SCIENTIFIC CULTURE

www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 11, No. 3.1, (2025), pp. 954-968
Open Access. Online & Print

DOI: 10.5281/zenodo.11032566

ITS AND DUI MODES OF INNOVATION: PROGRESS, REGIONAL APPLICATIONS AND CHALLENGES FOR THEIR INTEGRATION IN DIVERSE CONTEXTS

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Received: 29/07/2025
Accepted: 03/08/2025

ABSTRACT

Innovation does not respond to a single universal model, but takes diverse forms depending on the technological, institutional and cognitive conditions of each context. This review examines the complementarity between ITS (science, technology and R&D-based) and DUI (doing, using and interacting) modes of innovation, highlighting how their effectiveness varies between industrialised countries and developing regions. Through a bibliometric analysis, a growing academic interest in hybrid approaches was identified, with established networks of authors such as Alhusen, Bennat and Cantner, and the emergence of thematic clusters related to absorptive capacities, regional innovation systems and small and medium-sized enterprises. The findings show that combined STI+DUI strategies offer greater benefits in mixed institutional contexts, and underline the need to advance indicators that make tacit learning and collaborative interactions visible. It is concluded that the articulation of both modes, supported by territorially sensitive public policies, is key to promote more inclusive, sustainable innovation adapted to current challenges.

KEYWORDS: STI Mode Of Innovation; DUI Mode Of Innovation; Hybrid Innovation Strategies; Absorptive Capacity; Regional Innovation Systems; Innovation Policy; Smes.

1. INTRODUCTION

In recent decades, innovation studies have moved from linear models to more complex approaches, where the interaction between actors and the diversity of knowledge sources acquire a central role (Julia et al., 2024). In this context, the STI (Science, Technology and Innovation) and DUI (Doing, Using and Interacting) modes of innovation, developed by (Jensen et al., 2007a), have established themselves as key analytical frameworks for understanding the diversity of innovation trajectories in different regions and sectors.

While the STI mode is based on formal scientific and technological R&D production, publications and patents (Leandro et al., 2017), the DUI mode is based on practical and tacit knowledge generated by experience, organisational learning and informal interaction between actors (Alzate & Mejía, 2014). This distinction is crucial in countries or sectors where access to scientific infrastructure is limited, but rich empirical learning dynamics exist.

Despite growing interest, important gaps persist in the literature: little systematic comparison between the two modes, limited evidence on their application in developing countries, and insufficient articulation between absorptive capacities, type of sector and effectiveness of each mode. These gaps justify the need for an integrative review to identify common patterns, contextual conditions and strategies for combining these approaches.

Aim of the article: This article systematically reviews the recent empirical literature on ITS and DUI modes of innovation, with an emphasis on their application in European regions, developing countries and manufacturing and IT sectors, assessing their effectiveness, complementarity and implications for public policy and business strategies.

2. METHODOLOGY OF THE REVIEW

This article adopts an integrative review approach with a systematic, narrative character and complemented with bibliometric analysis tools. It sought to synthesise conceptual and empirical knowledge on STI (Science, Technology and Innovation) and DUI (Doing, Using and Interacting) modes of innovation, prioritising their application in different regional and sectoral contexts. The methodology was developed in five phases.

Firstly, the general objective of the review was to identify, classify and analyse the main advances, applications and challenges associated with STI and DUI modes of innovation in different productive sectors and regions of the world. Given the multidimensional nature of the phenomenon, an integrative review was chosen to include different methodologies, approaches and documentary sources (ArenasArenas-Peñaloza et al., 2024). A narrative thematic analysis was also employed, which facilitates the grouping and critical discussion of empirical findings. In addition, an exploratory bibliometric analysis was incorporated in order to identify publication patterns, temporal evolution, most influential authors and scientific collaboration networks related to modes of innovation.

In the second phase, inclusion and exclusion criteria were established to ensure the quality and relevance of the selected literature. Studies published between 2007 and 2025 that explicitly addressed ITS, DUI or their combination, either from a theoretical or applied approach, were included. Priority was given to articles analysing sectors such as manufacturing, knowledge-intensive services or software technology development, as well as regional case studies in Europe, Latin America, Asia and Africa ((Higuera Ojito et al., 2019). Relevant institutional documents from organisations such as the OECD, ECLAC and UNESCO were also included. Papers that did not directly address modes of innovation, that were limited to national approaches without sectoral analysis, or that lacked empirical support were excluded.

The literature search was carried out in various internationally recognised scientific and academic databases such as Scopus, Web of Science, SSRN, IEEE Xplore and Taylor & Francis, as well as institutional documents available online. Keyword combinations such as "STI innovation mode", "DUI innovation", "innovation systems", "absorptive capacity", "regional innovation", and "interactive learning" were used. This strategy allowed us to identify a representative and diverse set of relevant studies, suitable for both qualitative analysis and bibliometric trend analysis.

In total, 37 articles were selected for analysis. From these, 35 key studies were chosen for in-depth review based on their conceptual relevance, methodological quality and contribution to the understanding of ITS and DUI modes in specific contexts. The documents were organised in an analysis matrix that facilitated their classification according to the type of innovation addressed,

geographical region, productive sector, variables analysed (such as productivity, absorptive capacities, knowledge networks) and type of interaction between agents of the innovation system.

Based on this organisation, a thematic analysis was carried out that made it possible to identify four main axes of discussion: (1) theoretical foundations and conceptual evolution of the modes of innovation; (2) regional and sectoral configurations in the application of STI and DUI; (3) links between absorptive capacities, knowledge and modes of innovation; and (4) comparison of the relative effectiveness of STI and DUI according to different contexts. This categorisation allowed synthesising the main findings in a structured way, highlighting both regularities and contextual differences, and facilitated the subsequent critical discussion and elaboration of recommendations.

