

Industrial circular entrepreneurship: supporting sustainability in the machine tool industry of the Basque Country, Spain

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Emprendimiento industrial circular: apoyando la sostenibilidad en la industria de la máquina herramienta del País Vasco, España

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Empreendedorismo industrial circular: apoando a sustentabilidade na indústria de máquina-ferramenta do País Basco, Espanha

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Abstract

Purpose – This paper aims to explore the application of the National Expert Survey (NES) methodology in the circular economy, validating the model in the industrial ecosystem of the Basque Country to identify the challenges faced by the entrepreneurial ecosystem in the machine tool industry and to promote circular entrepreneurship.

Design/methodology/approach – This study uses the NES methodology, a globally recognized qualitative tool for gathering expert opinions. This methodology is adapted to the context of industrial circular entrepreneurship, ensuring that the constructs are relevant to the circular economy.

Findings – This study validates and expands the application of the NES model in the context of industrial circular entrepreneurship, providing a robust theoretical framework to evaluate the circular entrepreneurial ecosystem. The suitability of the Basque Country context, with its industrial legacy and cultural identity, has been key to this validation.

Practical implications – Concrete recommendations are provided to improve education, government intervention and financial conditions, highlighting key areas that facilitate the transition to sustainable business models and promote innovation and collaboration in the circular economy.



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Originality/value – A new model is proposed, pioneering the validation of the NES methodology in industrial circular entrepreneurship and providing a specific tool to evaluate environmental factors in the Basque industry. The adaptation of the NES model offers a solid foundation for future research and applications. The model aids in decision-making, and its use has a social impact.

Keywords Entrepreneurship, Circular economy, Sustainability, Industry, Industrial circular entrepreneurship, Entrepreneurial ecosystem, GEM

Paper type Research paper

Resumen

Objetivo – Este artículo explora la aplicación de la metodología NES en la economía circular, validando el modelo en el ecosistema industrial del País Vasco para identificar los desafíos que enfrenta el ecosistema emprendedor en la industria de la máquina herramienta y propone un modelo original para medir y promover el emprendimiento circular industrial. El modelo ha sido validado en el ecosistema industrial vasco, un contexto de referencia para la actividad y política industrial. Útil para la industria, la política y el ámbito académico, el modelo identifica factores favorables y áreas que requieren atención en el emprendimiento circular industrial.

Diseño/metodología/enfoque – El estudio utiliza la metodología NES, una herramienta cualitativa reconocida a nivel mundial para recopilar opiniones de expertos. Esta metodología se adapta al contexto del emprendimiento circular industrial, asegurando que los constructos sean relevantes para la economía circular. La metodología es clave para el estudio, ya que se ha diseñado una herramienta original basada en la metodología NES, ampliamente probada y validada, y específicamente adaptada para el emprendimiento circular industrial.

Resultados – El estudio valida y amplía la aplicación del modelo NES en el contexto del emprendimiento circular industrial, proporcionando un marco teórico robusto para evaluar el ecosistema emprendedor circular. La idoneidad del contexto del País Vasco, con su legado industrial e identidad cultural, ha sido clave para esta validación. Al abordar la notable falta de investigación sobre la economía circular desde la perspectiva del emprendimiento industrial, este artículo se presenta como una contribución particularmente valiosa.

Originalidad/valor – Se propone un nuevo modelo, pionero en la validación de la metodología NES en el emprendimiento circular industrial, proporcionando una herramienta específica para evaluar factores ambientales en la industria vasca. La adaptación del modelo NES ofrece una base sólida para futuras investigaciones y aplicaciones. El modelo ayuda en la toma de decisiones y su uso tiene un impacto social.

Implicaciones prácticas – Se ofrecen recomendaciones concretas para mejorar la educación, la intervención gubernamental y las condiciones financieras, destacando áreas clave que facilitan la transición hacia modelos de negocio sostenibles y promueven la innovación y la colaboración en la economía circular.

Palabras clave Emprendimiento, Economía circular, Sostenibilidad, Industria, Emprendimiento circular industrial, Ecosistema emprendedor, GEM

Tipo de artículo Trabajo de investigación

Resumo

Objetivo – Este artigo explora a aplicação da metodologia NES na economia circular, validando o modelo no ecossistema industrial do País Basco para identificar os desafios enfrentados pelo ecossistema empreendedor na indústria de máquinas-ferramenta e propõe um modelo original para medir e promover o empreendedorismo circular industrial. O modelo foi validado no ecossistema industrial basco, um contexto de referência para a atividade e política industrial. Útil para a indústria, políticas públicas e o meio acadêmico, o modelo identifica fatores favoráveis e áreas que requerem atenção no empreendedorismo circular industrial.

Design/metodologia/abordagem – O estudo utiliza a metodologia NES, uma ferramenta qualitativa reconhecida mundialmente para a coleta de opiniões de especialistas. Esta metodologia é adaptada ao contexto do empreendedorismo circular industrial, garantindo que os constructos sejam relevantes para a economia circular. A metodologia é fundamental para o estudo, uma vez que foi desenvolvida uma ferramenta original baseada na metodologia NES, amplamente testada e validada, e especificamente adaptada para o empreendedorismo circular industrial.

