

# Sustainable Development through Research and Innovation: Insights from East Asia and ASEAN's Engagement with SDGs

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## ABSTRACT

In an era marked by rapid economic growth, the nations of East Asia and the ASEAN stand at the forefront of innovation and sustainable development. Despite their significant progress, the depth of their research and innovation contributions has not been fully explored. This study aims to fill this gap by examining a comprehensive collection of 33,685 publications that have contributed to 21% of the global research efforts related to the United Nations Sustainable Development Goals (SDGs) since 2015. Focusing on China's leadership in SDG 7, "Affordable and Clean Energy," and the substantial efforts of countries such as Japan, Indonesia, the United States, South Korea, Malaysia, Taiwan, Thailand, Vietnam, the Philippines and Singapore, this research provides a detailed view of the innovation landscape in these regions. By utilizing advanced methods such as bibliometrics and BERTopic analyses, this study offers macroscopic as well as microscopic insights into innovation systems in the combined region of East Asia and ASEAN, thereby making it the first of its kind. As our study revealed an ongoing shift toward Industry 5.0, technological clusters related to key technologies such as digital twins, blockchain, network robotics, 3D printing or additive manufacturing will be game-changing technologies, while strategies based on digital and ICTs will be the key for marketing and managerial roadmaps of the region. By proposing evidence-based policy recommendations and highlighting the importance of embracing technologies crucial for Industry 5.0, this research presents valuable insights for building a more inclusive and sustainable future and for strengthening the innovation ecosystems of constituent countries. This study not only enriches the academic discussion on sustainable development and innovation but also provides practical guidance for policymakers, researchers and stakeholders across East Asia and the ASEAN, aiming to enhance the impact and effectiveness of their research and innovation ecosystems.

**Keywords:** Sustainable Development Goal, ASEAN, PRISMA, BER Topic Modeling, Citations analysis, Policy, Innovation.

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## INTRODUCTION

The Sustainable Development Goals (SDGs), endorsed in 2015 by 193 UN Member States, focus on eradicating poverty, promoting environmental sustainability and ensuring peace by 2030. However, only 12% of targets are on track, emphasizing the urgency for accelerated efforts.<sup>[1]</sup> Achieving SDGs requires countries to undergo significant, thoughtful and rapid transformations in terms of resource utilization, technologies, infrastructure, organizations and social relations.<sup>[2]</sup> The global

pursuit of SDGs consists of efforts at various levels spanning from the individual and community levels to the national and multinational/regional levels. For instance, as Asia is the most dynamic economic area in the world, the contribution of the Asia-Pacific region can be vital for overall global progress and the pursuit of SDGs. The Asia-Pacific region-including Japan; the Four Asian Tigers of South Korea, Taiwan, Hong Kong and Singapore; China; and other members of the Association of Southeast Asian Nations (ASEAN)-has emerged as the most vibrant economic bloc in the world, accounting for nearly 1/3<sup>rd</sup> of the global GDP.<sup>[3]</sup> Southeastern Asia's population is equivalent to 8.54% of the total world population and approximately 4.7 billion people, or 60% of the world's population and currently resides in Asia and the Pacific.<sup>[4]</sup> Together, East Asian countries (including China, Japan and South Korea) and Southeast Asian



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or ASEAN countries (including Singapore, Brunei and Thailand) constitute the critical economic mass of the Asia-Pacific region. Therefore, due to the economic and demographic importance of the combined region, the innovative R&D and allied industrial activities of this region deserve special global attention and we chose this region for our analysis.

ASEAN Member States are anticipated to fall short of 90% of their SDG targets based on current trends.<sup>[1]</sup> The ASEAN region faces heightened vulnerability without meeting these targets.<sup>[5]</sup> In terms of economic dimensions, East Asian economies lag, while Southeast Asia and Central/West Asia exhibit relatively better performance in achieving the SDGs. Socially and institutionally, East and Central Asian countries outperform their counterparts and West and South Asian countries demonstrate notably better environmental performance.<sup>[6]</sup>

The most substantial progress in the region has been made on affordable and clean energy (SDG 7) and industry, innovation and infrastructure (SDG 9).<sup>[11]</sup> Although ASEAN countries have recognized renewable energy targets, the region has yet to harness its vast renewable energy potential.<sup>[7]</sup> Progress on the environmental dimensions of the SDGs is widely considered insufficient, especially in Asia.<sup>[8]</sup> Distinct factors foster innovation for both R&D and non-R&D groups in ASEAN economies, focusing on technology transfer, startup support and international collaboration. Efficiently measuring the impact of these initiatives is crucial for guiding future strategies in achieving collaborative, sustainable progress toward the SDGs.<sup>[9]</sup> Glimpses of key findings of one such recent attempt related to the ASEAN region are shown in Figure 1.

Apart from these studies that somewhat directly tracked the progress of SDG pursuit in the region of interest (i.e., East Asian and ASEAN countries), some studies used a bibliometric approach that reviewed the developments, innovation systems and SDG-related contributions related to the region (please see the 'Literature Review' section) along with other regions and countries. However, these studies are either too broad (touching several aspects at a stretch, not providing deeper insights related to some or all) or too specific (intense discussions on one or two specific themes or fields related to SDGs) in scope. Studies that discuss the contributions of the region at both macroscopic and microscopic scales can be of immense use to multiple stakeholders. Some attempts at both macroscopic and microscopic (to some extent) analysis of research using bibliometric techniques are discussed next.

Tan *et al.*, analyzed approximately 21,225 papers related to climate change from the BRI (Belt and Road Initiative) region during 2013-2018.<sup>[10]</sup> They examined the top contributing countries, major broad thematic areas (macroscopic analysis) and major-specific topics (semi microscopic analysis). Uddin

and Singh, mapped 'Computer Science' research in SAARC countries to determine growth trends and impacts, collaboration levels and text-based research topic trends (macroscopic and semimicroscopic).<sup>[11]</sup> Dragomir and Dumitru, reviewed 'circular economy' research in the European region, created a thematic map, determined key clusters (semimicroscopic) and analyzed some key works in these clusters (microscopic).<sup>[12]</sup> Thus, regional studies that conducted systematic analyses using a bibliometric approach at both the macroscopic and microscopic levels are not abundant. To the best of our knowledge, in the case of the region in the Asia-Pacific region that is formed by combining East Asian and ASEAN countries, there are no such attempts. This gap is addressed in the current work.

This study aims to uncover the distinctive contributions of East Asian and ASEAN countries to the SDGs, providing crucial insights for targeted implementation. Considering diverse challenges, resources and cultural contexts, regional contributions are pivotal for global SDG achievement.<sup>[13]</sup> Recognizing and leveraging regional strengths promotes inclusive and sustainable approaches to address interconnected SDG challenges. Current research lacks a comprehensive regional analysis of SDG contributions, particularly for East Asian and ASEAN countries, necessitating an examination of commonalities, differences and leading contributors (such as countries) and leading funding agencies. For instance, Borgohain *et al.*,<sup>[14]</sup> explored leading countries and funding patterns related to nanotechnology research in the SAARC region, though with limited discussions of implications. This information might help governments and other decision-makers enhance collaborative research in the region with or without the formation of consortiums of funding agencies and a pool of resources within the region. More profound explorations are necessary in the case of SDG-related research for other regions, especially for the region of interest, as such explorations are not available to the best of our knowledge. In addition, macroscopic and microscopic analysis via the determination of (i) key research themes (macroscopic) in thematic clusters and (ii) key topics and key specific contributions within such topics (microscopic) is also attempted. These are vital for strengthening the national innovation ecosystems of respective individual countries and thereby strengthening the region as a whole and in turn at the global level. The findings will inform stakeholders, facilitating informed strategies for impactful progress toward SDGs.

The research questions for this study are as follows:

RQ1: Which are the major SDGs to which East Asian and ASEAN countries contributed predominantly?

RQ2. Which countries are leading contributors to SDG research?