3. RESULTS: STATE OF THE ART, BIBLIOMETRIC ANALYSIS AND THEMATIC ANALYSIS

3.1. General Bibliometric Analysis

Before addressing the thematic and conceptual analysis of ITS and DUI modes of innovation, a preliminary bibliometric analysis was conducted in order to characterise the selected corpus of documents. This review comprised a total of 35 scientific articles obtained mainly from academic databases such as Scopus and Web of Science, prioritising publications indexed between 1990 and 2025. The analysis made it possible to identify the evolution of academic interest in innovation modes, observing a progressive increase in recent years. Figure 1 shows the scientific production of the articles reviewed, which shows a higher concentration of publications between 2021 and 2024, reflecting the growing relevance of the ITS-DUI approach in the current scientific debate.

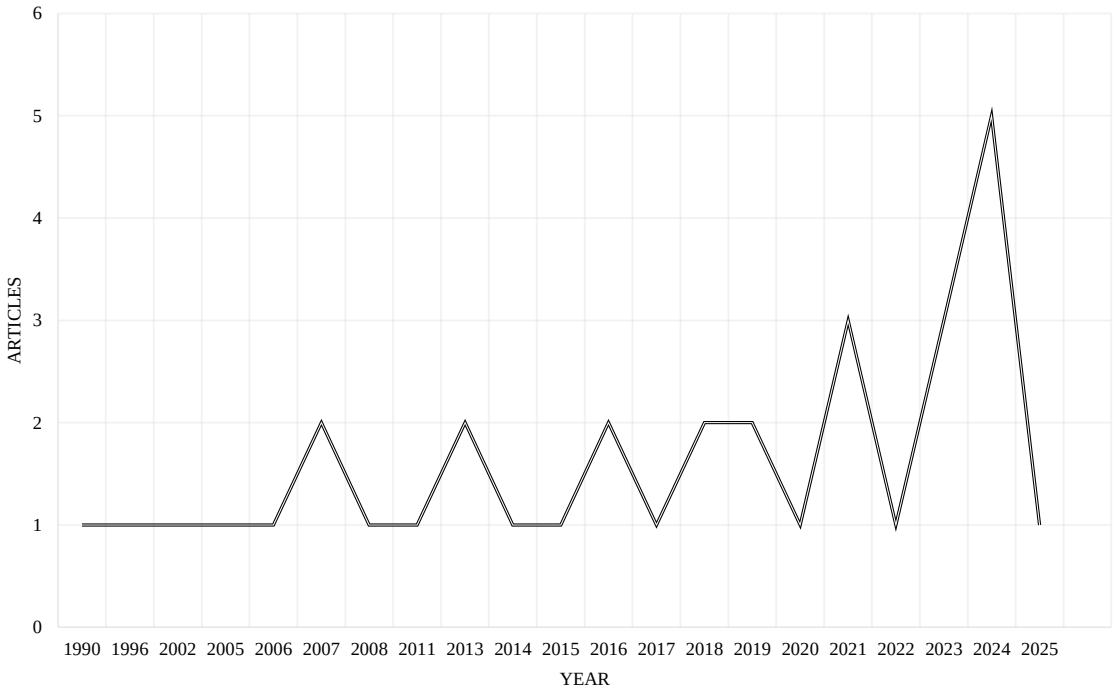

Figure 1: Scientific Production of Articles (1990-2025).

As part of the bibliometric analysis, Figure 2 identifies the main authors of the 35 papers selected in the review. This information allows us to recognise which researchers have had the greatest presence in the literature on ITS and DUI modes of innovation, as well as their most frequent contributions to the field.

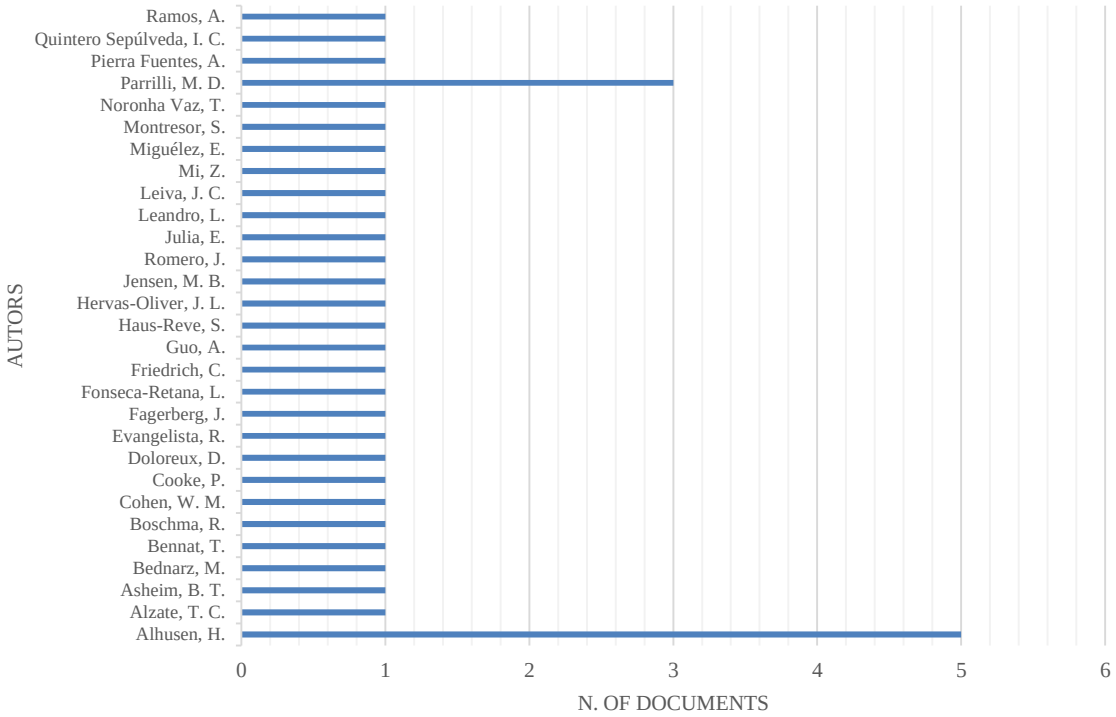

Figure 2: Most Relevant Authors.