Resultados – O estudo valida e expande a aplicação do modelo NES no contexto do empreendedorismo circular industrial, proporcionando um marco teórico robusto para avaliar o ecossistema empreendedor circular. A adequação do contexto do País Basco, com seu legado industrial e identidade cultural, foi essencial

para esta validação. Ao abordar a notável falta de pesquisa sobre a economia circular a partir da perspectiva do empreendedorismo industrial, este artigo se apresenta como uma contribuição particularmente valiosa.

Originalidade – Propõe-se um novo modelo, pioneiro na validação da metodologia NES no empreendedorismo circular industrial, fornecendo uma ferramenta específica para avaliar fatores ambientais na indústria basca. A adaptação do modelo NES oferece uma base sólida para futuras pesquisas e aplicações. O modelo auxilia na tomada de decisões e seu uso tem um impacto social.

Implicações práticas – São fornecidas recomendações concretas para melhorar a educação, a intervenção governamental e as condições financeiras, destacando áreas-chave que facilitam a transição para modelos de negócios sustentáveis e promovem a inovação e a colaboração na economia circular.

Palavras-chave Empreendedorismo, Economia circular, Sustentabilidade, Indústria, Empreendedorismo circular industrial, Ecossistema empreendedor, GEM

Tipo de papel Trabalho de pesquisa

1. Introduction

The Circular Economy, driven by the European Union and supported by organizations such as the Ellen MacArthur Foundation, has emerged as a crucial topic on the global public agenda, emphasizing the need to reassess the interaction between society, businesses and the environment (Elkington, 1997; Geissdoerfer *et al.*, 2017; Kirchherr *et al.*, 2023). In this context, the Machine Tool Industry in the Basque Country, which represents a vital component of the regional economy (Eustat – Euskal Estatistika Erakundea/Instituto Vasco de Estadística, 2022), faces significant environmental challenges.

Despite the recognition of the relationship between industry and climate change, the scientific literature has historically leaned towards reactive solutions, focusing on mitigating already generated effects. Khanna *et al.* (2022) suggest that mitigation measures have been prioritized over the design and implementation of proactive actions, revealing a gap in the literature regarding how to propose actions that prevent the adverse impact of industry on the environment.

Entrepreneurship emerges as a key catalyst to drive proactive strategies, facilitating the development of new business models that prioritize innovation and social and environmental values (Pirson *et al.*, 2019). However, the growing literature on the circular economy remains under-implemented in practice (Corvellec *et al.*, 2022; Ritzén and Sandström, 2017).

The transition towards a circular economy faces common challenges, although the specific characteristics of each sector and region are crucial for its success. Several barriers and opportunities for its adoption have been identified at a global level. In Romania, Staicu and Pop (2018) highlight the lack of collaborative spaces and low awareness of the circular economy as limiting factors, emphasizing the importance of cooperation among key stakeholders. In the fashion industry, resistance to change, driven by limited awareness of the economic benefits of circularity, underscores the relevance of socioeconomic and cultural dynamics (Ostermann *et al.*, 2021). In sectors such as plastic packaging (Zucchella *et al.*, 2021) and the food industry (Nielsen and Hakala, 2023), implementation depends on internal factors and external regulations, highlighting the fundamental role of public policies in accelerating the transition (Appolloni *et al.*, 2022; Zucchella *et al.*, 2021).

Unlike studies focused on waste management (Elnourani *et al.*, 2024), this research adopts an innovative approach by analysing how entrepreneurial ecosystems can accelerate the adoption of circular models in the machine tool industry. The study emphasizes entrepreneurship and intrapreneurship as drivers of change (Oliveira *et al.*, 2021), highlighting inter-firm collaboration and the use of digital technologies to optimize product life cycles, promote material reuse and generate new economic opportunities (Appolloni *et al.*, 2022; Zucchella *et al.*, 2021). By focusing on the machine tool industry, this work

provides an innovative perspective to promote sustainability in the sector, fostering a comprehensive approach to the transition towards circular models.

Recognizing the concept of the entrepreneurial ecosystem is essential, as it represents a regional environment where interdependent actors, resources and conditions converge to stimulate entrepreneurial activity and business growth (Mason and Brown, 2014; Stam, 2015). However, the lack of attention to this ecosystem limits the creation of fertile ground for industrial circular entrepreneurship, highlighting the need for deeper research in this area.

This article addresses the absence of research on the circular economy from the perspective of industrial entrepreneurship, aiming to identify the challenges faced by the entrepreneurial ecosystem in the machine tool industry of the Basque Country to foster circular entrepreneurship. The research question guiding this study is:

RQ1. What are the challenges faced by the ecosystem in promoting industrial circular entrepreneurship in the Basque Country?

The application of the validated NES methodology in the circular economy will be explored to identify environmental factors that facilitate and those that require greater attention.

This research directly impacts the literature by validating the NES methodology as a tool to analyse the circular entrepreneurial ecosystem in a specific industry. Its relevance transcends the academic realm, contributing to the development of a sustainable business environment and providing policymakers with a solid foundation for informed decision-making, which, in turn, will favour a positive change in society.

The article is structured as follows. Firstly, the theoretical framework of the study will be presented (Section 2). Then, the context of the machine tool industry in the Basque Country, where the study has been conducted, will be discussed (Section 3). Subsequently, the methodology used in the research will be described (Section 4). Next, the results obtained from applying the methodology will be presented and discussed (Section 5). Finally, the study's conclusions will be presented (Section 6).