RQ3: Who are the most prolific funding institutions for SDG research?

RQ4: Which are the SDGs to which East Asian and ASEAN countries can contribute better due to their interlinkage, with most contributing SDGs?

RQ5: Which major broad thematic areas are related to the SDGs to which East Asian and ASEAN countries have contributed predominantly?

RQ6: Which are the major specific topics related to SDGs to which East Asian and ASEAN countries contributed predominantly and which are the key specific contributions within those topics?

## LITERATURE REVIEW

SDGs constitute a universal action plan for global cooperation on sustainable development from 2015 to 2030, with the imperative that goals and targets be achieved by all countries and societal cohorts.<sup>[15]</sup> The 2030 Agenda outlines 17 SDGs encompassing 169 targets addressing poverty reduction, environmental protection,

human prosperity and peace, incorporating specific goals, targets and indicators.

In the past two decades, sustainable development has been explored from various perspectives, with increasing attention given to this topic in academic disciplines, including SDG research.<sup>[16]</sup> Körfgen *et al.*,<sup>[17]</sup> introduced a tool, using Austrian universities as an example, to map research aligning with SDGs, revealing a well-represented focus on SDG 3 (Good Health and Well-being) and SDG 4 (Quality Education), while SDGs 1 (No Poverty) and 14 (Life Below Water) are underrepresented. Raman *et al.*,<sup>[18]</sup> found that approximately 25% of business research aligns with SDGs, with SDGs 3 and 7 (Affordable and Clean Energy) being the most addressed. Pizzi *et al.*,<sup>[19]</sup> examined the impact of businesses on sustainable development, identifying four key research themes from 2012 to 2019. Kumar *et al.*,<sup>[20]</sup> conducted a bibliometric analysis of QREI research publications, identifying SDGs 9, 7 and 3 as the most prominent (Industry, Innovation and



Figure 1: Snapshot of SDGs in ASEAN. Source: The 2022 ASEAN SDG Snapshot Report.

Infrastructure; Affordable and Clean Energy; Good Health and Well-being).

East Asian nations, notably China and Japan, propel the impact of SDGs through strong economic growth and technological innovations, influencing poverty reduction and infrastructure advancements. Within the ASEAN region, collaborative efforts primarily focus on key social development goals, reflecting a shared commitment to holistic and sustainable development aligned with SDG principles. Elder and Ellis,<sup>[8]</sup> examined how ASEAN countries reported their environment-related SDG policies in Voluntary National Reviews (VNRs) and developed a dataset of these environmental policies.

Research on SDG contributors involve analyzing countries, organizations and authors, significantly contributing to the SDG-related literature. A bibliometric analysis focused on "good health and well-being" from 2015 to 2019, revealed the dominance of SDG research in the European region (52.2%).<sup>[21]</sup> Siddiqui *et al.*,<sup>[22]</sup> identified China as the foremost contributor to a systematic review of literature themes on SDG assessment methods. Mishra *et al.*,<sup>[23]</sup> explored SDG progress through a bibliometric analysis from 2015 to 2022, highlighting the USA, China and the UK as contributing 31% of research productivity. Yamaguchi *et al.*,<sup>[24]</sup> conducted a bibliometric analysis, pinpointing the UK, the USA and Australia as prolific regions. Bautista-Puig *et al.*,<sup>[25]</sup> explored trends in SDG-related research within higher education and research centers from 2000 to 2017. Ferrer-Estévez and Chalmeta,<sup>[26]</sup> focused on integrating SDGs in educational institutions, examining the incorporation of these principles. Singh *et al.*,<sup>[27]</sup> specifically investigated the response of the Indian scientific community to the SDGs, providing insights into research output and themes from Indian institutions.

Previous studies on SDG research contributions have employed diverse methodological approaches, showcasing the field's multidisciplinary nature. Network analysis has been instrumental in examining collaboration,<sup>[28]</sup> coauthorships and knowledge flows among researchers and institutions. Bibliometric analysis has been widely used to quantify and evaluate scholarly output.<sup>[29]</sup> It involves assessing publication trends, authorship patterns, citation impacts and thematic concentrations within the SDG research domain. Such analyses help identify influential works, emerging trends and gaps in the literature, informing future research directions. Systematic literature reviews have also been used to analyze SDG research contributions.<sup>[30,31]</sup>

While research has been conducted on sustainable development and the SDGs, there are notable gaps in the literature, particularly regarding comprehensive regional analyses of SDG contributions. An existing study,<sup>[17]</sup> have focused on specific regions, providing insights into mapping research related to sustainability topics defined by the SDGs. However, a broader examination of East Asian and ASEAN countries is needed to identify commonalities,

differences and leading contributors to SDG implementation. The literature also lacks a thorough exploration of funding patterns related to SDG research in different regions. Additionally, while there is some research on the environmental policies of ASEAN countries in the context of SDGs,<sup>[8]</sup> a broader examination of contributions from East Asian nations and the ASEAN region is necessary.

In this research, network analysis, inspired by Meschede,<sup>[28]</sup> will unveil collaborative patterns among East Asian and ASEAN countries in SDG research. Following Sreenivasan *et al.*,<sup>[13]</sup> bibliometric analysis quantifies scholarly output, authorship patterns and thematic concentrations, providing insights into regional contributions. This multidimensional approach addresses defined research questions by exploring collaborative networks, scholarly output and the literature on East Asian and ASEAN contributions to the SDGs. This study uniquely explores the SDG contributions of East Asian and ASEAN countries, revealing major contributors, funding dynamics and improvement areas. Scrutinizing leading SDG contributions addresses gaps in the literature and provides nuanced insights for evidence-driven decision-making. The upcoming section details the methodology, ensuring a systematic investigation aligned with research questions on major contributors, leading countries, institutional dynamics and funding patterns.

## METHODOLOGY

This research employs an innovative blend of bibliometric and BER Topic analyses to determine the contributions of the East Asian and ASEAN regions to the SDGs, guided by specific research questions. It utilizes bibliometric analysis to evaluate both the quantitative and qualitative dimensions of literature, adhering to a systematic methodology framed by the PRISMA-P 2015 guidelines. This approach ensures a structured review process, as depicted in Figure 2. Following PRISMA protocols, the review selectively includes East Asia and ASEAN studies relevant to Sustainable Development Goals (SDGs), specifically focusing on publications from 2015 to 2023 that align with SDG 9 criteria, including the availability of abstracts and critical details such as source and author names.

The Dimensions database is used for bibliometric analysis because it has more exhaustive journal coverage than the Web of Science and Scopus databases.<sup>[32]</sup> Other studies have compared the reliability and validity of data quality between Dimensions and other data sources.<sup>[33]</sup> Dimensional databases have developed distinct mechanisms for filtering and mapping SDG research publications.<sup>[34]</sup> Exclusion criteria were applied to ensure the robustness of the analysis. Publications were excluded if they lacked an abstract, source name, or author name. Any duplicate records identified during the screening process were excluded to prevent redundancy.

The dataset, gathered from the Dimensions database, encompasses 73,02,121 publications associated with various Sustainable Development Goals (SDGs 1-17). Of these, 17,46,540 publications underwent initial screening. A focused screening was conducted on 33,937 publications related to SDG 9 from East Asia and the Association of Southeast Asian Nations (ASEAN) for further analysis. The ASEAN currently includes ten member states: Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam, as reported by the Association of Southeast Asian Nations.<sup>[35]</sup> East Asia comprises China, Japan, South Korea, Taiwan, North Korea, Mongolia, Hong Kong and Macao, according to the World Bank.<sup>[36]</sup> The subsequent exclusion of 252 publications was necessary due to the absence of abstracts, source names and author names. Consequently, 33,685 publications pertinent to SDG 9 from East Asia and the ASEAN countries were selected for further analytical consideration. With this, RQs from 1 to 3 can be addressed.

