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Comparative analysis of national innovation systems: Implications for SMEs' adoption of fourth industrial revolution technologies in developing and developed countries

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Abstract

PURPOSE: *This study aims to identify the differences and similarities in the innovation systems of developing vs. developed countries that influence SMEs' adoption of Fourth Industrial Revolution (4IR) technologies. There is a notable absence of comparative research between National Innovation Systems (NIS) of developing and developed countries. Additionally, the current scholarly conversation lacks a holistic view of NIS. Our study aims to fill these gaps by employing Lundvall's framework to explore both developed and developing countries' systems comprehensively.* ***METHODOLOGY:*** *The data was collected through a Systematic Literature Review, identifying a total of 695 publications from SCOPUS, Web of Science (WoS), and ProQuest. The PRISMA process was adhered to, resulting in 32 papers undergoing quality evaluation using Gough's 'weight of evidence' guidelines. Twenty-nine primary papers were selected, comprising twelve from developed countries, another twelve from developing countries, and the remainder from both categories. Using Qualitative Meta-synthesis (QMS) with ATLAS.ti, a systematic alignment of codes with research inquiries pertaining to NIS ensued, revealing a multifaceted spectrum of findings across these scholarly investigations.* ***FINDINGS:*** *We found that there are similarities and differences between the innovation systems of developed and developing nations. The similarities include the intra-firm interactions taking place between managers and workers, inter-firm relations between the SMEs and Academia and other SMEs, as well as the role of the government in providing funding and regulation (albeit at significantly varying degrees). The most significant differences observed were in the funding mechanisms, the role of the government, and the R&D systems. It was found that governments in developed countries provided SMEs with substantial incentives, tax credits, and subsidies to adopt 4IR technologies, which appears to positively impact the adoption rate. We conclude by developing a conceptual framework for the NIS necessary for the adoption of SMEs' 4IR technologies in developing countries.* ***IMPLICATIONS:*** *This study contributes to the literature on innovation systems by examining the NIS of both developed and developing countries. This analysis allows us to gain deeper insights into how specific aspects of each country (developed or developing) affect (positively or negatively) SMEs' adoption of 4IR technologies. Practically, it informs governments in developing countries on which aspects to focus on in their NIS to increase the rate of the adoption of 4IR technologies by SMEs.* ***ORIGINALITY AND VALUE****: A distinctive aspect of this study lies in the creation of a comprehensive conceptual model delineating the essential components of the innovation system pivotal for the successful integration of 4IR technologies within SMEs. This model is designed to serve as a practical tool for governments in developing countries, providing a structured framework to facilitate and enhance the strategic development of their innovation landscapes.*

Keywords: *national innovation systems, fourth industrial revolution technologies, SME, adoption, developed countries, developing countries, comparative analysis, government policies, Lundvall's framework, qualitative meta-synthesis*

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INTRODUCTION

Developing countries are faced with a myriad of challenges ranging from access to housing, water, energy and the internet, as well as poverty, inequality and unemployment. These form part of the United Nations' Sustainable Development Goals, and the World Economic Forum (2020) recommends using Fourth Industrial Revolution (4IR) technologies as tools to overcome these challenges. Small and Medium Enterprises (SMEs) on the other hand are generally viewed as key drivers of job creation, poverty alleviation and economic growth (Adelowotan, 2021; Serumaga-Zake & van der Poll, 2021), meaning they have the potential to solve the above-mentioned social challenges, especially through the adoption of 4IR technologies to develop innovative solutions.

Several scholars have defined 'innovation' as a process of introducing new or existing knowledge to a context, such as a country, firm, or region (Alexander, 2021). To foster innovation, an appropriate innovation system is required in developing nations to enable SMEs to continue to solve social challenges. An innovation system is a network in which actors interact to exchange knowledge to undertake innovative activities (Kraemer-Mbula & Wamae, 2010). This study is concerned with the National Innovation Systems (NIS) of developed and developing countries that influence SMEs' adoption of 4IR technologies; in other words, which elements of the innovation system positively or negatively influence SMEs' adoption of 4IR technologies in developing vs. developed countries. We find various studies in this respect. Dosso et al. (2021) discuss the readiness of such a system in Sub-Saharan Africa. They observe the system from four lenses: infrastructure, skills, governance and R&D potential. In South Africa, Alexander (2021) analyzes the key concepts and abilities of the innovation system. She observes the system from three lenses, namely contextual factors, key actors, and key domestic and global networks. Similar studies were also conducted in developed countries. For instance, Lee and Lee (2018) investigated the impact of innovation systems on economic growth between Korea and four European countries. Before that, Nelson (1993) compared the innovation systems of various high-income and low-income countries.

While this scholarly conversation is insightful, there are two noticeable gaps. One is the holistic and comprehensive view of an NIS. Dosso et al. (2021) and Alexander (2021) touch on various aspects of an NIS that do not necessarily encompass the whole picture, hence their completely different lenses of observation. This study utilizes Lundvall's NIS framework to scrutinize developed and developing nations' innovation ecosystems. Developed by Bengt-Åke Lundvall in the 1980s, this conceptual framework generally prompts an examination of how different actors, institutions, policies, and structures interact and contribute to innovation processes within a specific economic context. Our focus encompasses critical components like intra-firm and inter-firm interactions, the public sector's role, the financial system's institutional setup, and R&D intensity. This approach allows a comprehensive analysis of how firms organize internal innovation, collaborate externally, and engage with governmental policies and financial structures. By examining these elements within the innovation systems of diverse economies, we aim to discern their varying impacts on SMEs' adoption of 4IR technologies, offering insights into innovation dynamics across different economic landscapes.

Secondly, a noticeable gap persists in research concerning the comparative analysis of NIS across developed and developing nations. This gap specifically revolves around the exploration of differences and similarities between these distinct systems, aiming to identify which strategies prove effective within each context. Essentially, there is a scarcity of comprehensive studies that scrutinize and contrast the innovation frameworks of developed and developing countries, emphasizing the need to uncover not just the differences but also the shared elements that facilitate or hinder SMEs' adoption of 4IR technologies. While the study mentioned above by Nelson (1993) comes close, he did not compare high income to low income. He compared countries within the high-income category and then proceeded to compare those within the low-income category. Understanding what works optimally within each setting is pivotal for devising tailored and effective approaches to innovation enhancement.

Therefore, this study aims to identify the differences in 4IR technologies adoption by SMEs in developing vs. developed countries, using Ludwig's NIS framework. In this way, we can attempt to understand which aspects of a country (developed or developing) influence (positively or negatively) SMEs' adoption of 4IR technologies. In this study, the classification of countries as 'developed' or 'developing' is based on income levels, aligning with the World Bank's criteria. This approach ensures consistency in comparisons and establishes a clear economic context for exploring the diverse adoption patterns of 4IR technologies. The data is collected through a Systematic Literature Review (SLR) and analyzed through a meta-synthesis. A conceptual framework for the NIS necessary for SMEs' adoption of 4IR technologies in developing countries is then generated.

The rest of the paper is organized as follows: Section 2 expands on the Theoretical Framework, focusing on explaining the different aspects of NIS. This is followed by a detailed description of the methodology used to conduct the SLR. The results and discussion are presented next, together with the development of the conceptual framework. The paper ends with a conclusion.

THEORETICAL FRAMEWORK

Innovation systems

Innovation systems literature comprises several subsets. NIS (Lundval, 2016) concentrates on a nation's interconnected institutions and policies to drive innovation and foster economic growth. In contrast, Regional Innovation Systems (RIS) prioritize innovation within specific geographical areas by aligning local industries, research centers, and governmental entities. Sectoral Innovation Systems (SIS) (Malerba, 2002), delve into innovation dynamics among entities within industries, aiming to enhance competitiveness and spur technology development. Additionally, Global Innovation Systems (GIS) (Binz & Truffer, 2017) involve international collaborations, enabling the exchange of knowledge and technology on a global scale to elevate competitiveness and facilitate overall progress. In the context of SMEs' adoption of 4IR technologies, NIS provides a holistic view, considering the national-level factors that shape the overall innovation landscape. While RIS, SIS, and GIS focus on more specific contexts, they contribute to the broader NIS by influencing innovation at regional, sectoral, and global levels, respectively. Understanding these interrelated systems is crucial for comprehensively assessing how SMEs navigate and benefit from the opportunities presented by 4IR technologies within different contextual frameworks.