2. Theoretical framework

Although many studies focus on waste management, the circular economy has emerged as a crucial approach to address sustainability and contemporary environmental challenges (European Union, 2018; Moraga *et al.*, 2019). The transition to a circular economy requires transformations at various levels, including technological innovation and the development of sustainable business models, where start-ups play an essential role in overcoming institutional and cultural challenges (Nunes *et al.*, 2022; Witjes and Lozano, 2016).

The literature review on circular economy in specific industries reveals globally adopted practices. In Pakistan and Iran, there is a need to enhance decision-making processes and adopt advanced technologies for sustainable development (Khodaparasti and Garabollagh, 2023; Shah *et al.*, 2023). In Bangladesh, the textile sector implements smart technologies, whereas Taiwan applies waste management systems in the plastics industry (Hossain *et al.*, 2022; Wu *et al.*, 2021). In Europe, the integration of Industry 4.0 and the circular economy has benefited SMEs (Findik *et al.*, 2023), and in Poland, universities promote collaboration between academics and entrepreneurs (Sukiennik *et al.*, 2021). In Italy, the meat sector employs material flow cost accounting (Bux and Amicarelli, 2022), and in Latvia, the tire recycling industry enhances its financial viability through circular models (Uvarova *et al.*, 2020). These studies emphasize the need to explore how entrepreneurial ecosystems can accelerate the transition to industrial circular entrepreneurship, particularly in traditional sectors.

Despite the growing body of literature on the circular economy, there remains a disconnect between theory and practice, highlighting the need for clear standards to facilitate

the adoption of sustainable business models (Brennan and Alexander, 2017; Corona *et al.*, 2019; Genovese *et al.*, 2017; Lewandowski, 2016; Roos Lindgreen *et al.*, 2020). Although challenges and opportunities in specific sectors have been identified, a gap persists in understanding how entrepreneurial ecosystems can support the transition to circular models in mature industrial sectors. Research such as that by Elnourani *et al.* (2024) and Staicu and Pop (2018) addresses technological aspects but neglects the role of public policies and framework conditions in sectors like machine tools.

The study of Emilia-Romagna presented by Mencherini *et al.* (2020) offers valuable lessons for the Basque Country, given the regional and per capita income similarities. It underscores the importance of integrating public policies with industrial symbiosis to coordinate key actors, overcome regulatory barriers and foster exchange networks, which is an approach applicable to the Basque Country, where mature sectors such as machine tools require institutional support to advance circularity.

The study by Centoamore and Pinto (2024) on circular machine tool remanufacturing, conducted in Brazil, examines the feasibility of reusing components from dismantled machines to design new equipment, generating economic and environmental benefits. It frames the circular economy from the perspective of equipment redesign, applicable to stamping companies in the automotive sector. This approach is relevant to the Basque Country, given the importance of its stamping sector and its role as a key destination for machine tools.

The scarcity of studies like those of Emilia-Romagna and Centoamore and Pinto (2024) highlights the novelty of this research, which seeks to address the existing gap in understanding how entrepreneurial ecosystems and public policies can drive the circular economy in mature sectors such as machine tools in the Basque Country.

Therefore, the aim is to provide a comprehensive perspective on the challenges faced by ecosystems in addressing the urgent need to implement measures that promote sustainable practices (United Nations, 2019).

Analysing circular entrepreneurship in the industry within a specific region is enriched by integrating various theories that allow for a deeper understanding of organizational dynamics in relation to sustainability. Institutional theory, formulated by DiMaggio and Powell (1983), suggests that organizations are influenced by social structures and norms that affect their behaviour, complemented by Dasgupta's (2021) theory, which emphasizes the importance of managing natural capital to ensure human well-being, as its degradation negatively impacts the production of goods and services. In this sense, circular entrepreneurship enhances company profitability and contributes to social and environmental well-being. The concept of the triple bottom line (TBL), proposed by Elkington (1997), highlights that business success should be evaluated in three dimensions: economic, social and environmental. Companies that adopt this model focus not only on economic efficiency but also on promoting environmental sustainability (UNEP, 2021) and generate social value by fostering responsible labour practices and community development (Alpsahin Cullen, 2023).

The interrelation between institutional theory, Dasgupta's theory (2021) and the TBL approach demonstrates how integrating sustainability into business strategy is fundamental for transforming the industry. Finally, the application of this theoretical framework is enriched by the methodology of the Global Entrepreneurship Monitor (GEM), which provides a comprehensive view of entrepreneurial ecosystems. Through the National Expert Survey (NES), GEM allows for the evaluation of not only traditional statistics but also entrepreneurs' perceptions of factors affecting their environment (Pfeifer *et al.*, 2021). This is especially relevant for analysing how companies in the circular entrepreneurship sphere

can adapt to institutional pressures and facilitate the management of natural capital in their operations, aligning with Dasgupta's ideas (2021).

The NES method has been used to identify factors that stimulate entrepreneurial development in various contexts. [Herrington and Coduras \(2019\)](#) apply it in Sub-Saharan Africa, [Hechavarriá and Ingram \(2019\)](#) analyse the influence of entrepreneurial ecosystems in 75 countries, [Pfeifer et al. \(2021\)](#) assess entrepreneurial conditions in Croatia and [Coduras Martínez et al. \(2010\)](#) investigate entrepreneurial education and training in 30 countries. In Spain, [Alvarez et al. \(2011\)](#) examine environmental factors impacting entrepreneurship. However, the NES has not been used to analyse an entrepreneurial ecosystem in a specific sector from the perspective of the circular economy, which represents a significant research opportunity.