Our co-occurrence analysis employed VOS viewer, a software application crafted for constructing and visualizing bibliographic networks.<sup>[37,38]</sup> VOS viewer software can analyze a significant amount of data and provide excellent network data mapping and

clustering.<sup>[39,40]</sup> The basis of our analysis lies in the co-occurrence of SDG mapping for each publication. Each node represents a distinct SDG of the publication, with lines connecting nodes indicating the frequency of co-occurrence. The color of a node often denotes the cluster or group to which a publication belongs and each color signifies a different thematic cluster. This clustering is grounded in the similarity of co-occurrence patterns, implying frequent discussion in the literature. The distance between nodes in the visualization is also significant; a shorter distance indicates a stronger or more frequent co-occurrence, suggesting closer relationships or a higher degree of topic relevance. This helped to achieve RQ4. Analysis of the top keywords in each of the identified clusters can provide an overview of the broad thematic orientation of clusters and thereby address RQ5. The satisfactory achievement of RQs 1 to 5 ensures the successful completion of macroscopic analysis.

In the process of topic modeling, the BER Topic method was employed. This sophisticated approach uses transformers and the Class-TF-IDF Transformer to create dense clusters, facilitating the generation of coherent topics that preserve the crucial terms in their descriptions.<sup>[41]</sup> The implementation of BER Topic allowed for the extraction and analysis of significant topics from

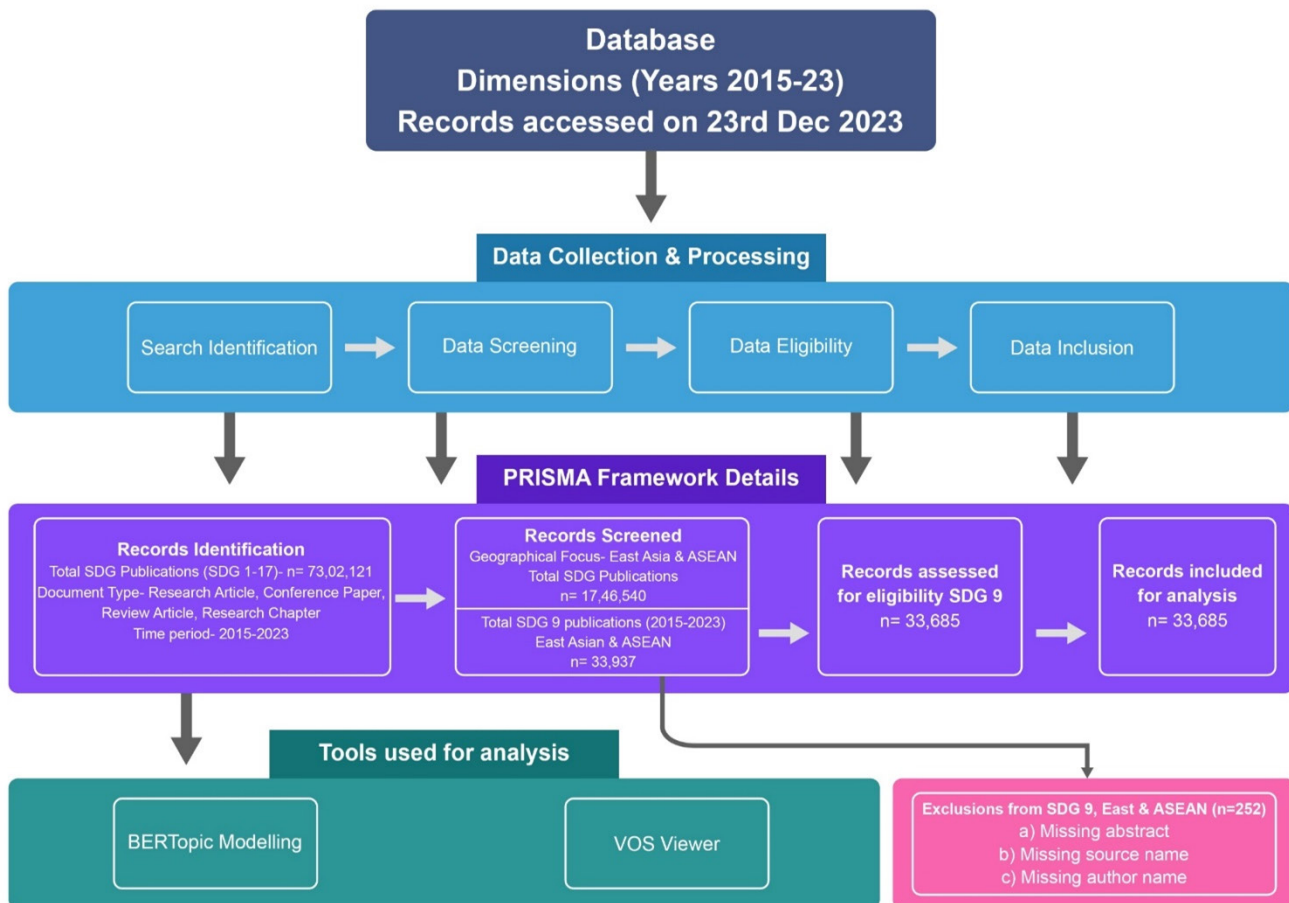


Figure 2: PRISMA framework.

reviews on AI and ML applications, enhancing the depth of understanding in this specific area of research. Following data extraction, the dataset underwent an extensive preprocessing phase to improve its quality and consistency. This phase included text cleaning, the application of Natural Language Processing (NLP) techniques and tokenization. Further refinement of the dataset was achieved through the use of sentence embeddings produced by the "all-mpnet-base-v2" model from the Sentence Transformer and the application of dimensionality reduction via Uniform Manifold Approximation and Projection (UMAP). These steps were instrumental in achieving precise topic extraction and effective visualization. The top ten papers on innovation from each cluster were identified. By employing BER Topic modeling again, seven topics represented by three representative papers were identified, providing a nuanced understanding of thematic concentrations and achieving RQ6.

## RESULTS AND DISCUSSION

### Major contributions to key SDGs

The commitment of East Asia and ASEAN countries to the United Nations Sustainable Development Goals (SDGs) is quantitatively significant, with a research output constituting 21% of global publications aligned with the SDGs since their inception in 2015. RQ1 highlighted the major SDGs to which East Asian and ASEAN countries contributed predominantly, as shown in Table 1.

Quantitatively, East Asia and the ASEAN have made noteworthy contributions to SDGs, constituting 21% of global research publications since 2015. Notably, SDG 7, "Affordable and Clean Energy," which accounts for 36.67%, showcased a robust focus on energy sustainability. SDG 3, "Good Health and Well-being," contributes substantially to 35.46%, highlighting the region's emphasis on health. SDG 13, "Climate Action," receives 8.75% of the total, aligning with the global imperative to address climate change. Moreover, 7.45% of SDG 4, "Quality Education," reflects a commitment to educational quality and accessibility for sustainable development. The scholarly focus on "Life on Land" (SDG 15), "Zero Hunger" (SDG 2) and "Life below Water" (SDG 14) highlights a concerted approach toward environmental conservation and biodiversity, which are vital for the sustainability of natural resources and food security. The substantial research on "sustainable cities and communities" (SDG 11) also reflects the regional investment in urban development that harmonizes economic growth with ecological balance.