SMEs and innovation systems

The correlation between entrepreneurship and innovation systems, encompassing diverse 'helix' concepts such as the Triple Helix, delves into how business, government, and Academia interact (Kochetkov, 2023). Isabelle et al. (2023) exemplify this connection in their study, where they developed an SME 4IR ecosystem framework by merging the triple helix with a dynamic perspective on the entrepreneurial ecosystem concept. Entrepreneurial ecosystems, building upon the foundations of innovation system literature, pivot their emphasis toward cultivating entrepreneurial knowledge rather than solely focusing on innovation creation (Cao & Shi, 2021). It specifically concentrates on nurturing an environment conducive to entrepreneurial activities, knowledge exchange, and the development of entrepreneurial skills and mindsets. In contrast, innovation systems encompass a broader framework involving interconnected elements such as institutions, organizations, and policies to foster innovation within a socio-economic context.

Alexander (2021) investigates the role of South Africa's NIS in either supporting or impeding 4IR-related innovations, examining how this system influences businesses' abilities to adopt and develop 4IR technologies. While the study discusses NIS through contextual factors, key actors, and network characteristics, it does not explicitly emphasize interactions among actors, institutions, and policies to foster innovation for the adoption of these technologies.

In this context, this study seeks to expand upon these approaches by applying Ludval's NIS lens. This lens emphasizes the interconnectedness of actors, institutions, and policies to drive innovation, providing a comprehensive framework for understanding how these elements interact and impact the adoption of 4IR technologies.

National Innovation System (NIS)

This study adopts NIS due to the following reasons. Firstly, Nelson (1993) highlights the significance of NIS, emphasizing a nation's technological prowess as pivotal for competitiveness. Countries like Japan, Korea and Taiwan thrived due to their advanced technical capabilities (Nelson, 1993). Developing nations historically lagged in previous revolutions (Marwala, 2021), facing hurdles in accessing electricity and the internet (3IR). Amid the 4IR, it is crucial for these nations to position themselves for its benefits. SMEs, often facing exclusion from the 4IR due to documented challenges (Isabelle et al., 2023; Serumaga-Zake & Van der Poll, 2021), should be at the forefront of adoption, as this should lead to improved technological capabilities and, therefore, improved competitiveness of the nation.

Secondly, Lundvall (2016) asserts that governments must understand how to foster innovation at the national level. Identifying challenges and opportunities on a national scale becomes vital for making informed policy recommendations to governments, especially in developing countries.

Thus, this study is concerned with those elements in the innovation system of a country that influence positively or negatively the adoption of 4IR technologies, on a national level. We chose Lundvall's framework as it offers a comprehensive and systemic way of understanding how innovation takes place within a country. It highlights the interactions among different actors and institutions, emphasizing the role of the public sector and financial sector in shaping a country's innovation performance. This framework is widely adopted by policymakers, researchers and practitioners to guide their strategies for innovation.

Lundvall (2016, p. 86) defines NIS as "constituted by elements and relationships that interact in the production, diffusion, and use of new and economically useful knowledge … located or rooted inside the borders of a nation state." Nelson (1993, pg. 4) defines a system as "a set of institutions whose interactions determine the innovative performance of national firms." In simpler terms, NIS may be taken as a set of elements that interact in the process or lifecycle of innovation. Lundvall (2016) describes the elements of NIS as follows:

Table 1. Elements of NIS

Element	Description
Intra-firm interactions	This element is worth examining because, as pointed out by Lorenz and Kraemer-Mbula (2021), it is individual firms that adopt 4IR technologies. It is, therefore, important to understand the innovation and learning processes that take place within a firm (Kraemer-Mbula & Wamae, 2010). Inside the firm, Lundvall (2016) suggests observing the interaction between the various departments such as sales, production and R&D. In our study, we will examine the interactions within SMEs that influence the adoption of 4IR technologies.
Inter-firm interactions	Relationships between firms are an important aspect to consider when examining innovation systems (Lundvall, 2016). These relationships affect competition and could include technical knowledge exchange, industrial districts, and user-producer interactions. Therefore, our study will examine the interactions between SMEs and other external parties that influence the adoption of 4IR technologies.
Role of the public sector	The public sector, specifically the government, plays an important role in innovation. This could be through science and development, regulations and standards, which are said to influence the rate and direction of innovation. Therefore, in our study, we will examine issues that have to do with the role of the government in influencing the adoption of 4IR technologies.
The institutional set-up of the financial system	It appears from the literature that there is a connection between the financial system of a country and the system of innovation. One aspect of this element is the role of Financial Institutions as funders of innovation (Lundvall, 2016). In this study, we will examine the issue of finance more broadly, seeking to understand the funding mechanisms and instruments that influence the adoption of 4IR technologies.
R&D intensity and R&D organization	According to Lundvall (2016), these include the R&D system, its resources, competencies, and organization. In this study, we will be examining the R&D systems of developing and developed countries to understand how they influence the adoption of 4IR technologies.

Source: Lundvall (2016).

Based on the elements in Table 1, we ask the following research questions (RQs) about SMEs in developing vs. developed nations:

RQ1: What are the interactions taking place between the various departments in SMEs that influence the adoption of 4IR technologies?
RQ2: What are the interactions that are taking place between SMEs and other actors that influence the adoption of 4IR technologies?
RQ3: What is the role of government in influencing the adoption of 4IR technologies by SMEs?
RQ4: What financial mechanisms/instruments are used to influence SMEs' adoption of 4IR technologies?
RQ5: What R&D systems are in place to influence SMEs' adoption of 4IR technologies?

METHODOLOGY

This study adopts a Systematic Literature Review (SLR) to select relevant literature for data collection. This is then followed by a Qualitative Meta-Synthesis (QMS) for data analysis. We use the PRISMA (Preferred Reporting Items for Systematic Literature Reviews and Meta-Analyzes) flow diagram (Page et al., 2021) to perform and report on our SLR and QMS, as shown in Figure 1. PRISMA is utilized in this study for its transparency, standardization, and quality assurance in reporting systematic reviews.

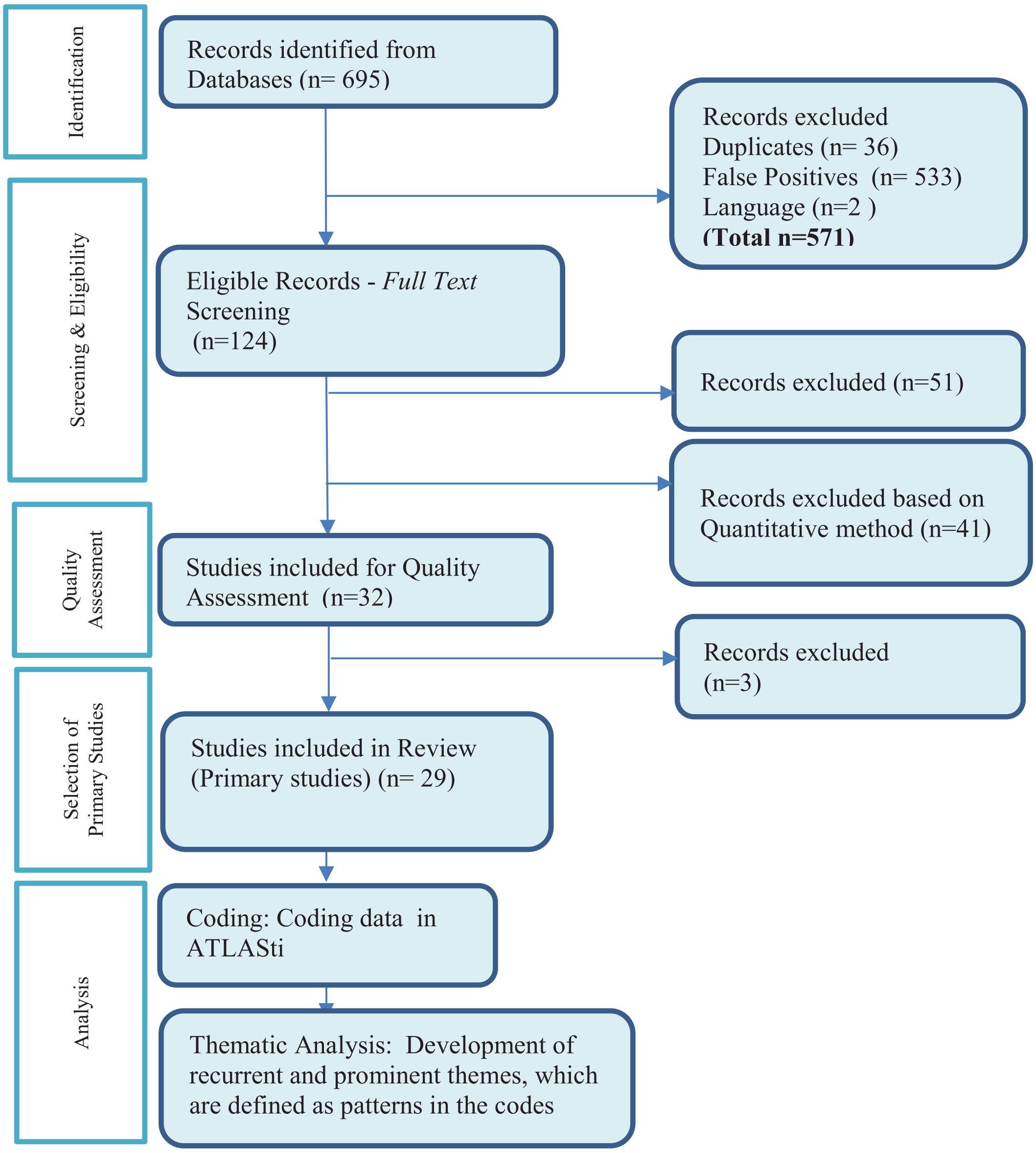

Figure 1. Systematic Review PRISMA process

Source: Page et al. (2021).