As can be seen in Figure 2, the author Alhusen, H. stands out for his leadership in five publications, followed by Parrilli, M. D. with three papers as lead author. This concentration suggests a strong thematic specialisation on the part of some researchers, who have been key in the theoretical and empirical development of these modes of innovation.

Next, Figure 3 identifies the most relevant countries of the selected papers. This information makes it possible to observe the geographical distribution of scientific knowledge related to ITS and DUI modes of innovation, as well as to recognise the regional contexts in which these studies have been developed.

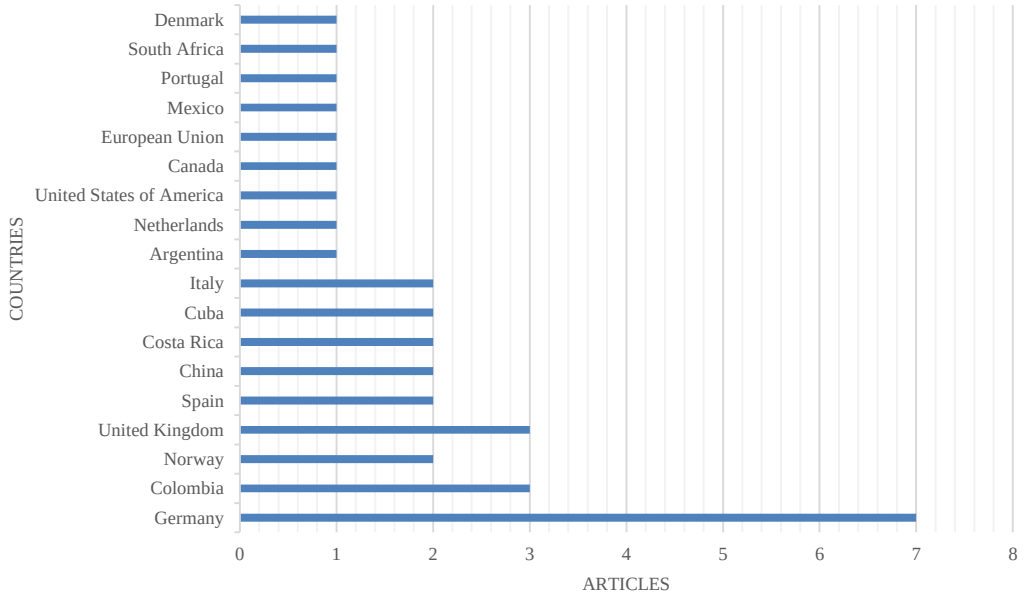

Figure 3: Most Relevant Countries.

Germany leads the scientific production in this field, followed by countries such as Colombia, the United Kingdom, and Norway. This geographical diversity is evidence of a global academic interest, with a significant presence of both developed economies and Latin American countries, which contributes to a broader and more contextualised view of innovation modes.

Visualising the collaboration networks between authors reveals two main clusters reflecting distinct lines of research. The green cluster is composed of authors such as *Harm Alhusen* and *Tatjana Bennat*, whose frequent collaborations indicate a focus on the integration of ITS and DUI modes of innovation in SMEs, together with other authors such as *Till Proeger*. In contrast, the red cluster groups researchers such as *Uwe Cantner*, *Rolf Sternberg*, *Martin Kalthaus*, *Elaine Horstmann* and *Kilian Bizer*, who form a dense and consolidated network focusing on regional innovation policies, absorptive capacities and evaluation of innovative processes. This segmentation reflects how the scientific communities have developed differentiated but complementary trajectories within the study of innovation modes (Figure 4).

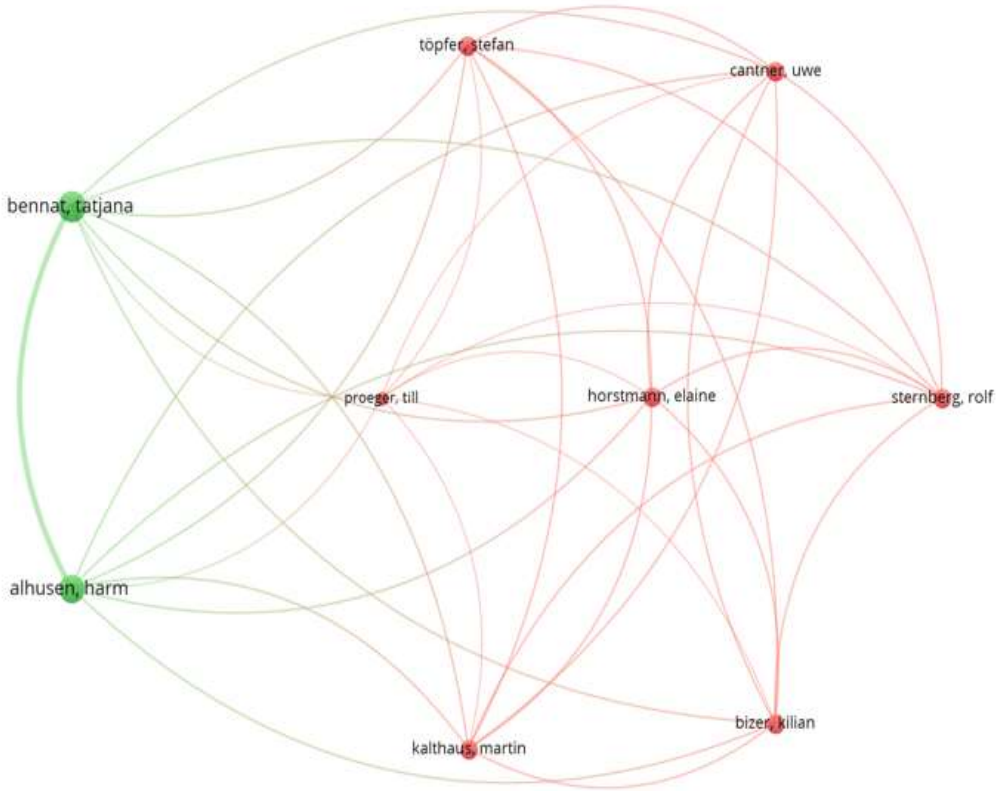

Figure 4: Clusters.