While commendable dedication is seen in SDG 7, "Affordable and Clean Energy," and SDG 3, "Good Health and Well-being," constituting 36.67% and 35.46% of research output, respectively, there is markedly lower academic engagement with SDGs 6, 5, 10 and 1. These SDGs, addressing "Clean Water and Sanitation," "Gender Equality," "Reduced Inequalities," and "No Poverty," collectively constitute less than 2% of publications. This disparity

**Table 1: The contributions of East Asian and ASEAN countries to the SDGs.**

SDG	TP	TC
 7 AFFORDABLE AND CLEAN ENERGY	6,39,959	1,34,72,869
 3 GOOD HEALTH AND WELL-BEING	6,18,951	83,70,479
 13 CLIMATE ACTION	1,52,724	29,83,470
 4 QUALITY EDUCATION	1,30,068	5,47,128
 15 LIFE ON LAND	94,656	13,31,457
 2 ZERO HUNGER	65,072	9,47,900
 14 LIFE BELOW WATER	64,378	9,20,983
 11 SUSTAINABLE CITIES AND COMMUNITIES	62,067	7,24,840
 16 PEACE, JUSTICE AND STRONG INSTITUTIONS	41,054	1,72,666
 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	38,600	6,90,395
 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	33,685	4,06,425
 8 DECENT WORK AND ECONOMIC GROWTH	26,179	2,07,689
 6 CLEAN WATER AND SANITATION	19,768	3,47,675
 10 REDUCED INEQUALITIES	16,196	1,45,755
 5 GENDER EQUALITY	8,827	44,777
 1 NO POVERTY	5,898	50,813
 17 PARTNERSHIPS FOR GOALS	1,257	14,146

might indicate either a strategic decision to focus resources where the impact is perceived to be greatest or a potential oversight of crucial dimensions of sustainable development. The underrepresentation in scholarly output for SDG 5 and SDG 10 raises questions about the integration of gender perspectives and addressing inequalities in the broader research agenda. Moreover, the relatively limited attention given to SDG 6 and SDG 1 suggests a need for increased academic and policy-driven research to

**Table 2: Most productive countries in SDG research.**

Name	TP	TC
China	11,32,598	2,17,15,877
Japan	2,02,360	27,65,660
Indonesia	1,88,404	5,88,607
United States	1,66,167	56,25,465
South Korea	1,47,442	27,43,264
Malaysia	75,651	11,85,203
Taiwan	70,489	11,70,164
United Kingdom	67,623	22,26,577
Australia	55,635	20,39,210
Thailand	42,131	5,88,211

innovate in water management and poverty alleviation, which is pivotal for the socioeconomic uplift of these regions.

For East Asia and the ASEAN to achieve balanced and inclusive development, diversifying their research portfolios across all 17 SDGs is strategic. While energy and health receive significant attention, there is a need to bolster efforts in underrepresented areas crucial for long-term sustainability. Encouraging interdisciplinary research can bridge the gap between environmental and social issues, fostering a holistic approach to sustainable development.

The scholarly contributions of East Asia and the ASEAN not only reflect their commitment to the SDGs but also suggest strategic prioritization based on regional developmental goals. Robust citation figures in energy and health-related research underscore their global impact, while the focus on environmental goals highlights a proactive stance on ecological issues. Emphasizing education aligns with sustainable socioeconomic advancement, collectively depicting deep engagement with the SDGs and contributing to a more sustainable and equitable future.

### Most Productive Countries

RQ2 addressed which countries are leading contributors to SDG research. In the landscape of global research contributions to SDGs, East Asia and ASEAN countries stand out for their substantial publication output, reflecting the vigor and extent of their academic and scientific endeavors. The most productive countries in terms of SDG research are highlighted in Table 2. China is at the forefront, leading with a staggering 11,32,598 publications, underscoring its colossal research infrastructure and strategic emphasis on innovation and academic excellence. This number represents a significant portion of the global research output, indicating that China is a dominant force in the scholarly world.

Japan follows China, with 2,02,360 publications, indicating its strong research culture and technological advancement. With 1,88,404 publications, Indonesia highlights the ASEAN region's growing research capabilities and commitment to knowledge

development, which is particularly impressive given its emerging economic status. These figures from Indonesia suggest a robust investment in academic growth, potentially transforming its regional influence on research and development.

The United States, often seen as a global leader in research, has 1,66,167 publications, which may reflect the competitive nature of research contributions from East Asia. South Korea and Malaysia follow suit with 1,47,442 and 75,651 publications, respectively, emphasizing their roles as significant contributors to global research and innovation. The presence of Taiwan and Thailand further cements the impression of East Asia and the ASEAN as active contributors to the international scholarly community. Notably, the data reveal that countries such as Vietnam, the Philippines and Singapore are not far behind, with their research outputs indicating a vibrant and growing academic presence on the global stage. This is particularly noteworthy for Singapore, which, despite its small size, boasts 19,962 publications, underscoring the efficacy of its research investments and the high quality of its academic institutions.

The data illustrate that East Asia and the ASEAN are not just participating but are actively shaping the global research landscape. Their contributions across a diverse array of scientific and scholarly fields underscore

Table 3 provides an insightful look into the varying research priorities of different East Asian countries concerning the UN SDGs.

China stands out as a dominant contributor across all SDGs, particularly in SDG 7, "Affordable and Clean Energy," reflecting a national focus on sustainable energy practices due to high industrial output. Japan's emphasis on SDG 3, "Good Health and Well-being," aligns with its established healthcare system and aging population. Indonesia's strong interest in SDG 4, "Quality Education," correlates with efforts to enhance educational standards and accessibility for ongoing development. South Korea, akin to China, emphasizes SDG 7, reflecting its technological leadership and focus on sustainable energy solutions. Malaysia shows balanced contributions across the SDGs, with a diversified approach to sustainable development. Taiwan's research spans SDGs 3 and 7, particularly focusing on "Good Health and Well-being" due to its robust healthcare system and medical research advancements.

Each country's research aligns with socioeconomic needs, developmental priorities and policy agendas. China's overarching presence emphasizes its global role, especially in sustainable energy. Japan prioritizes health in response to domestic challenges and global leadership in medical technology. The lower publication figures for SDGs 10, 5 and 1 suggest a potential gap in research focused on social issues, indicating a need for increased emphasis on equality, gender and poverty to ensure a balanced approach to sustainable development.

**Table 3: Varying research priorities of different East Asian countries.**

SDG	China	Japan	Indonesia	South Korea	Malaysia	Taiwan	Thailand	Australia
<b>7</b> AFFORDABLE AND CLEAN ENERGY	4,81,321	52,952	16,348	56,835	21,353	0,147	8,090	17,458
<b>3</b> GOOD HEALTH AND WELL-BEING	3,58,317	89,495	41,952	60,118	21,991	32,901	22,158	18,948
<b>13</b> CLIMATE ACTION	1,04,883	16,985	8,590	11,591	8,150	4,516	3,186	6,876
<b>4</b> QUALITY EDUCATION	40,096	13,080	54,387	5,462	8,242	5,067	3,067	2,598
<b>15</b> LIFE ON LAND	57,819	10,816	15,407	3,856	3,975	1,847	2,083	4,280
<b>2</b> ZERO HUNGER	38,689	7,011	9,387	3,332	3,019	1,578	1,967	2,626
<b>14</b> LIFE BELOW WATER	43,509	8,640	4,989	4,013	2,226	1,934	975	2,854
<b>11</b> SUSTAINABLE CITIES AND COMMUNITIES	36,643	7,596	9,223	2,886	3,541	1,838	1,175	1,997
<b>16</b> PEACE, JUSTICE AND STRONG INSTITUTIONS	12,147	3,254	18,273	2,158	2,520	1,171	890	1,014
<b>12</b> RESPONSIBLE CONSUMPTION AND PRODUCTION	23,618	2,659	4,165	2,490	4,078	1,865	1,369	1,425
<b>9</b> INDUSTRY, INNOVATION AND INFRASTRUCTURE	19,941	2,135	4,982	2,522	2,262	1,901	616	787
<b>8</b> DECENT WORK AND ECONOMIC GROWTH	11,353	2,900	6,189	1,817	2,003	801	690	816
<b>6</b> CLEAN WATER AND SANITATION	12,677	1,506	2,267	1,193	1,315	475	476	808
<b>10</b> REDUCED INEQUALITIES	9,533	1,795	2,002	1,239	577	573	408	639
<b>5</b> GENDER EQUALITY	2,425	1,123	3,106	704	583	334	283	373
<b>1</b> NO POVERTY	2,901	525	1,454	185	431	79	131	231
<b>17</b> PARTNERSHIPS FOR THE GOALS	574	177	190	141	75	33	59	66