Identification

All records available on the topic of SMEs' adoption of 4IR technologies and related innovation systems were identified as follows:

Search engines – Data was collected from SCOPUS and Web of Science (WoS). These databases are widely accessible by researchers globally and have a reputation for indexing high-impact literature, contributing to the study's academic rigor. Furthermore, these journals cover academic literature across various disciplines including technology adoption, innovation, and the Fourth Industrial Revolution. The researcher further consulted ProQuest Central, which has coverage in a wide variety of topics, specifically Business Studies and Entrepreneurship.

Type of literature – We reviewed scholarly literature such as peer-reviewed journal articles, conference proceedings, books, and book chapters.

Literature timeframe – All literature from 2011 to 2023 was reviewed. This timeframe was chosen because the 4IR was first deliberated at the Hannover fair held in Germany in 2011 (Schwab, 2017).

Search terms – The key terms were "SMEs", "adoption" and "4IR technologies." These were used with a combination of supplementary terms (see Table 2). "SME" is pivotal as it defines the study's target entities, while "adoption" is crucial as it signifies the primary variable of interest. The term "4IR technologies" broadens the search, encompassing the full spectrum of innovations related to 4IR. Notably, the terms "developing country" and "developed country" were avoided to prevent the exclusion of papers where specific countries are named. The researcher classified countries as "developed" or "developing" after reviewing the included literature. The same applied to "innovation systems" as most papers would not normally refer to this term but rather to an aspect of it. In total, 695 publications were identified as follows:

Table 2. Search strings, the quantity of identified and selected papers (last searched on 20 February 2023)

SCOPUS	
Search string	TITLE-ABS-KEY *(SME OR „Small and Medium Enterprise") AND Adoption AND („4IR technolog*" OR „Fourth Industrial Revolution technolog*" OR „Industry 4.0 technolog*" OR „Smart Manufacturing")*
Result quantity	39
WEB OF SCIENCE	
Search string	ALL FIELDS (SME OR „Small and Medium Enterprise") AND Adoption AND („4IR technolog*" OR „Fourth Industrial Revolution technolog*" OR „Industry 4.0 technolog*" OR „Smart Manufacturing")
Result quantity	21
PROQUEST	
Search string	(SME OR „Small and Medium Enterprise") AND Adoption AND („4IR technolog*" OR „Fourth Industrial Revolution technolog*" OR „Industry 4.0 technolog*" OR „Smart Manufacturing")
Result quantity	635

Screening and eligibility

Once the data was collected, screening and eligibility ensued. The data was screened for duplicates, language, and false positives, as reported in Figure 1.

Duplicates – A manual de-duplication method similar to that of McKeown and Mir (2021) was used, whereby data from all databases was exported to an Excel spreadsheet and then sorted alphabetically by author. Where a 'duplicate' author was found, the title of the study was looked at next to check whether the documents were the same article. If it was found that the articles were the same, one was eliminated. As a result, 36 papers were removed.

Language – Only articles written in English were included. In that regard, therefore, two papers written in Russian and Polish were excluded.

False positives – These are articles that contain the keywords searched but are of an unrelated topic (Linnenluecke et al., 2020). Articles that focused on 4IR technologies, but in relation to other topics such as labor or education (instead of SME adoption), were categorized as false positives. In this study, based on the review of the abstracts, 533 false positives were excluded.

The total number of excluded articles at this point was 571, leaving 124 for full-text screening.

Full-text screening – At this stage, all 124 articles were read in full, and the following inclusion and exclusion criteria were applied to select primary studies:

Inclusion criteria – Articles that focused on SMEs and their adoption of 4IR technologies. Articles that answered one or more of the research questions.

Exclusion criteria – Articles that did not answer any of the research questions. Articles that referred to the adoption of 4IR technologies by companies, projects, individuals (such as students), corporations, industries, sectors, enterprises, or firms that were not necessarily Small and Medium. Articles that focused on other technologies that are not 4IR related (for instance, social media). Articles that focused on other aspects of SMEs in relation to 4IR technologies such as the identification of reasonably priced 4IR technologies for SMEs. Bibliographies, although other types of systematic literature reviews were included. Quantitative studies – A meta-synthesis exclusively relies on the synthesis of qualitative studies (not quantitative), extracting and interpreting themes and patterns from qualitative data.

As a result, thirty-two (32) primary studies were selected. The assessment of their quality is discussed next.

Quality assessment

The selected papers were checked for quality, as this appears to be an important and contended feature of Qualitative Meta-Synthesis (Finlayson & Dixon, 2008; Gough, 2007). Numerous methods can be employed for this purpose. However, for this study, Gough's (2007) 'weight of evidence' guidelines were followed. It is used in fields such as law where evidence is weighed for decision-making (Gough, 2007) and therefore, considered more rigorous than the others. Furthermore, it allows for a nuanced assessment by considering various dimensions of study quality, such as methodological rigor and relevance to the research question, providing a comprehensive understanding of the evidence landscape. The weight-of-evidence approach employs the use of separate judgments made on various criteria, which are then combined for an overall judgment, as shown in Table 3.

Table 3. Quality assessment of primary studies

Weight of Evidence (WOE)	To check for	Primary study characteristics
WOE A: Quality of Execution of Study	Transparency, Accuracy, Accessibility, Specificity	The primary study must have a clear purpose or aim of study (Liu et al., 2021).
WOE B: Appropriateness of Method	Fit for purpose method	The primary study must have a methodology for data collection and analysis (Gjaltema et al., 2020)
WOE C: Focus/Approach of Study to Research Questions	Utility – provides relevant answers	The Primary study must have an answer to one or more research questions (Gough, 2007), in other words, one or more aspects of the NIS framework

Source: Gough (2007).

Some scholars, such as Liu et al. (2022), calibrated the answers from the selected studies with yes (1), 0.5 (partially), and no (0), then calculated the weights accordingly. Based on the final score, the papers were then ranked into three categories, namely good (score of 3.5 and above), fair (score of between 2.5 and 3), and poor (score of 2 and below). This study followed the same procedure. Only the papers in the good and fair categories were deemed of good quality and included in the final review. Three papers were excluded, leaving a total of 29 primary studies for analysis.

Data analysis

A Qualitative Meta-synthesis (QMS) is described as an integration or merging of information and results from carefully selected qualitative studies (Finlayson & Dixon, 2008). Finlayson and Dixon (2008) explain that this method is more than a summary or description of the literature but an interpretation of the findings to build a theory. It is appropriate for this study as we seek to develop a conceptual model for the innovation system necessary for SMEs' adoption of 4IR technologies. The following section describes the process, which is followed by an analysis of the data collected.

Extracting and coding data – All 29 publications were transferred to ATLAS.ti for extraction of data through coding. In the initial coding phase, structural coding, a top-down approach, was used where data was coded according to the research questions (Saldaña, 2013). In other words, the coded text answered one or more aspects of the NIS of the country studied in the publication (see Figure 2). Subsequently, similar codes were organized into categories or higher-order themes. In collaborative efforts, three researchers maintained consistency through regular ATLAS.ti meetings.