3. Context: machine tool industry in the Basque country

Institutional theory provides a robust framework for understanding how government policies and institutional changes can influence entrepreneurship and sustainable development ([Alwakid et al., 2021](#)). The unique context of the Basque Country, with its industrial legacy, affects entrepreneurial activity and policies that promote sustainable entrepreneurship oriented towards the circular economy, distinguishing it from other regions. Institutions are key in guiding society towards sustainable practices ([Bruton et al., 2010](#)) and their influence on entrepreneurship is crucial, highlighting the importance of considering regional differences in this analysis ([Urbano et al., 2019](#)).

The regional entrepreneurship system is essential for understanding the economic process, as entrepreneurs are influenced by their institutional environment ([Urbano et al., 2019](#)). The cultural identity of the Basque Country impacts the propensity for entrepreneurship and business activity, emphasizing the need to recognize the social and cultural context to promote equitable and sustainable business development ([Audretsch et al., 2017](#)). The view of entrepreneurship as an individual activity is being reevaluated, recognizing the influence of the context in which it develops, where institutions and culture are fundamental ([Audretsch, 2023](#)). Formal factors can affect society differently due to variations in institutional frameworks across regions ([Noguera et al., 2015](#)), influencing how aspects such as education and financial support vary according to the ecosystem. In this context, industry, especially in regions with an industrial legacy like the Basque Country, is key in terms of GDP, employment and productivity. However, it is also the most polluting sector, depleting resources and emitting significant emissions ([Ministerio para la Transición Ecológica y el Reto Demográfico, 2020](#)). The history of the Basque industry began in the 20th century with machine tool workshops, which developed significantly during World War I, positioning Gipuzkoa as a key centre ([Calabrese, 1993](#)). Currently, the Basque Country is one of the three main producers of machine tools in Europe and the ninth worldwide, benefiting from geographical proximity that fosters collaboration and innovation, supporting [Marshall's \(1890\)](#) theories on industrial agglomerations. In 2020, the sector represented 53% of the industrial sector and has received government support to promote innovation ([Eustat - Euskal Estatistika Erakundea/Instituto Vasco de Estadística, 2022; Ihobe, Sociedad Pública de Gestión Ambiental, 2018](#)).

This sector contributes more than 2% of total employment in the industries of the Basque Country ([Eustat – Euskal Estatistika Erakundea/Instituto Vasco de Estadístico, 2022](#)), but its pollution history poses environmental challenges, being responsible for 18% of direct emissions ([Ihobe, Sociedad Pública de Gestión Ambiental, 2018](#)). Addressing its environmental footprint is vital in the context of circular industrial entrepreneurship. From the perspective of the TBL ([Elkington, 1997](#)), the sector significantly impacts all three

dimensions, generating employment and economic growth, while facing environmental challenges that require a transition to a circular economy that protects the environment and ensures future well-being (Dasgupta, 2021).

This theoretical framework, applied to the NES in the Basque Country, highlights how a territory with a differential identity and significant industrial legacy shapes the entrepreneurial environment. We chose the machine tool industry to analyse its evolution towards sustainability.

4. Methodology

4.1 Procedure: National Expert Survey – Global Entrepreneurship Monitor

4.1.1 Rationale for selecting the National Expert Survey. The GEM is an international research project started in 1999 to provide comparative insights into entrepreneurship across countries. It collects data on entrepreneurial activity, attitudes and aspirations through two surveys: the Adult Population Survey (APS), which samples the adult population, and the NES, which surveys experts on business environments and policies.

GEM reports provide insights into the quality of contextual factors relevant to entrepreneurial behaviour in a particular country or region (Pfeifer et al., 2021), and policy recommendations at the global, national and regional levels are issued based on the findings. Governments, academics and professionals widely use these reports to understand and promote entrepreneurship worldwide.

In the literature, the NES is a promising avenue for research, as 87% of studies are based on the APS and only 3% use NES data (the remaining 10% use both sources of information), reflecting a clear underutilization of expert information (Alvarez et al., 2014). This creates a valuable opportunity to tap into the potential of NES, enriching future publications with new perspectives.

4.1.2 Application of the National Expert Survey methodology. This study focuses on the NES methodology to analyse the business environment and entrepreneurship policies. The GEM report has served as the primary data source on conditions for starting new businesses in participating countries, indicating that governments fostering EFC can expect higher entrepreneurial activity rates (Levie and Autio, 2007). Favourable conditions enhance the likelihood of entrepreneurial success and economic impact (Reynolds et al., 1999). The mixed methodology was initially considered for this study; however, the NES methodology was ultimately selected. This methodology has been validated globally, undergoing rigorous internal control and external evaluations at least three times, with the most recent one in 2019 conducted by a Commission of Experts in Composite Indices from the EU Joint Research Centre, which assessed the GEM concerning the NECI. The NES methodology allows for subjective evaluations of entrepreneurial contexts through latent variables (Pfeifer et al., 2021), generating valuable insights from specialists. After 23 years of operation, NES has established itself as a unique global tool for the subjective estimation of the conditions of the entrepreneurial framework as latent variables.