In relation to the terms used in the studies, Figure 5 presents the collaborative networks between keywords used in the articles analysed, grouped into different thematic clusters. The central node "innovation" stands out, acting as a connection point between terms associated with both theoretical and applied approaches. In the green cluster, there is a strong association between the concepts DUI, STI, and experience-based knowledge, which is evidence of a focus on modes of innovation linked to learning-by-doing. The yellow cluster revolves around terms such as innovation modes, R&D cooperation and knowledge bases, related to cooperation dynamics and technological capabilities. The blue cluster highlights the interest in modes of innovation in catching-up countries, while the red cluster focuses on SMEs and developing countries, reflecting a more applied approach in emerging contexts. This network allows identifying the main thematic axes that structure the field of study.

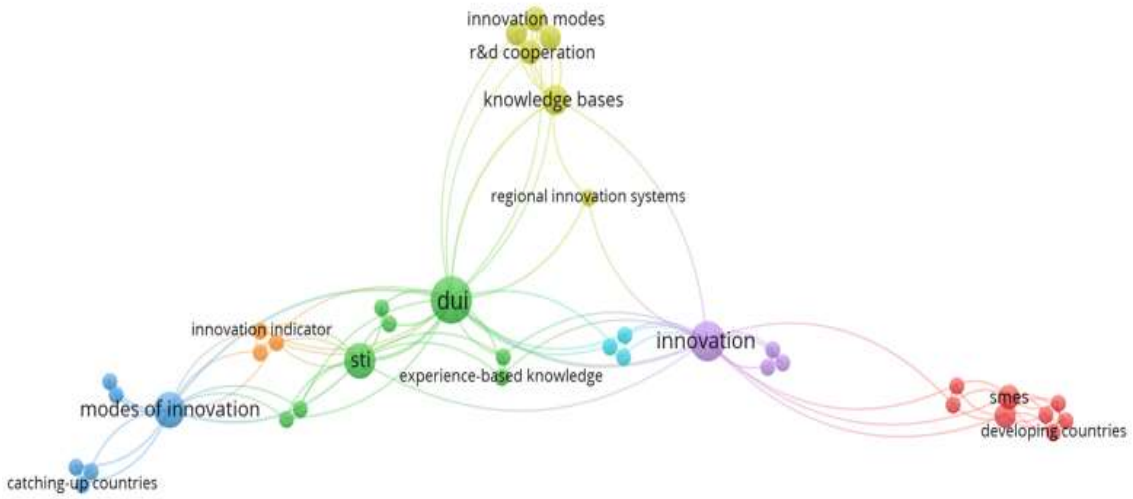

Figure 5: Keyword Collaboration Networks.

Based on the reviewed papers, key trends and common patterns were also identified to understand the evolution, application and outcomes of STI (Science, Technology and Innovation) and DUI (Doing, Using and Interacting) modes of innovation in various regional, sectoral and institutional contexts. The selected studies were grouped according to emerging categories that reflect both the conceptual foundations and the conditions that determine their effectiveness. This organisation allows visualising complementarities, tensions and adaptations of the ITS-ISD approach, considering factors such as the type of knowledge involved, absorptive capacities, the industrial sector and regional innovation policy.

3.2. Conceptual Foundations: Absorptive Capacities, Innovation Systems and Its/Idu Modes

The study of innovation modes requires an integrated theoretical understanding of the processes by which organisations and territories generate, adapt and apply knowledge. Three conceptual approaches provide the basis for this analysis: the theory of absorptive capacities, the classification of ITS and DUI modes of innovation, and the regional innovation systems approach.

First, the concept of absorptive capacity was introduced by (Cohen & Levinthal, 1990) to describe the ability of an organisation to identify, assimilate and exploit external knowledge for commercial purposes. This capability does not depend solely on R&D investment, but also on prior experience, organisational routines and willingness to learn. Subsequently, (Zahra & George, 2002) distinguished between potential absorptive capabilities (acquisition and assimilation) and realised absorptive capabilities (transformation and exploitation), extending their applicability in studies on technological innovation.

On the other hand, (Jensen et al., 2007a) propose a typology of innovation modes centred on two archetypes: the STI (Science, Technology and Innovation) mode, based on codified and formal knowledge (scientific publications, patents, R&D laboratories), and the DUI (Doing, Using and Interacting) mode, which emerges from practical learning, organisational experience and collaboration among actors. (Asheim et al., 2011) stress that these modes are not mutually exclusive, but can be combined depending on contextual factors, such as the economic sector, the level of regional development or institutional capacities.

Finally, from the regional innovation systems approach (Cooke, 1996); (Doloreux & Parto, 2005), it is argued that innovation is a socially embedded process, conditioned by the interaction between companies, universities, technology centres and local governments. In this framework, Key Enabling Technologies (KETs) -such as nanotechnology, robotics or biotechnology- acquire a strategic role, as they can enhance both STI and DUI processes, depending on the absorption capacities of the territory and the degree of institutional articulation.

These three conceptual frameworks allow an articulated approach to the comparative analysis of innovation modes, considering not only observable results, but also the cognitive, organisational and territorial dynamics that sustain them. On this theoretical basis, this article explores how ITS and DUI modes manifest and integrate in different

regions and sectors, and what conditions are necessary for their effective hybridisation.