Name	Grounded	Density	Groups
Inter-firm SME and solution provider	2	0	[RQ2_Inter-Firm]
Inter-firm SME and supplier - d	3	0	[RQ2_Inter-Firm]
Inter-Firm SME d and university	1	0	[RQ2_Inter-Firm]
Inter-firm SME to SME	3	0	[RQ2_Inter-Firm]
Inter-firm Supply chain	4	0	[RQ2_Inter-Firm]
Inter-Firm unions	1	0	[RQ2_Inter-Firm]
Intra -Firm d departments	2	0	[RQ1_ Intra-Firm Interactions]
Intra-Firm	3	0	[RQ1_ Intra-Firm Interactions]
Intra-firm - d	4	0	[RQ1_ Intra-Firm Interactions]
Intra-Firm d managemen and workers	1	0	[RQ1_ Intra-Firm Interactions]
Intra-firm generation to generation	2	0	[RQ1_ Intra-Firm Interactions]
Intra-firm Management and personnel	11	0	[RQ1_ Intra-Firm Interactions]
Intra-Firm R&D and workers	1	0	[RQ1_ Intra-Firm Interactions]

Figure 2. Partial list of initial codes in ATLAS.ti Code Manager

Initial coding aims to find and label what is in the data. This process resulted in 53 codes, which consisted of 218 quotations.

Method of qualitative meta-synthesis – A thematic analysis method was adopted for this study, as it allows for the analysis of patterns and themes in the codes (for each research question), to show the picture that is being portrayed in the literature (Castleberry & Nolen, 2018; Dixon-Woods et al., 2005). Themes were identified by exporting the codebook for each research question to Microsoft Excel and grouping the subcategories according to commonality. For Research Question 1, a sample is provided in Figure 3.

ID	Quotation Content	Codes	Theme
5:7	RP1: An organisational structure characterised by a wide span of control and a low number of hierarchical levels is associated with the adoption of I4.0 technologies.	Intra-Firm	Structural change
9:13	While in Italian large companies the knowledge transformation and application occur in dedicated units separate from any functional unit or division (Gramolati et al., 2018), in innovative SMEs it occurs mainly "on the job." Rold has created an intergenerational team to develop smart products inside the new sensors division. Seasoned technicians with great experiences, deep competences on the development of the	Intra-Firm	Intergenerational teams between young and old
11:8	A key consideration was the top management support, organisational resistance across ranks, and a culture shift focusing on managing its mindset. The vision and direction provided by the CEO and senior management was an extremely critical aspect. In the case of family-owned companies, it was felt that the younger generation's engagement	Intra-firm generation to generation Intra-firm Management and personnel	Management and workers
1:1	Planning & scheduling: There is no planning or scheduling taking place other than the rough manual prioritization of the jobs in progress. Senior engineers and management have a deep understanding of each	Intra-firm Management and personnel	Management and workers

Figure 3. Partial list of thematic analysis using the ATLAS.ti codebook in Microsoft Excel

Each research question varied in terms of the number of levels of thematic analysis and the findings are presented in the next section.

RESULTS

Developed and developing countries represented in the primary studies

In this section, the findings from the selected studies concerning the five research questions are presented. The selected primary studies are tabulated in Annexure A. They span several countries, as shown in Figure 4. As shown in Figure 4, 12 out of 29 papers were from developed countries, 12 were from developing countries and the rest were from both developed and developing countries. The most represented were from Italy (17%), India (14%) and South Africa (10%). In the remainder of this section, the key findings of the innovation systems between these countries are discussed.

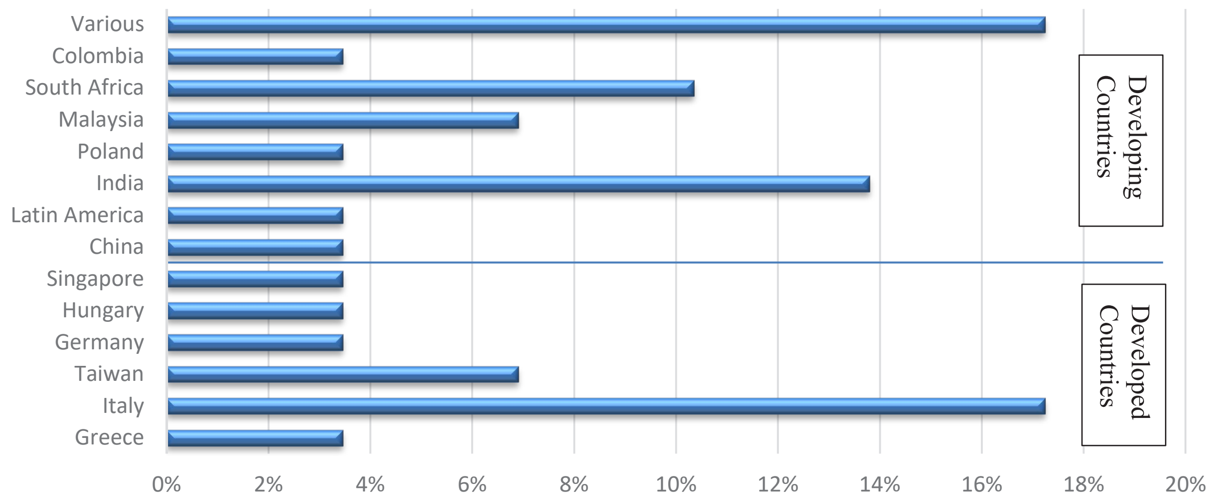

Figure 4. Developed and developing countries represented in the selected primary studies

RQ1: What are the interactions taking place between the various departments in SMEs that influence the adoption of 4IR technologies?

This section reports the findings of the interactions taking place within SMEs that influence the adoption of 4IR technologies in developing and developed countries. These are summarized in Table 4.

Table 4. Intra-firm interactions

Interaction by theme	Developed Countries	Developing Countries
Management and workers	1, 2, 5, 6, 9, 10, 11, 12	13
Structural change – Reduction of hierarchical levels	5	
Intergenerational teams between young and old	9, 11	
Departmental interactions		13, 15, 18
Management and workers	1, 2, 5, 6, 9, 10, 11, 12	13

It can be seen from Table 4 that there are interactions within SMEs that positively and negatively influence the adoption of 4IR technologies as follows:

Management and workers – The first similarity noted is the interaction between management and workers that influenced the SMEs' adoption of 4IR technologies. This interaction is mentioned in n=9 studies. We observe this interaction more in literature from developed than in developing countries. Several studies point to the positive mindset of the managers first, which then cascades to the workers. Surianarayanan and Menkhoff (2020) state that in Singapore, the vision and direction set by the leadership of the SME are key and critical to adoption.

Another key aspect of 4IR technology adoption in SMEs hinges on worker involvement. Da Roit et al. (2022, pg. 14) emphasize that "people give their best when they are involved". This sentiment is echoed by Arcidiacono et al. (2019), who stress the pivotal role of fieldwork operators in developing suitable technological solutions for successful adoption. Garbellano and Da Veiga (2019) highlight the significance of involving workers, including blue-collar workers, in digital transformation project kick-off meetings to address concerns, costs, and risks.

Wang et al. (2022) propose integrating the adoption of 4IR technologies, such as AI, into the key performance areas of workers to encourage active involvement and adoption. However, the literature indicates that a lack of vision, support, and direction from leadership adversely affects 4IR technology adoption. Arcidiacono et al. (2019) suggest that leadership may struggle to quantify the benefits, face resource optimization challenges in SMEs, and grapple with data security fears, leading to a company culture that impedes technology adoption. This unfavorable environment negatively impacts workers, causing resistance to change and sluggish acceptance of these technologies.

Additionally, a lack of awareness, guidance, and information from leadership regarding the adoption of 4IR technologies result in non-adoption (Shaikh, 2021). This underscores the crucial role of effective interaction between leadership and workers in fostering a conducive environment for successful technology adoption.

In developing countries, a lack of adoption within an SME appears to be due to fear of job loss (Joshi et al., 2022). Therefore, Joshi et al. (2022) encourage support at all levels of management, specifically towards the workers' development, involvement, and engagement.

Structural change – An observation made in Italy is a change in the organizational structure when 4IR technologies are adopted. It appears there is a relationship between the adoption of 4IR technologies and the structure of interaction between management and workers. In particular, Cimini et al. (2020) highlight the hierarchical level reduction that is taking place in organizations. Traditionally, there is a hierarchy, a pyramid within firms that depicts how management interacts with employees. In the current digital revolution, Cimini et al. (2020) explain that the organizational structure in Italy is changing from a pyramid to a network. In other words, it appears there is a widening span of control given to the workers when 4IR technologies are introduced to the SME, to promote agility and responsiveness to the 4IR (Cimini et al., 2020).