Furthermore, other recent articles have used this methodology for their research, as seen in the works of Campos et al. (2019), Hawi et al. (2022), Villegas Mateos and Amorós (2019), Villegas-Mateos (2021) and Villegas-Mateos (2022). These applications highlight the rigour of the NES methodology in analysing entrepreneurial contexts.

The NES monitors essential elements for fostering entrepreneurship, influencing policies that enhance the entrepreneurial environment in GEM countries. Evaluating the national environment identifies strengths and areas for improvement (Reynolds et al., 2005), supporting business establishment and growth over time. Coduras (2022) emphasizes that understanding the entrepreneurial environment's average state is vital for promoting entrepreneurship as part

of economic growth strategies. GEM data aids policymakers in informed decision-making to enhance entrepreneurship and economic growth ([Bosma, 2013](#)).

The NES methodology uses intentional sampling, enabling researchers to select participants based on specific criteria ([Patton, 2014](#)). Despite its bias, this method is more efficient than random sampling if informant quality is ensured. Nine blocks of questions assess key entrepreneurial environment conditions, with principal component analysis yielding scores for latent variables essential for the National Entrepreneurship Context Index (NECI) ([Pöge and Reinecke, 2021](#); [Reynolds et al., 2005](#)). This approach simplifies data complexity, allowing observable variables to be integrated into a model for enhanced understanding ([Ullman and Bentler, 2012](#)).

The questionnaire includes brief open-ended questions and a background section to gather expert characteristics, ensuring quality. Experts evaluate NES questionnaire statements on a scale from 0 (completely false) to 10 (completely true), with options for “don’t know” and “no answer”. Data analysis uses Cronbach’s alpha for response consistency ([Bosma, 2013](#)), providing reliable estimates of constructs related to the business framework.

Although the GEM questionnaire includes cultural and social indicators, sustainability has not been adequately addressed ([Roomi et al., 2021](#)). A comprehensive assessment of circular entrepreneurship requires a broader approach to accurately capture its complexity and influence. Historically, the focus on entrepreneurship has often overlooked social and environmental considerations. Several authors ([Dean and McMullen, 2007](#); [Pacheco et al., 2010](#); [Schmidheiny, 1992](#); [Sternberg, 1996](#)) highlight the negative societal and environmental impacts of entrepreneurial activity, underscoring the need to adapt the NES methodology for circular entrepreneurial contexts and fill the gap in environmental impact assessment.

4.2 Data collection: entrepreneurial framework conditions

This study was conducted between November 2022 and June 2023. Following the NES methodology, we selected experts in entrepreneurship from the Machine Tool district of the Basque Country to provide detailed information on EFC related to the circular economy. The experts were contacted and the study was explained to them in detail. Once they agreed to participate, the selected experts received the online questionnaire “Encuesta de Expertos: Emprendimiento Industrial en la Economía Circular en el País Vasco” and proceeded to complete it. They provided quantitative assessments of environmental conditions and open responses identifying three drivers, three restrictive factors and three recommendations for circular entrepreneurship.

After surveying 27 experts, we harmonized the data to calculate the nine EFCs and converted them into continuous quantitative variables. Nine open-ended responses were categorized for each expert. A Stata file was created for analysis, including averages, standard deviations, medians and Cronbach’s alpha coefficients for confidence intervals. We used a customized NES-based questionnaire focused on circular economy entrepreneurship, comprising nine blocks and 75 items, along with open questions and expert profiles. The nine basic blocks of EFC used by GEM have been adapted to analyse the entrepreneurial ecosystem related to the circular economy, as detailed in [Table 1](#).

The constructs presented, adapted from the NES standard and grounded in current literature on industrial circular entrepreneurship, reflect the necessary framework conditions to foster and facilitate the transition towards sustainable practices. An adaptation of the GEM constructs has been made by incorporating specific elements that promote sustainability, such as the integration of circular economy principles into business strategy, the creation of funding sources for circular projects, the development of supportive government policies and

Table 1. Entrepreneurial framework conditions adapted to a circular economy entrepreneurship ecosystem in the machine tool industry of the Basque Country

Entrepreneurial framework conditions, nine dimensions	
A	Corporate commitment to circularity
B	Financial support
C	Government programmes and policies
D	Education and training
E	R&D + I
F	Industrial infrastructure
G	Access to specialized suppliers
H	Entry barriers
I	Social and cultural norms

Source: Authors' own elaboration based on the Global Entrepreneurship Monitor

education focused on circularity skills. In addition, the importance of adequate infrastructure and access to specialized suppliers has been emphasized, as well as the promotion of a change in social and cultural norms that support circular entrepreneurship.

The first construct, corporate commitment to circularity, stands out as a fundamental element, consolidating the circular economy as a strategic imperative (Urbancová and Vrabcová, 2023; Yoshino *et al.*, 2023). Financial support is vital for companies to make investments in emerging technologies, facilitating sustainable practices and circular supply chains (Findik *et al.*, 2023). Government programmes and policies establish guidelines that facilitate the transition towards more sustainable practices (Alpsahin Cullen, 2023; Corona *et al.*, 2019; Nielsen and Hakala, 2023). Education and training are crucial to bridging the gap between theory and practice in the circular economy, empowering entrepreneurs with circular strategies (Den Hollander *et al.*, 2017; Khan *et al.*, 2023; Sukienek *et al.*, 2021). Research and development (R&D) are key to creating tools and fostering technologies that promote circularity (Despeisse *et al.*, 2017; Kayikci *et al.*, 2024; Vermeulen *et al.*, 2020; Yadav *et al.*, 2020). Adequate industrial infrastructure and access to specialized suppliers facilitate the implementation of circular practices (Franco and Rodrigues, 2022). Finally, entry barriers and social and cultural norms impact the adoption of circular economy initiatives, and it is essential to address them to promote a culture that values sustainability (Nunes *et al.*, 2022; Urbancová & Vrabcová, 2023; Den Hollander *et al.*, 2017).