3.2.1. Theoretical Foundations and Conceptual Evolution of It's And Dui

The evolution of innovation approaches reflects a substantial change in the way knowledge generation is understood and managed. From linear, science-centred models to more integrative approaches that value tacit knowledge, collaborative networks and adaptive policies, this shift has had a profound impact on both public policy and organisational strategies. Figure 1 illustrates the evolution of innovation approaches from the linear model to hybrid approaches, highlighting the progressive incorporation of interactive and collaborative mechanisms.

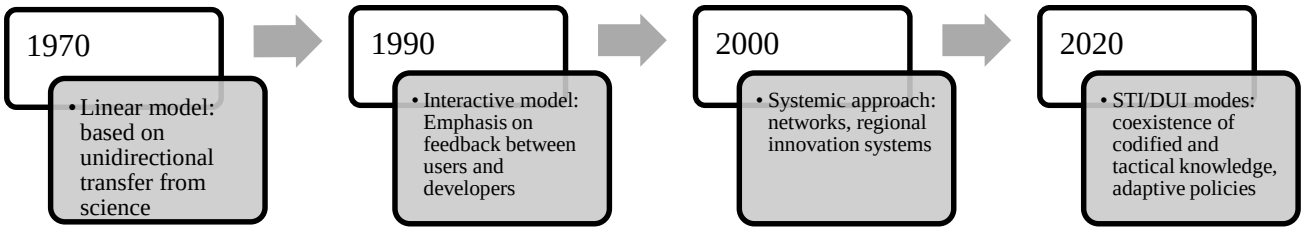

Figure 6: Chronology of the Evolution of the Innovation Approach.
Source: Authors Based On (Fonseca-Retana Et Al., 2016).

As can be seen, the linear model of the 1970s, focused on unidirectional transfer from science to the market, has been progressively replaced by interactive, systemic and finally hybrid approaches. This evolution culminates in the recognition of the coexistence of ITS and DUI modes, which integrate codified and tacit knowledge in diverse institutional contexts. This broadened perspective is fundamental to understanding the complexity of innovative processes today.

Furthermore, the distinction between STI (Science-Technology-Innovation) and DUI (Doing-Using-Interacting) modes of innovation is based on different learning paradigms. STI privileges codified knowledge, R&D and scientific links, while DUI is built on tacit knowledge, experience and practical interaction.

The study by (Alhusen et al., 2021) shows that innovative SMEs rely more on DUI than ITS, implying a redefinition of traditional innovation. This position is joined by other research that agrees that the most effective innovation is not only derived from formal science, but also from everyday practice, as pointed out by (Haus-Reve et al., 2023); (Bennat, 2022); and (Parrilli & Radicic, 2021). The study by (Pierra Fuentes et al., 2024) reinforces this view with the case of Cuba, where innovation emerges from collaborative ecosystems rather than formal scientific results.

The complementarity between the two modes has also become central. Research such as (Alhusen et al., 2019); (Bennat, 2022) presents theoretical and empirical arguments on how combining both approaches enhances outcomes. Also, (Alhusen & Bennat, 2019); (Guo et al., 2008) develop more detailed models on this integration, which is understood as an adaptive continuum rather than as mutually exclusive categories.

Table 1: Comparison between IT'S And DUI Innovation Modes

Category	ITS mode	DUI mode
Main source of knowledge	Formal science, R&D, universities	Practical experience, learning on the job
Type of knowledge	Codified	Tacit
Key actors	Research centres, scientists, universities	Users, technicians, workers, clients
Common indicators	Patents, scientific publications, R&D expenditure	Informal feedback, practical improvements, collaborative networks
Expected results	Disruptive innovations, new technologies	Incremental innovations adapted to the context
Advantages	Promotes scientific breakthroughs, basis for radical innovation	Increased inclusiveness, adaptable to limited resources
Limitations	Requires high investment, difficult to access in developing countries	Difficult to measure, may limit radical technological breakthroughs

Source: Authors Based On (Jensen Et Al., 2007b).

Table 1 summarises the key differences between the ITS and DUI modes in terms of knowledge origin, actors, results and limitations, providing a useful comparative basis for sectoral and regional analyses. While the ITS mode relies on formal scientific knowledge and R&D

activities, the DUI mode relies on learning-by-doing, accumulated experience and interaction between actors. These differences are reflected both in the predominant types of knowledge (codified in ITS and tacit in DUI) and in the actors involved: universities and research centres in the first case, and workers, users and customers in the second.

Likewise, the innovation indicators vary: the ITS favours metrics such as patents or publications, while the DUI is reflected in practical improvements or informal collaboration. In terms of results, ITS tends to generate disruptive innovations, and DUI favours incremental adaptations useful in local contexts. Each approach has advantages and limitations, which underlines the importance of their complementarity, especially in resource-constrained regions or sectors.

3.3. Sectoral and Regional Configurations

Modes of innovation do not operate homogeneously: they are strongly conditioned by the territorial and sectoral context.

In Europe, (Wessendorf et al., 2024) analyse the role of KETs (Key Enabling Technologies) in 141 German regions, revealing differentiated, even negative, impacts depending on the type of technology. (Boschma et al., 2023) introduce the concept of relatedness, showing that major inventions are mostly built on technologies already existing in the region.

In Africa, (Parrilli et al., 2024) reveals that SMEs link more effectively to the DUI mode than to the ITS, although they achieve remarkable improvements in process innovation when they integrate the ITS. This phenomenon is related to the structural conditions of low human capital and limited technological absorption.

In Cuba, (Pierra Fuentes et al., 2024) highlight the success of open source ecosystems at the University of Computer Science, where the combination of communities of practice, agile methodologies and informal linkages defines a robust SID system.