Intergenerational teams – Another observation made only in developed countries is the interactions between employees of different generations. It appears a few firms are intentionally putting together teams consisting of workers who are old and experienced and workers who are young and techno-savvy. Garbellano and Da Veiga (2019) found that in developing smart products, Italian SMEs combine the expertise of seasoned technicians with young recently graduated software engineers. They also found that in family businesses, the adoption of 4IR technologies is driven by the children of the founders, successfully invigorating the sluggish business and its competitive position. Surianarayanan and Menkhoff (2020) also observed that the successful adoption of 4IR technology was largely driven by the engagement of the younger employees to harvest the benefits of 4IR technologies in Singaporean SMEs. This suggests that the younger generation has the potential to influence positively the adoption of 4IR technologies within SMEs.

Departmental interaction – We find that this interaction is only mentioned in the literature from developing countries. Joshi et al. (2022) highlight the importance of a supportive learning environment in SMEs in India, where learnings are captured and shared between departments, ensuring an understanding of how their work affects the rest of the organization. Also in India, Mittal et al. (2020) found that input was sought from different departments such as sales, design, and production when a particular technology was being designed in their selected manufacturing SMEs. On the contrary, De Lucas et al. (2022) found that in Latin America, there is a lack of such an environment, which they opine is required for innovation and knowledge sharing, especially for employees who are unfamiliar with the 4IR process within the company. They found that there are no documented models regarding the relationship between the different departments and collaboration between different areas of the SME. However, there is an intention by departmental managers to develop a communication plan for employee information. Mittal et al. (2020) found that input was sought from different departments such as sales, design, and production when technology was being designed.

RQ 2: What are the interactions that are taking place between SMEs and other actors that influence the adoption of 4IR technologies?

This section reports the findings of the interactions taking place between SMEs and other external parties that influence the adoption of 4IR technologies, in developing and developed countries. These are summarized in Table 5 below.

Table 5. Inter-firm interactions

Theme	Actors influencing adoption	How they are interacting with SMEs to influence adoption	Developed country studies	Developing country studies
Innovation intermediaries	*Competence Centre*	Bring together Academia, government and private sectors to support SMEs toward a human-centered implementation of 4IR, rather than a techno-centric one.	10	
Academia	*Universities*	Partnerships with SMEs to develop new products provide knowledge to SMEs and train human resources in the use of 4IR technologies.	9	21, 27
Supply and value chain partnerships	*Customer*	Far ahead in technology adoption, forcing SMEs to adopt technologies to meet their needs	6, 9	13
Supply and value chain partnerships	*Solution provider*	Provide technology solutions to SMEs	2, 27	
Supply and value chain partnerships	*Supply chain*	Receive products/services from SMEs in the value chain	3, 6	
Other SMEs	*Other SMEs*	Collaboration, networking, sharing knowledge, best practices, information and solutions	3,4,9	18

We see from Table 5 that several actors interact with SMEs and influence their adoption of 4IR technologies.

Innovation intermediaries – These are viewed as critical and key to the innovation system (Vidmar, 2021). The role of innovation intermediaries is well documented in the literature and it includes knowledge brokering (De Silva et al., 2018) and providing innovation stakeholders with infrastructure and tools (Vidmar, 2021). In this study, an observation is made about developed countries which appears to be absent in developing countries; and that is Competence Centers. Ietto et al. (2022) point to the technocentric approach prevalent in business when adopting 4IR technologies and opine that a more human-centric approach is needed. Therefore, the role of Competence Centers is to bring together key actors in the innovation ecosystem, namely Academia, government, and private sectors, to support SMEs towards a human-centred implementation of 4IR. This includes activities such as:

- worker skill enhancement through training;
- customized robotics that focuses on worker safety in the workplace, and
- workers' well-being whereby automation of tasks is encouraged as well as wearables for analysis of workers' vital parameters.

Competence Centers are also used by SMEs to acquire 4IR competencies. Ietto et al. (2022) stated that although SMEs are aware of the competencies they need, the gap between the competency provider and the SME is so wide that they are unable to find the right provider without intermediaries.

Academia – The interaction between SMEs and Academia is also noted in the literature. In developed countries such as Italy, we observe SMEs partnering with universities for the development of new digital products, which in turn positively affects the firm's competitive position (Garbellano et al., 2019). However, the literature appears to suggest that this interaction is not necessarily taking place in developing countries. Rojas-Berrio et al. (2022) found that technological development is slow in LATAM countries because of the non-existent relationship and interaction between Academia and SMEs. This is echoed by Ghobakhloo et al. (2022), who pointed to the lack of access to external digitalization experts in universities by SMEs as a critical barrier to the adoption of 4IR technology in developing countries such as Brazil. Rojas-Berrio et al. (2022) stress the importance of Academia and SME partnerships, in that Academia provides knowledge to SMEs and trains human resources in the use of 4IR technologies.

Customers – Da Roit and Iannuzzi (2022) and Garbellano et al. (2019) found that customers are a significant driver of 4IR technology adoption by SMEs in Italy. Both studies reveal that this interaction with customers is more important to SMEs than government incentives as SMEs believe that customers are further ahead in technology than they are. Therefore, to meet their needs, these SMEs had to transform digitally. In LATAM countries, De Lucas Ancillo et al. (2022) demonstrate that there is a lack of interaction between the SME and the customer; not even efforts by the SME to get to know the customer better.

Solution providers – The interaction between the SME and the solution provider appears to be a complex one in both developed countries. In some instances, SMEs form bonds with solution providers to co-develop the best technology solutions for the firm, such as in Italy (Arcidiacono, 2019; Ghobakhloo et al., 2022). In other instances, we see information asymmetries between the two parties resulting in the exploitation of SMEs, whereby solution providers present solutions beyond SME needs and recommendations of obsolete technology solutions (Arcidiacono, 2019). This behavior creates fear within SMEs and hinders the adoption of 4IR technologies on their part. Another factor discussed by Ghobakhloo et al. (2022) is the monopolistic nature of 4IR technologies, which creates a lack of competition, resulting in apprehension in SME technology adoption. This aspect does not appear to be a point of discussion in the literature from developing countries.

Supply chain – It appears most SMEs act as suppliers to large companies (Chen, 2020) and other customers and, therefore, are determined to not be the weakest link in the supply chain. This has led to the adoption of various technologies. Arcidiacono et al. (2019) give an example of an Italian factory that was forced to automate their warehouse as the manual system was causing delays to the customers. At times, they would not be able to fulfill customer requests because the stock was hidden so far in the warehouse that it could not be physically reached. Again, in Italy, Da Roit and Iannuzzi (2022) interviewed a company that adopted 4IR technology because of an explicit request from the large company they serve as an SME. This aspect does not appear to be a point of discussion in the literature for developing countries.

Other SMEs – In developing countries, the literature indicates that there are interactions taking place between SMEs. Some interactions occur at conferences and with competitors (Mittal et al., 2020), where SMEs learn new knowledge and implement it in their businesses. However, we note the difficulty of SMEs collaborating with other SMEs to learn and share knowledge in both developed and developing nations. Chen et al. (2021) highlight this issue in Taiwan, explaining that the interaction has not matured in the country, while in Italy, there is significant interaction between SMEs, forming networks, sharing knowledge, best practices, information, and solutions among each other.

It appears that the government is another key actor in the adoption of 4IR technologies by SMEs, and this is discussed in the next research question.

RQ 3: What is the role of government in influencing the adoption of 4IR technologies by SMEs?

The literature reveals that the government has various roles to play in influencing SMEs to adopt 4IR technologies, as shown in Table 6.

Table 6. The role of the government

Role of government by theme	Developed country studies	Developing country studies
Funding/Incentives/Subsidies	2, 4, 6, 11	21, 22
Training	4, 6, 8	
Regulation/Law/Standards	4	22, 27
Create Ecosystems/Networks	4	
Provide Infrastructure		22, 24

It can be seen from Table 6 that the role of the government is vast and influences adoption in various ways, as discussed below:

Funding/incentives/subsidies – Funding (or lack of it) was mentioned in n=6 articles. In developed countries, Arcidiacono et al. (2019) highlight the positive impact of government funding through the I4.0 National Plan in Italy. This plan, they assert, encourages SMEs to adopt and implement 4IR technologies by offering them incentives and tax credits to do so. The same trend is observed in another developed country, Singapore, where Surianarayanan and Menkhoff (2020) point out that the adoption of 4IR technologies by SMEs is largely driven by government incentives, financial assistance, and subsidies available to them. This trend is unfortunately not witnessed in developing countries. In the Sub-Sahara, Serumaga and Van der Poll (2021) state that government funding towards digital infrastructure, R&D, and training is low and negatively impacts the adoption of 4IR technologies in the manufacturing sector. The same appears to be true in Columbia, where Rojas-Berrio et al. (2022) report that one of their interviewees sought funding from the government, which turned out to be a process that took six months to a year, while the need for the technology was immediate and unmet.