The EFCs are converted into continuous quantitative variables to facilitate comparison and analysis in statistical models. By adapting and harmonizing these constructs through principal component analysis, a more focused and reliable analysis of the circular business environment in the Machine Tool district of the Basque Country is achieved.

4.3 Presentation of the experts

Experts in the NES methodology are crucial for assessing environmental conditions conducive to entrepreneurship. Our key informants, including entrepreneurs, investors, policymakers, service providers and researchers, provide insights into the machine tool district's entrepreneurial landscape. They help us understand the conditions and challenges circular entrepreneurs face in this industrial district.

A rigorous expert selection process was conducted for the interviews to ensure valid results. The 27 selected individuals represent diverse perspectives and experiences. They were grouped into profiles based on the nine entrepreneurial framework conditions, ensuring

variety in entrepreneurial, financial, governmental, educational, industrial and strategic focuses. Each condition/profile had three experts, ensuring an equitable distribution of knowledge. Among the 27 experts, 13 were “context experts” and 14 were “entrepreneurs”. This mix provides essential perspectives: “context experts” offer analytical views based on experience, whereas “entrepreneurs” provide practical insights from direct involvement.

The sociodemographic profile of the experts participating in the study reflects certain gender inequalities and relevant professional characteristics. A total of 66.67% of the experts are men, whereas 33.33% are women, a disparity that can be partially understood as a reflection of the structural inequality in the Basque Country’s manufacturing sector, where only 20.85% of employees are women, according to data from [Eustat - Euskal Estatistika Erakundea/Instituto Vasco de Estadística \(2023\)](#). In addition, the average age of participants is 47 years and 81.48% hold a master’s or doctoral degree. On average, the experts have 10 years of experience in entrepreneurship-related fields.

Regarding professional specializations, 51.85% of the experts identify as individual entrepreneurs, 48.15% as service providers, 22.22% belong to academia as teaching or research staff, 7.41% act as investors or individual financiers and only 3.70% hold roles as policymakers. It is worth noting that the percentages do not add up to 100% because some experts perform multiple professional roles. This distribution reflects a diversity of professional profiles among the experts involved in the study.

5. Results and discussion

5.1 Academic discussion

The NES methodology is a valuable tool for gathering expert opinions, emphasizing contextual coherence and depth of information ([Clayton, 1997](#)). This qualitative approach not only strengthens the validity of the results but also ensures a high internal consistency in the measurement of the constructs, as evidenced by the Cronbach’s alpha obtained in the study ([Spector, 2013](#)). The meticulousness in crafting the questions and the use of a Likert scale reinforce the methodological robustness, allowing for a precise analysis of the results. This robust validation, reflected in [Table 2](#), is crucial for adapting the NES model to specific contexts.

[Tables 3](#) and [4](#) provide evidence of the consistency and variability in the perceptions of the constructs of the entrepreneurial environment.

Table 2. Cronbach’s alpha coefficients for the internal consistency of the environmental conditions (EFC)

EFC	Reliability coefficient	Cronbach’s alpha for 10-point variables
		Construct variables
Construct A	0.7913	A01,A02,A03,A04,A05,A06,A07,A08,A09,A10,A11
Construct B	0.9133	B01,B02,B03,B04,B05,B06,B07,B08,B09,B10,B11,B12
Construct C	0.9178	C01,C02,C03,C04,C05,C06,C07,C08,C09,C10,C11,C12,C13,C14,C15
Construct D	0.9358	D01,D02,D03,D04,D05,D06,D07
Construct E	0.9414	E01,E02,E03,E04,E05,E06
Construct F	0.8757	F01,F02,F03,F04,F05,F06,F07
Construct G	0.9119	G01,G02,G03,G04,G05,G06
Construct H	0.7631	H01,H02,H03,H04,H05,H06
Construct I	0.8022	I01,I02,I03,I04,I05

Source: Authors’ own elaboration

Table 3. Descriptive statistics of entrepreneurial environment conditions based on the circular economy (constructs)

Variable	Obs	Mean	SD	Min.	Max.
NESCE_A	27	6.962.963	1.198.712	4.727.273	9.090.909
NESCE_B	27	5.554.938	1.354.155	2.583.333	7.833.333
NESCE_C	27	61.415	1.346.939	3.066.667	7.933.333
NESCE_D	27	4.883.598	1.945.101	0	8.428.571
NESCE_E	27	5.783.951	1.783.001	1	8.666.667
NESCE_F	27	6.656.961	1.511.251	1.571.429	8.714.286
NESCE_G	27	641.049	1.378.447	2	8.5
NESCE_H	27	5.669.136	1.091.573	2.833.333	7.666.667
NESCE_I	27	642.963	1.095.029	3.666.667	8.5

Source: Authors' own elaboration

Table 4. Descriptive analysis of the national entrepreneurship context index (NECI)

Variable	Obs	Mean	SD	Min.	Max.
NECI	27	6.084.216	1.006.868	3.130.303	7.373.236

Source: Authors' own elaboration

This study not only enhances understanding of the factors affecting industrial circular entrepreneurship but also propels the development of the NES model in new directions, focusing on aspects of the environment that have been little explored, specifically those related to sustainability. This adaptation provides a solid foundation for future research and practical applications, validating the relevance of the model in assessing critical factors and strengthening its utility in the context of industrial circular entrepreneurship.