In China, (Guo et al., 2008) present the case of CIMC as an exemplary experience of continuous innovation through the dynamic combination of DUI and ITS throughout different phases of development. On the other hand, the study by (Hervas-Oliver et al., 2021) reveals that DUI industries in China have expanded territorially more than ITS, which remain concentrated in highly developed regions.

The analysis of the collected studies reveals how the adoption and effectiveness of ITS and DUI modes of innovation vary significantly by region. This diversity is determined by structural, institutional and cultural factors that influence absorptive capacities and the way knowledge is managed. Table 2 summarises different empirical cases that exemplify the predominant modes of innovation in each geographical context, highlighting the main results observed and their corresponding sources.

Table 2: Cases by Region, Dominant Mode and Highlighted Results.

Region	Dominant mode	Observed results	Main source
Europe (Germany)	ITS	KETs-based innovation, differentiated impacts	(Wessendorf et al., 2024)
Africa	DUI	Process innovation, limited technology absorption	(Parrilli et al., 2024)
Cuba	DUI	Collaborative open source ecosystems	(Pierra Fuentes et al., 2024)
China	Combined ITS-DUI	Territorial expansion and continuous innovation	(Guo et al., 2008)
Eastern Europe	DUI	Effectiveness in process innovation	(Hervas-Oliver et al., 2021)
Latin America (generic)	DUI	Incremental innovation, low science-industry articulation	(Quintero Sepúlveda et al., 2021)
Mexico	DUI + incipient STI	National standard for knowledge management; model validated in the public sector	(Romero, 2020)
Colombia	DUI/STI mixed	Emerging ranking in investment and infrastructure for AI in the region	(Ramos & Montoya, 2024) (Villa-Enciso et al., 2023)

As can be seen in the table above, industrialised countries tend to base their innovative processes in the ITS mode, with an emphasis on key enabling technologies (KETs) and a strong institutional presence. In contrast, in regions such as Africa, Latin America or the Caribbean, the DUI mode predominates, where innovations emerge from the practical and collaborative use of knowledge, especially in the absence of robust scientific systems. However, some cases, such as China, demonstrate the effectiveness of a hybrid

strategy that combines both modes to drive innovation in a sustainable and scalable way. Nevertheless, some cases, such as China and, to a lesser extent, Mexico and Colombia, demonstrate that a hybrid strategy that integrates elements of the ITS and the DUI can be effective in promoting more inclusive and sustainable innovation processes, adapted to local productive trajectories and capacities.

3.4. Relationship between Absorptive Capacities, Knowledge and Modes of Innovation

The development of disruptive innovations is often influenced by the degree of affinity between new technological knowledge and existing capabilities in a region or organisation. This affinity, known as relatedness, refers to the cognitive closeness between an emerging technology and previously accumulated knowledge. When this connection is strong, it facilitates the integration of new ideas, which in turn improves technological absorptive capacity and accelerates the creation of patents and inventions (Bednarz & Broekel, 2019). The concept of unrelatedness refers to the combination of knowledge that is cognitively very different from the existing knowledge base in a region. Although this type of variety does not usually lead to frequent or continuous innovation, it is associated with radical technological transformations, as it allows for the integration of very different types of knowledge (Miguélez & Moreno, n.d.).

At the level of small enterprises, it has also been shown that the relationship between prior knowledge and new technological knowledge influences the capacity to innovate. According to (Leiva & Brenes-Sanchez, 2018), when this connection is balanced, neither too close nor too distant, it favours better innovative performance. Too close can limit learning, while too much distance can hinder the understanding and implementation of new ideas, so the balance between both extremes is key.

In regional innovation systems (RIS), cross-cutting enabling technologies or KETs such as biotechnology, nanotechnology and advanced robotics play an important role in driving technological diversification. These technologies fuel smart strategies by expanding the capacity of regions to develop novel technological advantages and accelerate productive renewal (Evangelista et al., 2018). Moreover, regions with less innovative trajectories may find in KETs a privileged path to regional growth, as these technologies help to generate moderate economic improvements and strengthen sectoral integration (European Parliamentary, 2021).

KETs not only facilitate innovations related to the existing base, but also reduce cognitive dependence on previous technologies, which favours exploratory processes and disruptive breakthroughs. This makes them key vectors for NIS, capable of supporting both incremental improvements and radical leaps in innovation (Montresor & Quatraro, 2015).

A thorough understanding of the STI (Science, Technology and Innovation) and DUI (Doing, Using and Interacting) modes of innovation requires an analysis not only of their outcomes, but also of the epistemological foundations that underpin them. A key category for understanding how they work is the nature of knowledge: on the one hand, codified knowledge, characteristic of the STI mode, is formalised through scientific publications, patents and systematised technological developments. On the other hand, tacit knowledge, central to the DUI mode, is learned in practice, difficult to transfer, and is transmitted through experience and interaction between actors. These two types of knowledge require different absorptive capacities on the part of organisations, understood as the ability to identify, assimilate and apply external knowledge. In contexts where codified knowledge predominates, such as in more formal innovation systems, greater investment in R&D and a strong institutional infrastructure are demanded. In contrast, environments where tacit knowledge predominates prioritise collaborative networks, organisational skills and situated learning. Figure 2 graphically depicts these relationships, articulating the link between types of knowledge, absorptive capacities and STI and DUI modes of innovation.

