, while the threshold variable is represented by digital inclusion, the proxy for digitalisation. We employed the abovementioned metrics in conjunction with other indicators to provide an original framework for understanding the complex factors that drive entrepreneurship by including four control variables: the Economic Complexity Index (ECI), educational attainment through school enrolment – secondary level, the gender parity index (GPI) and the Economic Sentiment Indicator (ESI). We expected a positive relationship between digitalisation and entrepreneurship and a threshold effect between individuals' digital inclusion as a proxy for digitalisation and new business density rate as a proxy for entrepreneurship.

As a novelty, our methodology accounts for non-linear attribution, resulting in more accurate outcomes by capturing the non-linear relationship between digitalisation and entrepreneurship in EU countries. We acknowledged the performance heterogeneity across EU countries, separating EU countries from the perspective of their innovation performance into Innovation leaders, Strong innovators, Moderate innovators, and Emerging innovator countries. The results confirm a strong single threshold effect between individuals' digital inclusion, as a proxy for digitalisation, and new business density rate, as a proxy for entrepreneurship,

confirming that the entrepreneurs' skills, knowledge, and experience play a role in entrepreneurial activities. This underscores the premise that mere accessibility to digital instruments is not the sole determinant; rather, the competencies and knowledge are pivotal in harnessing these tools effectively for entrepreneurial initiatives. When separating the EU countries from the perspective of their innovation performance, the threshold value was the lowest for countries classified as moderate innovators. The strongest positive influence of digitalisation towards entrepreneurship was visible in emerging countries, as they have lower innovation performance. As the EU emerging countries (from the perspective of their innovation performance) are potentially at earlier stages of their innovation journey, introducing or expanding digital tools and platforms could provide a pronounced boost to entrepreneurial initiatives than in more developed innovation ecosystems.

The study, rooted in human capital theory, initially hypothesised that a more educated workforce would boost entrepreneurship due to the importance of skilled employees for business success. Contrary to expectations, the findings showed that higher education levels deter new business formation up to a certain digitalisation threshold. This could be due to increased risk aversion and opportunity costs among the highly educated, who may prefer stable, well-paying jobs over starting businesses. However, beyond this threshold, in more digitalised economies, higher education positively impacts new business creation, possibly because digitalisation lowers entry barriers and demands specialised skills and innovation, areas where the highly educated excel.

This study evidenced the importance of innovation performance in terms of the influence of digitalisation on new businesses. Our results also emphasise the importance of integrating digitalisation and innovation efforts for organisations in the process industry to remain competitive and adapt to changing market demands. Collaborative governance in promoting digitalisation and fostering innovation is essential. Previous research also identified several elements of effective governance, such as multi-stakeholder engagement, participatory decision-making processes, and shared value creation. The impact of digital transformation on various performance measures was previously evidenced by researchers, concluding that digital technologies and fostering innovation in products and services could lead to significant performance improvements. Therefore, depending on the countries analysed and their focus on specific industries, we expect different thresholds and more significant influences from digitalisation to entrepreneurship. Public policies are also crucial for supporting entrepreneurship and digitalisation. The taxonomy of digital innovation strategies might become a critical factor in determining the success or failure of start-ups.

In terms of recommendations, the results indicate that policymakers should consider the optimal level of digitalisation to maximise benefits while minimising potential drawbacks. This approach will help create a balanced, inclusive, and sustainable entrepreneurial ecosystem. A digital industrial policy ensuring investments in digital infrastructure, support for R&D, fostering digital skills, and encouraging cross-border cooperation could increase the positive impact on the business environment. There is a particular need for a comprehensive and coordinated approach to overcome Europe's digital divide and enhance its global standing in the digital economy.

However, it is essential to consider the limitation of using the new business density rate as a sole proxy for entrepreneurship. For instance, it may not account for the quality or growth potential of the new businesses, nor does it capture informal entrepreneurship or self-employment. Future research should consider new control variables as long as this study evidences different threshold values when considering other factors (e.g., education, diversity,

capabilities, and know-how in a country) with potential influence on digitalisation and entrepreneurship.

Author contributions

ACN, ORL and EB conceived the study and were responsible for the design and development of the data analysis. ACN and EB were responsible for literature review and data collection. SV and ORL were responsible for methodology development and data interpretation. CAN and ORL conceived the conclusions and policy implications section.

Disclosure statement

The authors declare no conflict of interest.

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