5.2 Policy discussion

5.2.1 *Summary of key findings.* The results in Table 5 show that "Corporate Commitment to Circularity" has been highly valued (average score of 6.96 out of 10), positioning it as the main favourable condition in the environment. This reflects a strong commitment from the machine

Table 5. Average rating of environmental conditions. National Entrepreneurship Context Index (NECI on the circular economy)

National Entrepreneurship Context Index (NECI)	6.08
Corporate commitment to circularity	6.96
Industrial infrastructure	6.67
Social and cultural norms	6.43
Access to specialized suppliers	6.42
Government programs and policies	6.14
R&D + i (research, development and innovation)	5.78
Entry barriers	5.67
Financial support	5.55
Education and training	4.88

Source: Authors' own elaboration

tool sector companies in the Basque Country to adopting circular practices. “Industrial Infrastructure” is also considered a very positive aspect (6.67 out of 10), indicating good conditions for entrepreneurship in the circular economy. “Social and Cultural Norms” (6.43 out of 10) reflect a high awareness of the circular economy in the region, which is important because entrepreneurial culture, involving favourable attitudes and norms towards entrepreneurship, plays a crucial role in shaping entrepreneurial ecosystems ([Brown and Mason, 2017](#)).

In contrast, “Education and Training” obtained the lowest score (4.88 out of 10), signalling inadequacy in the availability of education and training related to circular entrepreneurship. “Financial Support” is moderate (5.55 out of 10). The NECI, which evaluates the entrepreneurial ecosystem of the machine tool sector in the circular economy, indicates a slightly positive assessment (6.07 / 10), similar to the result of the GEM Basque Country 2021–2022 report ([Saiz-Santos et al., 2022](#)).

5.2.2 Policy implications. The findings suggest that government policies should focus on enhancing education and training in the circular economy, as it is an area identified as weak, to drive circularity in the industry ([Nielsen and Hakala, 2023](#)). Facilitating knowledge transfer towards digitalization is essential to strengthen these capabilities ([Hervas-Oliver, 2022](#)). It is crucial for the government to continue promoting collaboration among companies, research institutions and public agencies, aligning with the hypothesis that a collaborative ecosystem facilitates the promotion of circular entrepreneurship ([Dyba and Marchi, 2022](#)).

Furthermore, it has been demonstrated that appropriate policies can create a regulatory and incentive framework that fosters the development and growth of circular businesses, allowing companies to focus on their core activities and gain efficiency and specialization ([Levie and Autio, 2007](#)). In this regards, the Basque Government, through Ihobe, has implemented multiple strategies to align companies with the circular economy ([Ihobe, Sociedad Pública de Gestión Ambiental, 2022](#)), thus shaping an entrepreneurial environment where entrepreneurs act as agents of change ([Audretsch, 2023](#)).

This study has a significant impact for policymakers, as it guides their decision-making, indicating the way forward to foster industrial circular entrepreneurship in the Basque Country.

5.2.3 Practical recommendations. Education and training: Increase the provision of specific educational and training programmes. Research and Transfer Institutes should act as catalysts for knowledge transfer and the promotion of sustainable practices ([Hervas-Oliver, 2022](#)). Train trainers to strengthen the skills and capabilities of entrepreneurs in the circular economy ([Table 6](#)).

Government programmes: It is crucial for the Basque Government to enhance its intervention to create a favourable environment for circular business models ([Ács and Szerb, 2010](#)). Showcase successful references in the circular economy and raise awareness of the opportunities for circular models in the industry. Create incentives to facilitate company collaboration and innovation ([Mason and Brown, 2014](#)). Promote policies that support the internationalization of circular ventures ([Bettoli et al., 2022](#)) ([Table 6](#)).

Labour cost, access and regulation: Provide financial support for sustainable investments, improve credit conditions and interest rates for circular economy projects ([Homrich et al., 2017; Amorós et al., 2008](#)). Create specific funds for R&D of circular technologies ([Table 6](#)).

These recommendations contribute to the policy discussion, highlighting critical areas for the development of the circular economy and the establishment of a favourable environment for industrial circular entrepreneurship.

5.3 Economic and social importance

The machine tool industry is essential for the production processes of various manufacturing companies and plays a crucial role in the transition to a circular economy. Its high business

Table 6. Conditions identifying supports, limiting factors and recommendations for circular entrepreneurial activity in Basque Country industries

Condition	Support (%)	Limiting factors (%)	Recommendation (%)
Financial support for circular entrepreneurship	16.05	3.70	4.94
Government policies	14.81	4.94	11.11
Political, institutional, and social context	14.81	2.47	
Education and training	9.88	24.69	32.10
Commercial and professional infrastructure	8.64	12.35	9.88
Norms and social impact	8.64		3.70
Circular entrepreneurship capability	4.94	7.41	
Government programmes	3.70		17.28
Economic climate	3.70	1.23	
R&D transfer	2.47	2.47	2.47
Physical and services infrastructure	1.23		1.23
Market openness		4.94	1.23
Labour costs, access and regulation		24.69	
Different performance in circular and traditional companies		1.23	
Do not know, missing responses	11.11	9.88	17.28

Source: Authors' own elaboration

concentration and geographical proximity have fostered a collaborative and innovative industrial district ([Ortega, 2017](#)). This environment promotes industrial symbiosis, enabling companies to share resources, optimize material use and minimize waste generation, thus creating a network of synergies that strengthens the sustainability of the industrial ecosystem ([Martin and Harris, 2018](#)).