### Prolific Funding Institutions

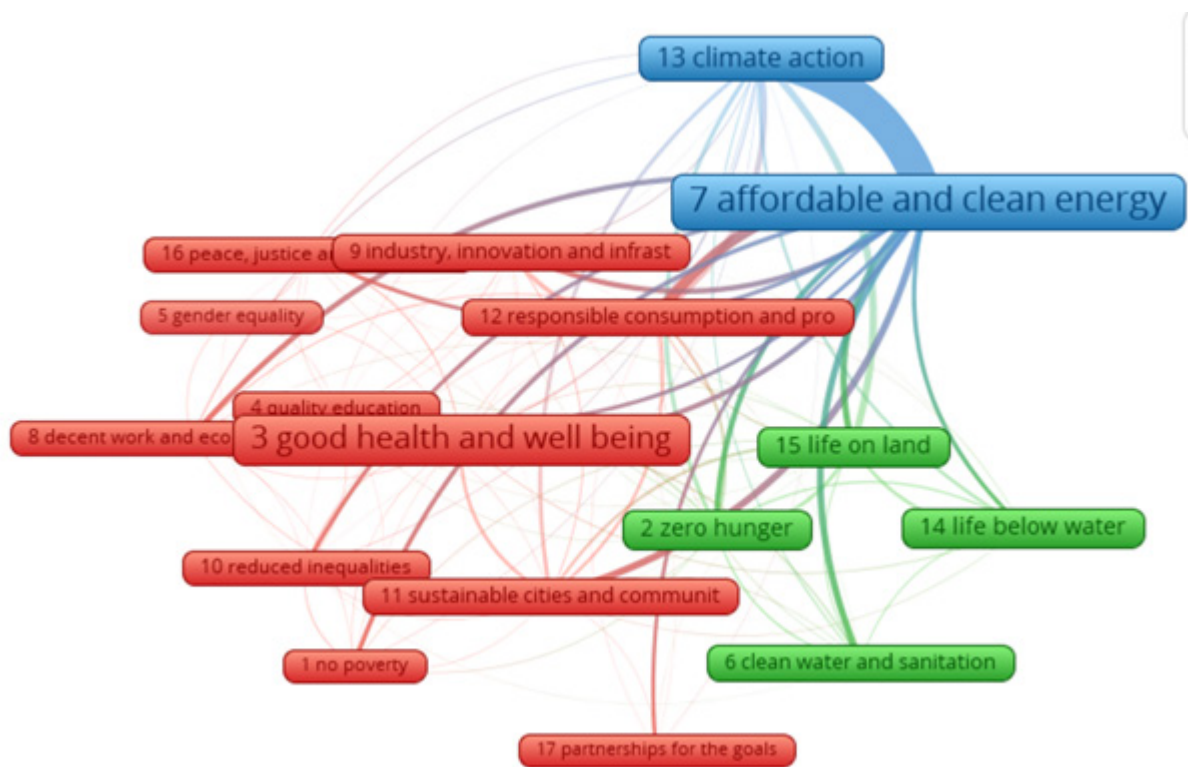
By addressing RQ4, this research aims to provide a comprehensive overview of the major financial contributors shaping the landscape of SDG research in East Asia and ASEAN countries. The data in Table 4 indicate that within East Asia and ASEAN countries, funding for research is highly concentrated and led by major national agencies. The National Natural Science Foundation of China (NSFC) has many publications, highlighting China's enormous investment in scientific research. This is followed by other Chinese institutions, such as the Ministry of Science

and Technology and the Chinese Academy of Sciences, further underscoring China's leading position in the region's research funding landscape.

The Japan Society for the Promotion of Science (JSPS) plays a crucial role in research funding, reflecting Japan's commitment to advancing scientific knowledge. In South Korea, the National Research Foundation (NRF) and the Ministry of Science and ICT (MSIT) emphasize technological development. Taiwan's Ministry of Science and Technology (MOST) significantly contributed to

**Table 4: Prolific funding institutions.**

Name	Country	TP	TC
National Natural Science Foundation of China (NSFC).	China	5,77,185	1,38,02,512
Ministry of Science and Technology of the People's Republic of China (MOST).	China	1,60,072	47,75,968
Japan Society for the Promotion of Science (JSPS).	Japan	60,907	11,86,191
Chinese Academy of Sciences (CAS).	China	53,999	17,35,964
National Research Foundation of Korea (NRF).	South Korea	48,729	11,04,962
Ministry of Education of the People's Republic of China (MOE).	China	42,094	14,69,179
China Postdoctoral Science Foundation.	China	40,989	11,17,337
Ministry of Science and ICT (MSIT).	South Korea	32,115	6,95,257
Ministry of Science and Technology (MOST).	Taiwan	24,597	4,39,088
China Scholarship Council (CSC).	China	20,349	6,69,394

**Figure 3: SDG network cocitation map.**

research funding, highlighting Taiwan's strategic approach to fostering innovation.

The concentration of funding in these agencies indicates strong governmental influence on research direction, with a focus on national interests such as technology, health and energy, which are crucial for economic and social development. East Asia and ASEAN's prolific state-backed funders underscore state policy's role in driving research agendas aligning with national goals.

Examining resource allocation across SDGs reveals prioritization patterns (Table 5). The National Natural Science Foundation of China (NSFC) demonstrated a profound commitment to SDG 7, "Affordable and Clean Energy," aligning with the region's focus

on energy sustainability for economic growth. SDG 3, "Good Health and Well-Being," receives significant attention, aligning with East Asia's emphasis on medical research and public health initiatives.

Moderate funding for "Climate Action" and "Life on Land" suggests growing awareness of environmental challenges. However, comparatively lower funding for SDG 4, "Quality Education," and SDG 11, "Sustainable Cities and Communities," raises concerns about underutilizing academic research in shaping education policies and urban development.

Notably, the SDGs underpinning social equity receive minimal funding, indicating a critical gap. Modest backing for

**Table 5: Allocation of resources among prolific funding institutions.**

SDG	National Natural Science Foundation of China (NSFC)	Ministry of Science and Technology of the People's Republic of China (MOST)	Japan Society for the Promotion of Science (JSPS)	Chinese Academy of Sciences (CAS)	National Research Foundation of Korea (NRF)	Ministry of Education of the People's Republic of China (MOE)	China Postdoctoral Science Foundation	Ministry of Science and ICT (MSIT)	Ministry of Science and Technology (MOST)	China Scholarship Council (CSC)
 7 AFFORDABLE AND CLEAN ENERGY	2,95,783	74,094	14,889	23,084	27,004	21,784	24,227	19,748	9,531	10,377
 3 GOOD HEALTH AND WELL-BEING	1,27,207	36,895	26,536	6,508	12,962	6,450	7,159	7,383	9,003	2,714
 13 CLIMATE ACTION	58,255	19,980	5,055	10,226	3,950	3,953	3,710	2,580	1,718	2,926
 4 QUALITY EDUCATION	4,181	758	2,479	245	793	1,672	268	328	1,471	240
 15 LIFE ON LAND	31,914	10,662	3,464	7,404	1,048	2,319	1,929	550	633	1,588
 2 ZERO HUNGER	17,342	8,086	1,838	2,013	735	1,265	1,142	370	359	843
 14 LIFE BELOW WATER	25,491	8,385	3,685	4,898	1,185	1,238	1,604	654	822	1,220
 11 SUSTAINABLE CITIES AND COMMUNITIES	15,259	3,898	1,627	1,242	856	1,696	964	512	502	727
 16 PEACE, JUSTICE AND STRONG INSTITUTIONS	2,303	361	734	110	290	510	161	113	215	98
 12 RESPONSIBLE CONSUMPTION AND PRODUCTION	11,218	2,800	660	790	789	1,263	894	580	570	517
 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	7,105	1,282	442	176	581	1,244	398	508	514	222
 8 DECENT WORK AND ECONOMIC GROWTH	2,940	282	898	149	246	724	155	81	169	89
 6 CLEAN WATER AND SANITATION	6,900	2,242	391	845	324	513	531	193	161	315
 10 REDUCED INEQUALITIES	4,472	373	749	148	348	475	268	156	135	169
 5 GENDER EQUALITY	384	26	304	20	90	87	16	22	75	19
 1 NO POVERTY	933	136	132	73	21	213	66	8	19	51
 17 PARTNERSHIPS FOR SUSTAINABLE DEVELOPMENT	164	14	38	8	14	47	13	5	5	5