Training – Governments are also expected to assist in training and skills development of 4IR technologies. In both developed and developing countries, SMEs generally do not have the finances to train and upskill their employees and, therefore, require assistance from the government, otherwise, their digital capability will worsen (Chen et al., 2021). Chen et al. (2021) go on to say the assistance that SMEs need from the government is the provision of digital platforms and programs to help them find qualified talent and/or train their employees, as well as funding for these. Some governments in developed countries, such as Italy, appear to support training activities by offering tax credits for SMEs. The Hungarian government has also developed programs to assist SMEs in improving their skills and innovation capabilities to adopt 4IR technologies.

Regulation/law/standards – In developing nations, it appears there is a lack of regulation on 4IR technologies, and this negatively affects the adoption by SMEs. Even though this is the case, Serumaga and Van der Poll (2021) demonstrate that some African countries including Kenya, Rwanda, and Uganda are beginning to consider this issue by initiating programs and policies that address economic growth. India on the other hand is guided by the National Manufacturing Policy and most importantly, the Make-in-India Directive (Dutta et al., 2020). It appears it is not so in developed countries. Germany and governing bodies in Europe have comprehensive policies that support and promote SMEs' adoption of Industry 4.0 technologies (Ghobakhloo et al., 2022). Italy is guided by the I4.0 policy (Da Roit & Iannuzzi, 2022)

Create ecosystems/networks – Chen et al. (2021) studied the role of the Taiwanese government in digital transformation and suggested that the government build a collaborative ecosystem that assists SMEs in connecting and collaborating with others. In this way, SMEs overcome a lack of financial and human resources as well as a lack of knowledge (Chen et al., 2021).

Provide infrastructure – This is an aspect observed only in developing countries. The governments in these countries appear to be lax in installing or upgrading digital infrastructure. Serumaga and Van der Poll (2021) argue that the lack of high-speed internet technology infrastructure limits information access and business performance. This is echoed by Wankhede and Vinodh (2022) who raised data rate transfer concerns (the speed at which data is transferred) in India. They explained that the slow rate of data transfer harms the manufacturing sector and their adoption of cyber-physical systems. In contrast, countries such as Hungary have launched programs to develop SMEs' digital infrastructure, as the national digital infrastructure is sound, unlike in developing countries.

RQ 4: What financial mechanisms/instruments are used to influence SMEs' adoption of 4IR technologies?

This section reports the findings of the existing funding mechanisms, instruments, and funding actors that influence the adoption of 4IR technologies in developing and developed countries. These are summarized in Table 7.

Table 7. Funding mechanism for adoption of 4IR technologies

Funding mechanism	Developed country studies	Developing country studies
Government Funding (subsidies/incentives)	2,4, 6, 9, 11, 15	
External funding (bank loans, private funder)		19, 21
Internal funding		27, 28

SMEs in developed and developing countries do not generally have sufficient funds and human capital to adopt 4IR technologies (Chen et al., 2021). In acquiring 4IR technologies, they have to consider direct and indirect costs that include hardware and software costs, maintenance expenses, and ongoing training. Due to a lack of resources, SMEs then opt to invest in what they know rather than in digital technologies that have no guarantees of success in their firms (Chen et al., 2021). Nevertheless, digital transformation literature tells us that the cost of implementation is a primary barrier to digital technology adoption in SMEs (Chen et al., 2021).

Government funding – As previously discussed, government funding appears in more papers (n=6), indicating its importance. In the literature, we note that the governments in developed countries have made provisions for incentives (Arcidiacono et al., 2019; Da Roit & Iannuzzi, 2022); tax benefits (Da Roit & Iannuzzi, 2022; Garbellano et al., 2019) and subsidies (Surianarayanan & Menkhoff, 2020) to SMEs to encourage adoption. In developing countries, it appears government funding is available, however, it is insufficient and takes longer to acquire, as explained by Serumaga and Van der Poll (2021) and Rojas-Berrio et al. (2022).

External funding – Perhaps the lack of government funding in developing countries is the reason for approaching other funders, such as banks and private funders, as these only appear in papers from developing countries. In terms of banks, Rojas-Berrio et al. (2022) found that in Colombia, SMEs have a negative perspective of banks in that they have encountered barriers and impediments to accessing loans to purchase 4IR technologies. This could be because banks are generally apprehensive about lending to SMEs. In terms of autonomous vehicles, Mokonyama et al. (2022) opine that funding should be easier to obtain from external funders as these vehicles record and keep historical data on how the asset was utilized. They add that this type of information is important to funders as they use it to calculate matrices such as Return on Capital and that if an SME keeps this data, they are more likely to access that funding.

Internal funding – This sort of funding may be making an appearance in developing countries to avoid the barriers SMEs have to overcome to access external funding. Another reason could be that the costs of 4IR technologies have dropped significantly of late, making them more affordable to SMEs (Ghobakhloo et al., 2022).

RQ 5: What R&D systems are in place to influence SMEs' adoption of 4IR technologies?

This section reports the findings of the existing R&D systems, resources, competencies, and organizations that influence the adoption of 4IR technologies in developing and developed countries. These are presented in Table 8 below.

Table 8. R&D systems

R&D systems	Developed country studies	Developing country studies
R&D systems	7,8	22, 29

Table 8 reveals that R&D systems are not frequently discussed in the literature. Nevertheless, we found that there are some differences in the R&D systems in developed and developing countries. In developed countries, it appears the systems are strong. Dressler and Paunovic (2021) found that on German wine farms the practical use of 4IR technologies such as AI and Big Data appeared absent, however, R&D was ongoing. A few of their interviewees were wine farm managers/owners who are involved in R&D in one way or the other. For instance, they had one interviewee who is a winery owner and wine software developer, another who runs experimental wine software development at a university and finally a professor of robotics and geoinformatics in the wine industry. In Hungary, we note the abundant availability of R&D resources, which Endrődi-Kovács and Stukovszky (2022) emphasize are only slightly below the EU average. However, SMEs do not participate in these research projects (Endrődi-Kovács & Stukovszky, 2022) for reasons that include a lack of skill on their part.

In developing countries, we note that R&D appears to be poor. This is attributed to the lack of investment by the government (Serumaga & Van der Poll, 2021). Serumaga and Van der Poll (2021) proceeded to put forth a proposition in their study that increases in R&D investments by the government may facilitate the adoption and implementation of 4IR technologies in sub-Saharan countries.

DISCUSSION

The findings indicate that there are similarities and differences in the NIS of developed and developing countries. These are shown in Table 9.

Table 9. NIS of Developed and Developing Countries – Similarities and Differences

Innovation system element	Similarities	Differences	
		Developed country	**Developing country**
Intra-firm interactions	Manager-Worker	Organizational structural change Intergenerational teams	Departmental interactions
Inter-firm relationships	SME-Academia SME-SME	SME-Competence Centers SME -Customers SME-Solution provider	
Role of the government	Provide Funding Develop Regulation	Provide Training Create ecosystems	Lack of digital infrastructure provided
Funding mechanisms	Government Funding		External funding (bank loans, private funders) Internal funding
R&D systems		R&D systems	

Intra-firm interactions

The literature suggests that departmental interactions are taking place within SMEs to capture and share knowledge for accountability purposes, where each department understands how their work affects the rest of the organization (Joshi et al., 2022) and for input in technology solution design (Mittal et al., 2020). This finding was only observed in studies from developing countries. However, the researcher opines that this interaction must be taking place in developed countries, albeit not recorded in the primary studies used for this research. It is generally accepted that knowledge and its flow are important for innovation to take place. As explained by Edquist (2006), the innovation process is complex and involves the emergence and diffusion of knowledge. Furthermore, Lundvall (2016) explained that innovation requires dialogue, an exchange of information, and knowledge between different people in different departments and at different levels. It follows then that the flow of knowledge would be both internal and external to the firm for innovation to take place in developed and developing countries.