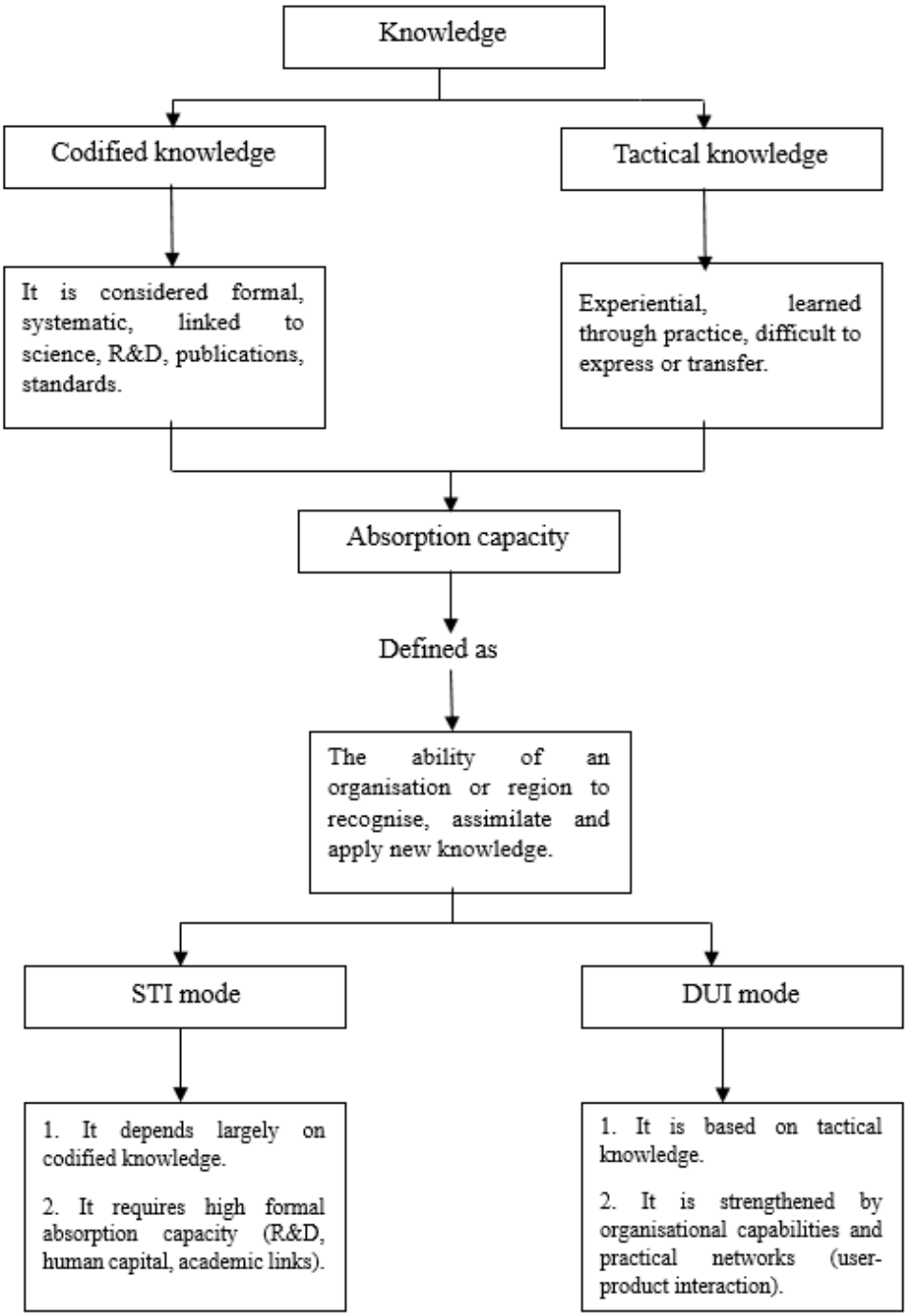

Figure 7: Conceptual Map of Relationships between Tacit Knowledge, Absorptive Capacities and STI/DUI Modes.

Source: Authors Based On (Alhusen & Bennat, N.D.).

As shown in Figure 2, the ITS mode is based on codified, systematised and scientifically validated knowledge, which implies higher demands in terms of formal absorption. In contrast, the DUI mode relies on tacit knowledge, emerging from practice and reinforced by organisational networks and collaborative learning. This differentiation helps to understand why different sectors and regions adopt different innovation strategies according to their capabilities, available resources and institutional structures.

3.5. Comparison of Effectiveness: Its Vs.

Studies show clear differences in the effectiveness of each mode of innovation according to the economic and technological context.

As mentioned (Parrilli et al., 2024) in Africa, DUI has a moderate effect on innovation, while ITS - although less common - achieves significant impacts on process innovation. This suggests that ITS may be more effective in environments where technology support policies are adequately implemented.

(Hervas-Oliver et al., 2021) find that in converging European countries (Eastern and Southern Europe), SID is more effective for process innovations, while ITS is not as effective as in advanced economies.

On the other hand, (Friedrich & Kagel, 2024); (Santos et al., 2022) reinforce the need to customise innovation policies according to the type of economy. The study by (Mi et al., 2025), with its analysis of Chinese industries, supports this conclusion by showing that DUI industries have been more effective for regional expansion.

Finally, (Parrilli & Radicic, 2021) and (Bennat, 2022) show that, in contexts of high economic liberalisation (such as the UK), the DUI mode is directly associated with superior innovation performance, which reinforces its validity in market-oriented economies.

4. DISCUSSION

4.1. Critical Reflection on the Findings

The results reviewed allow us to affirm that the duality between ITS and DUI modes should no longer be understood as a rigid dichotomy, but as a dynamic and contextual combination. This complementarity has been extensively documented in different studies ((Alhusen et al., 2021); (Alhusen & Bennat, 2019); (Alhusen & Bennat, 2020)), showing that the most innovative companies do not limit themselves to one mode, but integrate both depending on their background, environment and internal capabilities.

Furthermore, research confirms that the DUI mode is dominant in traditional sectors, low-tech industries and regions with limited infrastructure, as evidenced by studies in Africa (Parrilli et al., 2024), Cuba (Parrilli & Radicic, 2013), Eastern Europe with the research of (Hervas-Oliver et al., 2021), and in Chinese DUI industries with the study of (Mi et al., 2025). However, this domain does not imply less sophistication: DUI can generate incremental innovation with high territorial and economic impact.