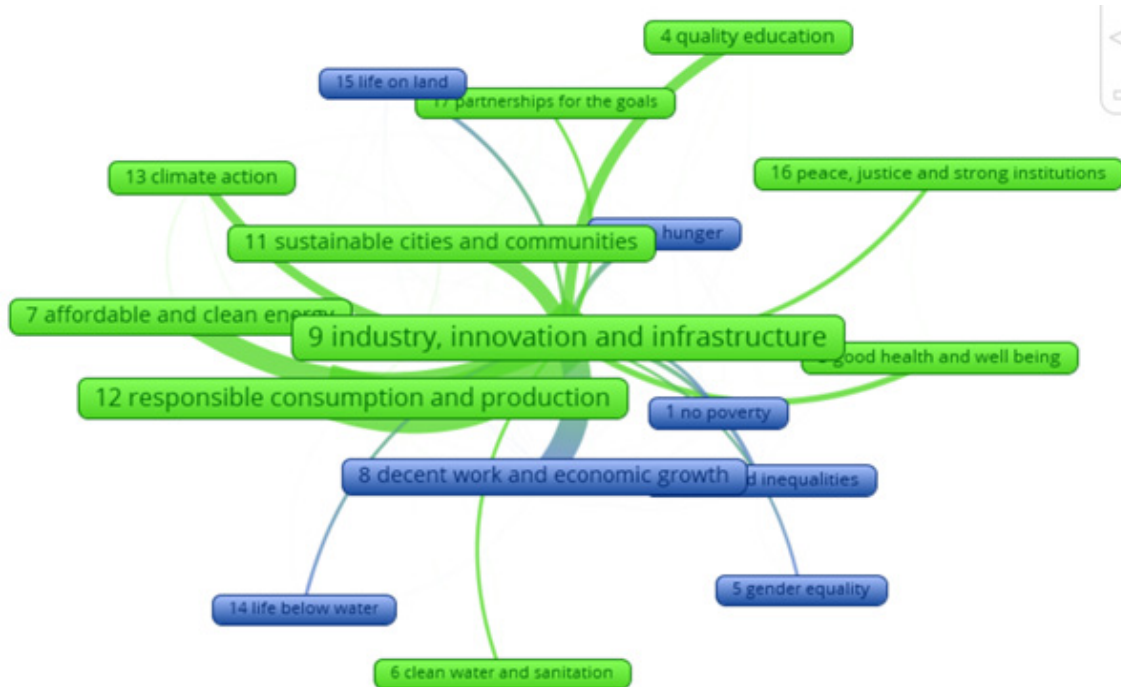


Figure 4: Interlinkages of SDG 9 with other SDGs.

Table 6: Ten highly cited papers related to innovation under SDG 9.

Title	Citations	Year	Authors	Country
Fintech: Ecosystem, business models, investment decisions and challenges.	706	2018	In L; Jae SY	South Korea; United States
State Ownership and Firm Innovation in China: An Integrated View of Institutional and Efficiency Logics.	640	2016	Zheng ZK; Yong GG; Hongxin Z	China
Green process innovation, green product innovation and corporate financial performance: A content analysis method.	576	2019	Xuemei X; Jiage H; Hailiang Z	China; China
Green Innovation and Performance: The View of Organizational Capability and Social Reciprocity.	493	2015	Jing-Wen H; Yong-Hui L	Taiwan
The Future of Healthcare Internet of Things: A Survey of Emerging Technologies.	475	2020	Ahmad QY; Ali N; Yousaf BZ; Athanasios VV; Won KS	China; South Korea; Sweden
Relationship between innovation capability, innovation type and firm performance.	445	2018	Jayani RRP; Yan H	China
The impact of legitimacy pressure and corporate profitability on green innovation: Evidence from China's top 100.	383	2017	Dayuan L; Mi Z; Cuicui C; Xiaohong C; Shenggang R; Min H	China; China
Green innovation and firm performance: Evidence from listed companies in China.	362	2019	Dayong Z; Zhao R; Qiang J	China; China; China; China
Green Innovation, Managerial Concern and Firm Performance: An Empirical Study.	361	2017	Mingfeng T; Grace W; Daniel L; Markus FA; Qiaohua L	Chile; China; Germany; Australia; Ireland; China; France; Spain
A state-of-the-art survey of Digital Twin: techniques, engineering product lifecycle management and business innovation perspectives.	361	2019	Hong LKY; Pai Z; Chun-Hsien C	China; Singapore

"Partnerships for the Goals" suggests potential underinvestment in collaborative efforts for achieving SDGs through international cooperation.

While East Asian and ASEAN funders heavily invest in technology and health, reassessing funding strategies could ensure more equitable distribution, foster advancements in science and technology and address pressing social challenges integral to comprehensive sustainable development.

### Thematic clusters based on SDGs

The SDGs operate in a mutually reinforcing manner, where the progress of one often depends on the advancement of others. A network analysis reveals uneven distributions in the connections between these goals.<sup>[42]</sup> Some SDGs have an extensive web of targets linking them to other goals, while others are less interconnected within the SDG network. To address RQ5, we utilized a cocitation map (Figure 3) that illustrates these links based on how frequently they are referenced in the literature; the map mirrors the topical relatedness of SDGs. The node size indicates the publication volume for each SDG and the line width reflects the cocitation frequency. The blue cluster predominantly addresses environmental goals, specifically SDGs 7 and 13. The red cluster focuses on social and economic goals such as SDGs 3, 11, 12 and 10, while the green cluster emphasizes SDGs 14, 15, 2 and 6.

**Blue Cluster (Environmental Goals):** This cluster, characterized by its focus on SDGs 7 (Affordable and Clean Energy) and 13 (Climate Action), represents a concentration on environmental sustainability. The significant size of the nodes for these SDGs suggests a high volume of research output, while the thick edges indicate frequent cocitations. This implies that these environmental goals are often discussed in tandem within academic circles, highlighting the interlinked nature of energy issues and climate change.

**Red Cluster (Social and Economic Goals):** Encompassing SDGs 3 (Good Health and Well-being), 11 (Sustainable Cities and Communities), 12 (Responsible Consumption and Production) and 10 (Reduced Inequalities); the red cluster signifies a scholarly emphasis on the intersection of social equity and economic development. The proximity of these goals suggests that research in these areas often intersects, recognizing the complexity of social and economic challenges and their interdependencies in achieving sustainable development.

**Green Cluster (Life on Land and Water, Hunger and Clean Water):** Green clusters home to SDGs 14 (Life Below Water), 15 (Life on Land), 2 (Zero Hunger) and 6 (Clean Water and Sanitation). The clustering of these goals indicates a scholarly narrative that ties the vitality of aquatic and terrestrial ecosystems with fundamental human needs such as nutrition and water.

The cocitation frequency echoes an understanding within the literature.