Our findings, aligned with Lundvall's (2016) insights on organizational interactions, highlight that the predominant interaction within SMEs is between managers and workers. Leadership extends beyond vision-casting, encompassing responsibilities for cultivating an innovation-driven environment. This involves guiding, ensuring resource provision, fostering skill development, and notably, dismantling hierarchical structures to encourage open idea exchange among workers. Overlooked is the significance of worker empowerment, which goes beyond seeking opinions to emphasize active engagement. This empowerment involves granting decision-making authority, facilitating skill enhancement, promoting a culture valuing diverse perspectives, and recognizing the pivotal role of workers in technological decisions. The literature suggests that when managers provide vision, leadership, and guidance to workers, and workers are actively involved and engaged in decision-making for 4IR technological solutions, the likelihood of successful adoption increases.

Two striking differences between developed and developing nations were observed in this study. SMEs in developed nations are changing the structure of their organizations by reducing the hierarchical levels and adopting a more 'network' approach, where workers are given more control and power to make decisions about new technologies (Cimini et al., 2020). We see the inappropriateness of high levels of hierarchy in digital transformation literature, where they are considered inappropriate in the sense that they hinder communication and knowledge sharing among organization members, with lower-level workers suffering the most because they have no authority to make decisions (Agrawal et al., 2020). This is detrimental to the adoption of 4IR technologies as it is the worker who works with the technology, and if they have no input in the decision-making process, then adoption would be difficult. Therefore, we make the following research proposition (RP):

RP1: Lowering the levels of hierarchy within the SME may positively influence the adoption of 4IR technologies in developing countries.

We also observed the use of intergenerational teams within organizations in developed countries, where the young and techno-savvy work together with the old and experienced workers for innovation purposes (Garbellano & Da Veiga, 2019; Surianarayanan & Menkhoff, 2020). This is in line with studies performed on intergenerational teams, whereby findings indicate that age difference, amongst other things, positively affects a firm's innovation activities (Zhu & Kang, 2022). Intergenerational teams leverage diverse skills and experiences for innovation. They facilitate knowledge exchange and offer varied perspectives, enhancing problem solving. However, communication barriers and conflicts in work styles can impede collaboration. Understanding contextual influences, addressing resistance to change and promoting inclusive leadership is vital. While intergenerational teams hold potential, effective management of diverse dynamics is crucial for maximizing innovation outcomes. It is on this basis that we make the following research proposition (RP):

RP2: The use of intergenerational teams within the SME may positively influence the adoption of 4IR technologies in developing countries.

Inter-firm interactions

The findings indicate that SMEs in both developed and developing countries interact with Academia and other SMEs. This is in line with Edquist (2006) who stated that firms do not innovate in isolation but through interactions with other firms to develop and exchange knowledge and resources.

Lundvall (2016) echoes the same sentiments and adds that recent innovation models show that firms interact with suppliers, customers, and knowledge institutions (Academia). On that note, our findings further indicate that SMEs in developed countries are the ones interacting with customers and solution providers. In developing countries, it is noted that there is a lack of interaction between SMEs and customers (De Lucas Ancillo et al., 2022). However, of interest are the Competence Centers noted in developed countries. The role of these Centers is to bring together key actors in the innovation ecosystem, namely Academia, government and private sectors, to support SMEs toward a human-centered implementation of 4IR (Ietto et al., 2022). They are also used by SMEs to acquire 4IR competencies. This has proved to be of influence in the adoption of 4IR technologies in developed countries. While innovation hubs and labs exist in developing countries, they facilitate organic skill transfer through interaction and may not always offer structured learning opportunities tailored to particular technological domains. In contrast, Competence Centers provide a focused approach, offering targeted programs and resources to bridge skill gaps in critical areas, enabling a more directed and accelerated acquisition of specialized knowledge and capabilities necessary for technological development. These centers help address the need for structured skill development, ensuring a more efficient and comprehensive transfer of expertise required to leapfrog technological barriers often faced by developing economies. On that basis, we make the following research proposition (RP):

RP3: Introducing Competence Centers to the innovation systems of developing countries may positively influence the adoption of 4IR technologies by SMEs.

The academic discourse appears to lack an in-depth exploration of the societal dimension within these interactions. Specifically, there is a noticeable gap in examining socio-cultural factors, societal perceptions, digital literacy rates, and cultural attitudes toward technology, and their impact on SMEs' inclination to adopt emerging technologies. Alexander (2021) proposes the cultivation of collaborative co-creation involving industry, civil society, research, and government stakeholders, highlighting the need to address this lacuna in academic discussions.

Role of the government

It appears from the literature that the role of the government is to assist SMEs with funding, incentives, and subsidies. However, we note that this is more prevalent in developed nations (Da Roit & Iannuzzi, 2022, Garbellano et al., 2019) than in developing where even though funding is available, it is insufficient and takes long to access (Serumaga and van der Poll, 2021, Rojas-Berrio et al., 2022), negatively affecting 4IR adoption. This could be because developed countries have finances to support SMEs, which developing countries do not necessarily have.

It also appears that the role of the government includes regulation. There is a plethora of literature that echoes these findings and adds that the role further includes the generation, development, and enforcement of national policies, standards, roadmaps, and strategies as well as creating a legal framework that deals with challenges created by 4IR technologies (Burgess & Connell, 2020; Zervoudi, 2020).

Of interest to note is the lack of digital infrastructure in developing nations. It appears this is a pain point that is negatively affecting the adoption of 4IR technologies by SMEs in developing countries (Serumaga & Van der Poll, 2021). As highlighted by Lundvall (2016), the government needs to build infrastructure to contribute to the technical advancement of a country. Nevertheless, we see countries such as South Africa attempting to mend this issue. The Independent Communications Authority of South Africa (ICASA) concluded the long-standing radio frequency auction in March 2022, releasing spectrum for 5G, for use by 2024 (Business Tech, 2022; ICASA, 2022). This is indicative of high-speed internet technology improvements in the country, which should improve adoption. Therefore, we make the following research proposition (RP):

RP4: The improvement of digital infrastructure by governments in developing countries may positively influence the adoption of 4IR technologies by SMEs.

In the context of developing countries, the government's role should encompass considerations of inclusivity and equity in the adoption of 4IR technologies. However, the existing literature seems to overlook this critical aspect. There is an evident gap in understanding how government policies and strategies are formulated to ensure that the adoption of technology benefits a diverse range of SMEs, particularly those operating in marginalized or underrepresented sectors.

This area warrants exploration to gauge the effectiveness of policies in fostering equitable access and opportunities for technological advancement across different segments of the SME landscape in developing nations.

Funding mechanism

Our findings reveal that government funding is important in encouraging SMEs to adopt 4IR technologies in both developed and developing countries. However, it appears that because of the insufficiency of government funding in developing countries, SMEs tend to approach banks and other external funders, who are also of not much help (Rojas-Berrio et al., 2022).

In developing countries, there tend to be numerous issues that governments must deal with, specifically social issues such as poverty, unemployment, public health, and community development. In South Africa, for instance, these take about 40% of the country's income, while only 10% is allocated to economic development. In developed countries, the same appears to be true. For instance, the USA spends about 60 to 70% of its budget on defense, healthcare, pensions, and welfare (https://www.usgovernmentspending.com) while China spends almost half of its budget on defense and about 10% on science and technology (https://chinapower.csis.org). However, even though the allocated percentages are somewhat similar, what we notice is that the budgets in developed countries are much larger than in developing countries. For instance, the total 2023 budget in China is $4 trillion while South Africa is $0.1 trillion. This means that China can spend a significantly larger amount on technology than South Africa can. Therefore, the following research proposition (RP) is made:

RP5: An increase in the total budget of developing countries may positively influence the adoption of 4IR technologies by SMEs.

R&D systems

Our findings suggest that R&D systems in developed countries exhibited greater strength compared to those in developing nations. This aligns with Alexander's (2021) observations, particularly in South Africa, where the research system presents a mix of strengths and challenges. While it excels in research-related domains, deficiencies emerge in education and research output. Challenges within public research encompass restricted knowledge exchange and insufficient engagement between Academia and businesses. Furthermore, the system lacks interdisciplinary research, and sectoral mobility, and emphasizes practical applications and public education to a lesser extent

Serumaga and Van der Poll (2021) further highlight the lack of government investment as another challenge. The World Bank data shows that developed countries spend a larger portion of their GDP on R&D in comparison with developing countries, as shown in Figure 5.