In contrast, the ITS mode, more common in developed regions and scientific sectors, shows more consistent results in contexts with higher R&D investment, as observed in Germany (Wessendorf et al., 2024) and regions with high-tech industries (Mi et al., 2025). However, it also has limitations when there is no local capacity to absorb this knowledge, as reflected in the poor performance of ITS in developing countries ((Parrilli et al., 2024); (Hervas-Oliver et al., 2021)).

4.2. Contrasts and Tensions between It's And Dui Modes

While ITS and DUI modes have been presented as complementary approaches, their practical implementation reveals structural tensions that limit their integration. On the one hand, the ITS mode often fails in contexts where adequate absorptive capacities do not exist, i.e. when organisations do not have the necessary background knowledge, cognitive skills or organisational structures to incorporate codified external knowledge (Cohen & Levinthal, 1990). This is especially problematic in regions with weak scientific infrastructure or nascent innovation systems, where R&D investments do not automatically translate into tangible results.

On the other hand, the DUI mode, although effective in traditional sectors and low-tech environments, faces limits in its scalability and ability to generate radical innovation. Over-reliance on tacit knowledge can hinder the systematisation of learning and the diffusion of innovations beyond the local environment (Noronha Vaz & Asheim, 2013). This tension is exacerbated when public policies are designed under linear assumptions of innovation, which prioritise formal investment in science and technology without recognising the value of collaborative networks and situated learning (Parrilli & Radicic, 2013).

Moreover, there are policy dilemmas when attempts are made to combine the two modes without addressing the enabling conditions. As pointed out by (Alhusen & Bennat, 2019), imposing ITS structures in environments dominated by SID practices may generate institutional frictions, generate duplication of efforts or even displace pre-existing innovation mechanisms. Similarly, designing mixed policies without a clear understanding of sectoral or regional trajectories may result in ineffective or contradictory strategies (Fagerberg, 2006).

While some cases, such as China or Germany, demonstrate that hybridisation of both modes is possible and desirable, these examples also confirm

that such integration requires specific conditions: network density, institutional co-evolution and accumulated cognitive capacities. Therefore, rather than promoting hybridisation as a universal solution, it is necessary to understand the contexts in which each mode may fail, reinforcing the need for flexible and adaptive policies.

4.3. Conditions for Effective Its-Isd Combination

The studies analysed indicate that effective combination between ITS and DUI depends on three key conditions:

- Absorptive capacities: Firms need not only technical infrastructure, but also organisational and cognitive skills to translate scientific knowledge into practical improvements ((Alhusen & Bennat, 2019), (Alhusen & Bennat, 2020)).
- Territorial innovation networks: Links with universities, technology centres and regional consultancies facilitate knowledge transfer and adaptation ((Bennat, 2022); Article 15(Alhusen & Bennat, 2019)).
- Evolutionary trajectory and entrepreneurial phase: The experience of CIMC (Guo et al., 2008) and Cuban ecosystems (Pierra Fuentes et al., 2024) shows that companies adopt different modes according to their stage of maturity and strategic orientation.

4.4. Gaps in The Measurement Of The Dui Mode

A critical issue identified in several studies ((Pierra Fuentes et al., 2024); (Friedrich & Kagel, 2024); (Weidner et al., 2023)) is that traditional innovation indicators (publications, patents, R&D expenditure) do not adequately capture the contributions of the DUI mode. This leads to an underestimation of the real innovation capabilities of less formal science-intensive sectors.

Alternative indicator frameworks have therefore been proposed to measure DUI innovation, including:

- Levels of user-producer interaction.
- Degree of organisational learning.
- Participation in collaborative networks.
- Non-patentable commercial outcomes.

However, methodological standardisation is still required in order to be able to rigorously compare across lines and sectors.

4.5. Transferable Lessons and Recommendations

The findings allow deriving important implications for public policy, especially in developing economies or in processes of technological convergence:

Mixed policy design: It is not enough to foster R&D; there is a need to promote ecosystems where interaction, learning-by-doing and collaboration between actors play a central role ((Haus-Reve et al., 2023); (Santos et al., 2022); 18(Alhusen & Bennat, 2020)).

Non-financial support to SMEs: Advisory services, training and network facilitation have a greater impact on ITS and SID integration than isolated grants ((Alhusen & Bennat, 2019); (Alhusen & Bennat, 2020)).

Adaptation to local contexts: Innovation policies must be adapted to the degree of maturity of the productive system. For example, in Africa or Cuba, policies aimed at strengthening DUI networks are more effective (Article 11(Pierra Fuentes et al., 2024); (Parrilli et al., 2024)), while in Western Europe the emphasis may be on smart specialisation and ITS-DUI integration ((Wessendorf et al., 2024); (Boschma et al., 2023)).

5. CONCLUSIONS AND RECOMMENDATIONS

This study offers a significant contribution to both the theoretical and policy-making domains of innovation. Conceptually, it is argued that ITS and DUI modes are not mutually exclusive approaches, but represent complementary forms of knowledge generation and application, the combination of which depends on structural, cognitive and institutional variables. In particular, the role of absorptive capacities is highlighted as a critical bridge for integrating the two modes, which enriches the analytical framework of innovation systems.

At the practical policy level, the findings allow outlining concrete recommendations for the design of context-sensitive public policies. Evidence suggests that in regions with limited infrastructure or low R&D investment, strengthening collaborative networks, situated learning and valuing tacit knowledge are more effective strategies than simply replicating formal science-centred models. Conversely, in more technologically sophisticated environments, the strategic combination of both modes can enhance more robust and sustainable innovation processes.

Finally, this article highlights the urgency of advancing towards alternative indicators that make the contributions of the DUI mode visible, as well as the need to adapt innovation policies to specific regional trajectories. This perspective contributes to the construction of more inclusive, resilient and adaptive innovative environments, capable of responding to contemporary economic and social

challenges.

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