### SDG 9-Industry, Innovation and Infrastructure

Delving into SDG 9, which zeroes industry, innovation and infrastructure, we examine its nexus with other SDGs, revealing two distinct clusters highlighted in green and blue (Figure 4). The first, a green cluster where SDG 9 is prominent, exhibits robust connections to SDGs 12 (Responsible Consumption and Production), 7 (Affordable and Clean Energy), 11 (Sustainable Cities and Communities), 13 (Climate Action) and 4 (Quality Education), as evidenced by the pronounced line thickness. These strong ties imply that advancements in industry and infrastructure are intrinsically linked to responsible consumption and production, sustainable energy, urban development, climate action and education. This suggests that fostering innovation and building resilient infrastructure drives economic growth and is critical for addressing environmental challenges and promoting sustainable urban development. The link with education (SDG 4) also indicates that building a knowledge-based, innovative economy is essential for sustainable industrialization. This cluster's emphasis on clean energy (SDG 7) and climate action (SDG 13) reflects an understanding that industry and innovation must evolve in environmentally sustainable ways. Meanwhile, the second cluster, tinted blue and led by SDG 8 (Decent Work and Economic Growth), shows a significant linkage to SDG 9, suggesting a tight interplay between economic growth and industrial innovation. This relationship implies that achieving decent work and economic growth (SDG 8) is closely tied to advancements in industry and innovation (SDG 9). This could mean that efforts to stimulate the economy and create jobs will likely be more effective when aligned with strategies that enhance industrial capacity and innovation.

Table 6 presents a comprehensive overview of innovation within the context of SDG 9, covering diverse topics such as fintech, green processes and the healthcare IoT. Notably, the papers predominantly originate from East Asian countries, particularly China, South Korea and Taiwan, underlining the regional focus of the study. The substantial citations received by papers such as "Fintech" highlight their impact and the international collaboration among authors suggests a global perspective in SDG 9-related innovation research. These papers explore the intricate links between innovation and corporate performance, contributing to economic and environmental considerations. Additionally, including a digital twin survey reflects a focus on cutting-edge technologies within the SDG 9 innovation discourse. Spanning various years, the temporal diversity of the papers underscores the evolving nature of SDG 9-related innovation research, providing a robust foundation for further exploration and understanding.

## Topic Modeling

Topic modeling analysis identifies various vital specific topics among various topics of interest in a region. Among the topics identified from the literature analyzed, we have chosen 7 key topics for detailed analysis, i.e., for presenting glimpses of key specific contributions from these topics. This exercise addresses RQ6 and might help retrieve useful insights for stakeholders, including policymakers, academics and industry leaders, highlighting the active engagement of the East Asia and ASEAN regions with the SDGs and providing guidance on collaborative efforts, policy development and investment strategies to enhance the region's impact on the 2030 Agenda for Sustainable Development. The titles and details of the top 3 representative works from topics 0 and 1 are given in Table 7.

Topic 0 (*indonesia\_digital\_marketing\_market*): The top representative article in topic 0 by Kamaludin *et al.*,<sup>[43]</sup> highlighted the importance of and determined the right internal, external and interactive marketing strategies (with quality standard benchmarks as the core) for microentrepreneurs in the Industrial Revolution 4.0 era. The second work by Prasetya *et al.*,<sup>[44]</sup> attempted to implement a digital marketing strategy for MSMEs (with a prime focus on increasing knowledge of digital marketing and instilling the ability to create content) in Indonesia to keep pace with global business standards and survive during pandemics (such as COVID-19) and other adverse situations. The third work in topic 0 by Habibi *et al.*,<sup>[45]</sup> also reported a community

service activity that targeted every aspect, from educating about concepts and technological products, training and simulations on digital media use, development of direct marketing strategies for MSME products, etc., the impact of which included improving the community's knowledge and skills by 23.26% and increasing sales turnover by 172% every month.

Topic 1 (*manufacturing\_fabrication\_printing\_3d*): The top representative work in topic 1 by Nordin *et al.*,<sup>[46]</sup> was an extensive review of additive manufacturing materials and proposed a new material for additive manufacturing that can be obtained from powder glass (recycled from the automotive industry). The new technique of additive manufacturing based on the new material is found to be promising in terms of cost minimization. The second paper on this topic by Arifin *et al.*,<sup>[47]</sup> reviewed the environmental, economic and social implications of Additive Manufacturing (AM) and highlighted the need for a thorough understanding of such sustainability implications for companies and researchers switching to AM. The third work by Sheng *et al.*,<sup>[48]</sup> attempted to provide a detailed account of different aspects of AM technologies, including their advantages to the aviation industry, such as waste product reduction, cost reduction and emission reduction.

The titles and details of the top 3 representative works from topics 2 and 3 are given in Table 8.

Topic 2 (*robotics\_robots*): Most representative work on this topic by Xiao,<sup>[49]</sup> reviewed research on the vision-sharing method

**Table 7: Details of the top 3 representative works from topics 0 and 1.**

Topic label	Titles of top 3 publications	Method/Approach
0_indonesia_digital_marketing_market	Analisis Strategi Pemasaran Bagi Pelaku Usaha Mikro Di Era Revolusi Industri 4.0 (Kamaludin <i>et al.</i> , <sup>[43]</sup> )	Qualitative approach (Observation, interview and documentation techniques were used for Data collection).
	Strategi Pemasaran Digital Bagi Double Six Coffee Yang Terdampak Pandemi COVID-19 DI Kota Malang (Prasetya <i>et al.</i> , <sup>[44]</sup> )	Training method and assistance in the implementation till MSMEs became truly capable of implementation.
	Pengembangan Pemasaran Produk UMKM Di Desa Larangan Tokol Jawa Timur (Habibi <i>et al.</i> , <sup>[45]</sup> )	Training based on observation, training and mentoring
1_manufacturing_fabrication_printing_3d	Advances in High-Temperature Materials for Additive Manufacturing (Nordin <i>et al.</i> , <sup>[46]</sup> )	New material was tested using Fused Deposition Modeling (FDM). Analysis of Hardness, Strength, melting point, microstructure, etc., using Scanning Electron Microscopy (SEM).
	Sustainability Implications of Additive Manufacturing (Arifin <i>et al.</i> , <sup>[47]</sup> )	Reviewed existing studies related to the implications of additive manufacturing on environmental, economic and social aspects.
	3-D printing of airplane parts (Sheng <i>et al.</i> , <sup>[48]</sup> )	Detailed accounts of the advantages of 3-D printing/additive manufacturing (AM), usage of AM on airplane parts, industrial players who adopted AM, etc., were provided.

**Table 8: Details of the top 3 representative works from topics 2 and 3.**

Topic label	Titles of top 3 publications	Method/Approach
2_robotics_robots	Vision Sharing Method of Network Robot Based on Deep Learning (Xiao, <sup>[49]</sup> )	Concrete analysis of specific problems for making data comparisons and drawing conclusions.
	Dynamics of 6 Dof manipulator robot on robot operating system (Firdaus <i>et al.</i> , <sup>[50]</sup> )	URDF (Unified Robot Description Format) was used for robot modeling with the help of features of ROS (Robot Operating System). Stability during motion is ensured by the usage of PID controllers for every joint. Testing used loads with different weights and angle error for each joint was recorded and plotted.
	A digital twin-based framework for task planning and robot programming in HRC (Ren <i>et al.</i> , <sup>[51]</sup> )	Virtual simulation was used for task planning (assembly task allocation and scheduling) to robot control (robot trajectory planning and programming). Online optimization was conducted for real-time control.
3_twin_digital_twins_technology	An Introduction to Digital Twin Standards (Sun <i>et al.</i> , <sup>[52]</sup> )	Reviewed progress on digital twin network and highlighted challenges for successful deployment of digital twin.
	A systematic review of the digital twin about physical entities, virtual models, twin data and applications (Liu <i>et al.</i> , <sup>[53]</sup> )	A systematic review clarified (i) definitions, characteristics and application areas of the digital twin by clarifying the relationship between the digital twin and cyber-physical system, (ii) core components of the digital twin were identified as physical entities, virtual models and twin data and analyzed.
	A Bibliometric Analysis of Digital Twin in the Supply Chain (Lam <i>et al.</i> , <sup>[54]</sup> )	The bibliometric analysis covered trend and development analysis, focus area determination of digital twin in the supply chain.

based on the robotic theory algorithm and emphasized the necessity for nations (special focus on China) to draw lessons from successful practices of the advanced foreign robot industry and formulate a development strategy and related policies for the robot industry. The second work on this topic by Firdaus *et al.*,<sup>[50]</sup> addressed the need for a control that can ensure the stability of the manipulator robot during motion without producing large errors for industrial robotic applications such as sorting by the development of a dynamic simulation of a small-scale model of a 6 DoF manipulator robot (shaped like a human arm). The third work on this topic by Ren *et al.*,<sup>[51]</sup> presented and validated (using an industrial case study) a digital twin-based framework for complex assembly tasks in a human-robot collaborative assembly system that can support the planning, decision and implementation of collaboration between humans and robots.