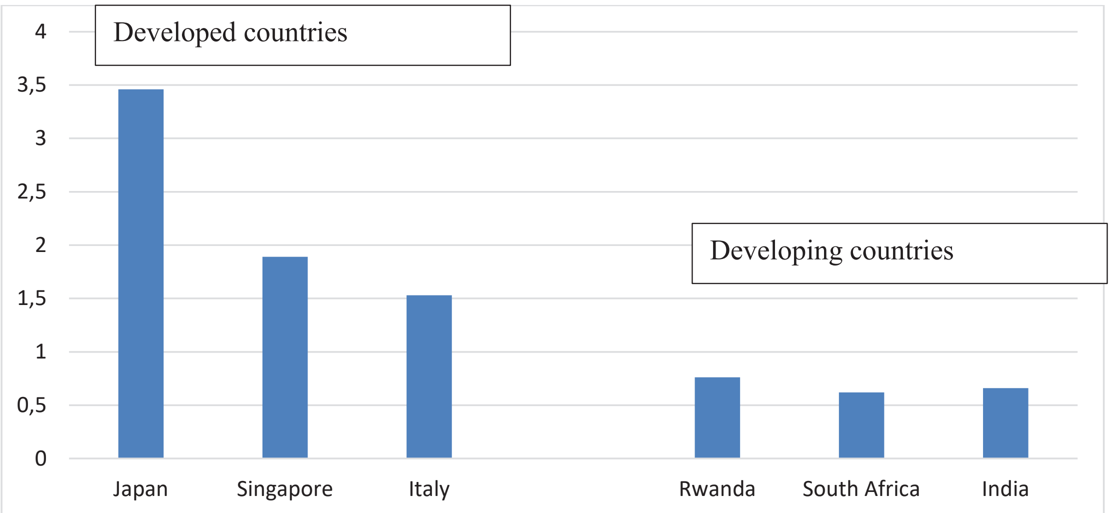

Figure 5. R&D expenditure as a percentage of GDP (developed vs. developing countries)
Source: World Bank (2022).

It can be seen in Figure 5 that developed countries can spend more than 1% of their GDP on R&D while developing countries spend less than 1%. Therefore, similar to Serumaga and Van der Poll (2021), the following research proposition (RP) is made:

RP6: An increased investment in R&D by governments in developing countries may positively influence the adoption of 4IR technologies by SMEs.

Conceptual model

Based on the propositions made in this study, the following conceptual model (Figure 6) is proposed to improve the innovation systems in developing countries and to encourage the adoption of 4IR technologies by SMEs.

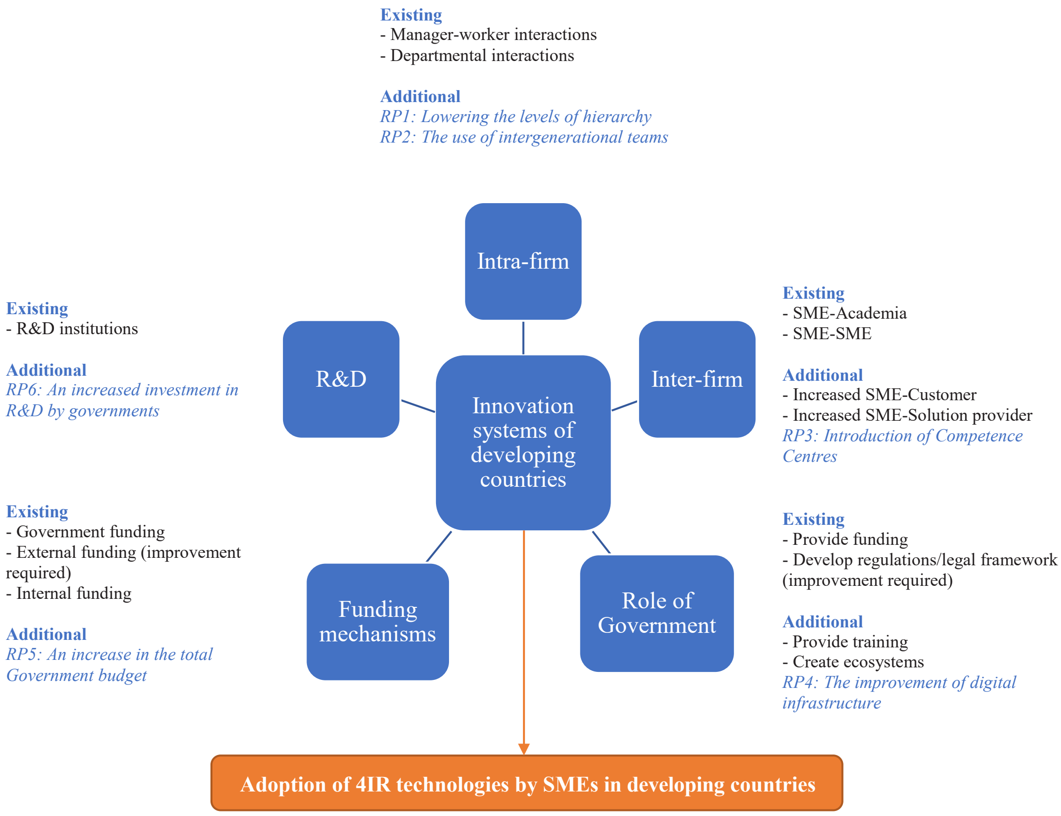

Figure 6. Conceptual model for the innovation system necessary for SMEs' adoption of 4IR technologies in developing countries

CONCLUSION

This study contributes significantly to the field of innovation studies by delving into the comparison of NIS in developed and developing countries. It is concluded that the innovation systems of developed and developing countries are more different than similar. Based on the findings, the intra-firm and inter-firm interactions in developed and developing countries have slight variations. The most significant differences were seen to occur in the funding mechanisms, the role of government, and R&D systems. The differences appear to have their roots in the level of investment made by developed nations vs. developing. Due to the larger budgets that are characteristic of developed countries, it was found that the elements of the innovation systems are stronger than in developing countries. Therefore, several propositions are made that relate to the level of investment and budget allocation.

In terms of practical implications, these findings hold significance for policy development and execution. Policymakers can leverage this study's insights to prioritize intra-firm and inter-firm collaborations, bolster government support through financial aid and regulatory frameworks, and invest in digital infrastructure and robust R&D systems. The study also presents a conceptual model for innovation systems in developing countries, offering a roadmap for policy formulation. On a theoretical level, this study underscores the pivotal role of intra-firm collaborations, inter-firm relationships, and governmental intervention in shaping innovation systems. It emphasizes the need for further exploration into stakeholder dynamics, hierarchical structures' impact, and the efficacy of diverse funding mechanisms and R&D systems in fostering 4IR technology adoption among SMEs. This suggests a direction for future research aimed at comprehensively understanding the intricate dynamics of innovation ecosystems within different economic landscapes.

It is the opinion of the researcher that to a small degree, the elements of the innovation system limited the reporting of the findings from the literature. A large number of papers mentioned the lack of competencies and digital skills in SMEs, highlighting how this has a significant impact on the adoption of 4IR technologies. The framework does not appear to allow for a discussion around these competencies, except in R&D systems where competencies are referred to in the context of research and development rather than in the adoption and implementation of technology.

Furthermore, the concept of an ecosystem is not clear in the framework and this has hindered the researcher from reporting on aspects of education and the role of Academia in the NIS. In his book, Lundval (2016, pg. 99) notes the national education and training system as "extremely important" but not covered well in the book. He recommends the integration of education with innovation as an aspect to consider for further research. This integration is crucial as it aligns education with the dynamic demands of innovation. Additionally, the collaboration between Academia and industry can facilitate knowledge exchange, research collaboration, and the development of practical solutions. This not only benefits educational institutions by providing real-world relevance to their programs but also empowers SMEs with a workforce well versed in cutting-edge technologies. We recommend the same for future research.

Further research is also essential to explore critical gaps identified in the literature review that could significantly impact SMEs' adoption of 4IR technologies. These gaps encompass socio-cultural elements, societal perspectives, as well as inclusivity and equity. Specifically, investigating how government policies and strategies are crafted to ensure technology adoption benefits a wide array of SMEs, particularly those operating in marginalized or underrepresented sectors, is crucial.

Moreover, it is important to acknowledge the limitations in the data collection. Focusing solely on "4IR technologies" as search terms may have inadvertently excluded relevant papers that discuss similar concepts using different terminology. For instance, some papers may have explicitly mentioned technologies like AI or Blockchain, which fall under the umbrella of 4IR. To address this issue, a broader array of synonymous terms or related keywords should be considered in future research to ensure a more comprehensive scope in the literature review.

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Authorship contribution statement

Lebogang Mosupye-Semenya: The author conducted all aspects of the research, including conceptualization, data collection, analysis, and writing of the manuscript.

Conflicts of interest

The author declares no conflict of interest.

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