This approach not only fosters a culture of sustainable innovation but also enhances access to suppliers and markets, increasing regional competitiveness. Inter-company collaboration optimizes recycling and reuse processes for by-products, reducing costs and improving operational efficiency. To maximize these benefits, companies are advised to invest in advanced technologies that facilitate material recovery and explore strategic partnerships with technology start-ups that can provide innovative solutions in the field of the circular economy. At the socioeconomic level, the machine tool industry not only generates quality employment but also contributes significantly to local economic development and the well-being of communities.

5.4 Basque industrial context as an example of a solution

The adoption of the circular economy in the industry must be based on circular business models, sharing resources, optimizing material use and reducing waste generation, creating a network of synergies that maximizes energy efficiency and minimizes environmental impact while generating competitive advantages. Regulation and sociocultural changes facilitate this transition, although cultural and institutional obstacles persist that limit adoption ([Nielsen and Hakala, 2023](#); [Nunes et al., 2022](#); [Ortega, 2017](#)). The Basque Country can serve as a model for other regions with an industrial legacy by combining favourable public policies, innovation and education to transform polluting sectors into circular ones, balancing economic development with environmental and social protection. This study

provides a framework for integrating the circular economy and strengthening industrial entrepreneurial ecosystems.

6. Conclusions

This study proposes a methodology to evaluate industrial entrepreneurial ecosystems, aiming to facilitate the transition toward circularity in the industry. In this context, entrepreneurship is considered a key element for creating new business models (Pirson *et al.*, 2019). Furthermore, the data provided by GEM offers policymakers a solid basis for making informed decisions that promote both entrepreneurship and economic growth (Bosma, 2013). Recent studies emphasize that government policies are fundamental in promoting circularity in the industry (Nielsen and Hakala, 2023). Therefore, this analysis focuses on the entrepreneurial ecosystem of the machine tool sector in the Basque Country, to evaluate the effectiveness of these policies and recognize the challenges in establishing circularity in the industry.

Academically, the NES model for evaluating circular industrial entrepreneurial ecosystems is validated and extended, ensuring coherence and reliability. This model provides a robust theoretical framework, especially in the context of the Basque Country, where the industrial legacy and cultural identity favour the application of institutional and cultural approaches in analysing entrepreneurship and its impact on sustainable development (Alwakid *et al.*, 2021), supported by the TBL approach.

The findings of this study offer useful guidance for policymakers by identifying challenges in the circular entrepreneurial ecosystem of the machine tool sector in the Basque Country. These results support the literature that emphasizes the need for specific interventions, such as strengthening education and training, developing government programmes for successful entrepreneurial ecosystems, promoting public-private collaboration and improving access to financing (Aspen Network of Development, 2013; Hervas-Oliver, 2022; Spigel, 2017; Homrich *et al.*, 2017; Amorós *et al.*, 2008; Dyba and Marchi, 2022; Nielsen and Hakala, 2023). It is essential that policies prioritize improving education in the circular economy, a vulnerable area that limits circularity in the industry (Nielsen and Hakala, 2023), and that knowledge transfer towards digitalization enhances these capacities (Hervas-Oliver, 2022). In addition, the Basque Government should continue to foster collaboration among companies, research institutions and public bodies, following the hypothesis that a collaborative ecosystem favours circular entrepreneurship (Dyba and Marchi, 2022).

In the industrial realm, implementing circular economy practices in the machine tool sector of the Basque Country is essential to mitigate environmental impact and enhance competitiveness. The high concentration of companies in this region favours collaboration and innovation, key elements for a successful transition to a more sustainable economic model. The adaptation of this industry could result in the creation of high-quality jobs and an improvement in social well-being in the region (Mason and Brown, 2014).

From a social perspective, understanding the entrepreneurial environment is vital to promote entrepreneurship and economic growth (Coduras, 2022). The recommendations promote responsible labour practices and support community development, contributing to improved quality of life (Alpsahin Cullen, 2023).

The methodology used has demonstrated its validity in worldwide research, supported by examples such as the studies by Alvarez *et al.* (2011), Campos *et al.* (2019), Coduras Martínez *et al.* (2010), Herrington and Coduras (2019), Hawi *et al.* (2022), Hechavarria and Ingram (2019), Pfeifer *et al.* (2021), Villegas Mateos and Amorós (2019), as well as Villegas-Mateos (2021 and, 2022). However, its main limitation lies in its exclusive

dependence on the NES model. In future research, it would be pertinent to consider a mixed methods approach that includes a case study on machine tools in the Basque Country, which could contribute to a deeper understanding of current findings. Although this study focuses on a specific regional context, it is important to note that its results may not be fully generalizable to other areas with different institutional and cultural characteristics.

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