### Topic 3 (digital\_twins\_technology)

The top representative work on this topic by Sun *et al.*,<sup>[52]</sup> attempted to provide an overview of the recent progress of digital twin standards to ensure high fidelity of the virtual model due to provisions for continuous updating and self-learning in contrast to conventional modeling and simulation technologies, challenges and other aspects for emerging standardization to realize the interconnection of data, models and services between enterprises or areas. The second representative work on this topic by Liu *et al.*,<sup>[53]</sup> involved a systematic review for clarifying the relationship between the digital twin and cyber-physical

systems, identification of the core components of the digital twin and discussion of application scenarios of the digital twin. The third work on this topic by Lam *et al.*,<sup>[54]</sup> presented a bibliometric analysis of the digital twin in the supply chain and identified several key clusters related to the design and integration of digital twin models, applications of digital twins in quality control and digitization relevant to Industry 4.0, as well as for the shift toward applications in Industry 5.0 human-centric systems and mass personalization.

The titles and details of the top 3 representative works from topic 4 are given in Table 9.

### Topic 4 (blockchain\_bitcoin\_ledger\_transaction)

The top representative work in topic 4 by Li and Feng,<sup>[55]</sup> revealed a positive impact of blockchain technology on the management activities of e-commerce enterprises by integrating the principles of blockchain technology into the management activities of enterprises in the digital economy and observed a mediating role of integrating innovation-related resources. The second work on this topic by Guo *et al.*,<sup>[56]</sup> proposed a framework that can be used as a benchmark based on obtained insights by reviewing identified critical issues related to smart manufacturing and solutions offered by blockchain technology. The third work on this topic by Zhao,<sup>[57]</sup> reviewed the financial industry's development status and existing problems and found that existing combined problems in finance and blockchains suggest natural adaptability.

**Table 9: Details of the top 3 representative works from topic 4.**

Topic label	Titles of top 3 publications	Method/Approach
4_blockchain_bitcoin_ledger_transaction	The Innovation of Enterprise Management Mode of Digital Economy Based on Blockchain Technology (Li and Feng, <sup>[55]</sup> )	Defined variables and constructed theoretical models, conducted research hypotheses test on the impact of blockchain on innovation in digital economy enterprises based on questionnaire data (using SPSS and AMOS software).
	A Comprehensive Review of Blockchain Technology-Enabled Smart Manufacturing: A Framework, Challenges and Future Research Directions (Guo et al., <sup>[56]</sup> )	Analyzed literature related to four critical issues in smart manufacturing: data security, data sharing, trust mechanisms and system coordination. Corresponding blockchain solutions were reviewed.
	Application and Development Trend of Blockchain in the Financial Field (Zhao, <sup>[57]</sup> )	Analyzed problems in finance and blockchain and found that combined problems in both suggest a natural adaptability. Summarized current applications of blockchain technology in finance and listed future development trends of blockchain in finance.

The titles and details of the top 3 representative works from topic 5 are given in Table 10.

### Topic 5 (buying\_purchasing\_consumers)

The most representative work on this topic by Wirawan and Seminari,<sup>[58]</sup> was intended to study the effect of price, brand image and product quality on smartphone (XIAOMI phones) purchasing decisions and found that price, brand image and product quality have positive and significant effects on purchasing decisions. The second work on this topic by Tonibun et al.,<sup>[59]</sup> attempted to determine the effect of product and service quality (mediated by brand image) on the purchasing decisions of Wuling four-wheeled motorized vehicles and reported (i) a significant effect of service quality and product quality on brand image, (ii) a significant effect of service quality on purchasing decisions mediated by brand image and (iii) no significant effect of any of these aspects on purchasing decisions. The third work by Katu and Suparna,<sup>[60]</sup> revealed a significant positive effect of price and brand image on purchasing decisions while reporting the standalone partially significant effects of price and brand image on purchasing decisions.

The titles and details of the top 3 representative works from topic 6 are given in Table 11.

### Topic 6 (construction\_infrastructure\_infrastructures\_building)

The top representative work on this topic by Yang et al.,<sup>[61]</sup> adopted cutting-edge technologies such as the Internet of Things (IoT), 5G and artificial intelligence to establish an intelligent construction site management system of electrical construction, especially for managing five aspects: personnel management, risk avoidance, quality control, automatic and real-time information collection and processing of the construction site, etc. The second

work on this topic by Zaid et al.,<sup>[62]</sup> attempted to address the gap related to the lack of studies on information requirements at various phases of infrastructure development for BIM (Building Information Modeling) and claims its usage as a referential benchmark for avoiding information redundancy and overload of information. The third representative work on this topic by Gu et al.,<sup>[63]</sup> observed that BIM cannot wholly meet the infrastructure management challenges in some aspects of railway construction and emerging technology, viz. A digital twin that plays a crucial role in the digital transformation of the construction industry can be a better alternative because railway infrastructure management needs a unique model throughout the entire life cycle.

### Implications for National Science, Technology and Innovation Policymakers for Strengthening National Innovation Systems

Strengthening the national ecosystem requires crisp, comprehensive and timely revision of innovation policies after careful review of the existing ecosystem and identification of its strengths, weaknesses, challenges and opportunities. This approach might help to eliminate weaknesses or convert those into strengths. Additionally, sufficient pondering on how challenges can be addressed internally and with external help should occur. Thus, in the case of nations falling in the region formed due to the combination of East Asian and ASEAN countries, nations must individually strengthen their internal innovation ecosystems by using their internal resources efficiently and by collaborating with other countries. In regard to collaboration, collaboration within the region must be strengthened along with the maintenance and strengthening of existing external ties through effective science diplomacy practices, as noted by Dua et al.,<sup>[64]</sup> in the case of the SAARC region. The information of the most prolific countries, institutions, etc., revealed by us can provide a sense of direction

**Table 10: Details of the top 3 representative works from topic 5.**

Topic label	Titles of top 3 publications	Method/Approach
5_buying_purchasing_purchase_consumers	Pengaruh Harga Citra Merek Dan Kualitas Produk Pada Keputusan Pembelian Produk Smartphone Xiaomi (Wirawan and Seminari, <sup>[58]</sup> )	The research was conducted in the area of Denpasar on the population that had either bought or used Xiaomi smartphones based on 'purposive sampling.' Multiple linear regression was used for data analysis.
	Kualitas Produk dan Kualitas Layanan terhadap Keputusan Pembelian yang Dimediasi oleh Citra Merek pada Penjualan Kendaraan Bermotor Roda Empat (Tonibun <i>et al.</i> , <sup>[59]</sup> )	The research was conducted using a nonprobability sampling method with purposive sampling type and analysis conducted with Smart PLS 3.3.
	Peran Brand Image Memediasi Pengaruh Harga Terhadap Keputusan Pembelian Di Masa Pandemi (Studi Pada Produk Smartphone Xiaomi di Kota Denpasar) (Katu and Suparna, <sup>[60]</sup> )	The research was conducted on consumers of Smartphone Xiaomi in Denpasar City. Nonprobability sampling method with a purposive sampling type was used. Data collected through a questionnaire was analyzed using Partial Least Squares (PLS).

**Table 11: Details of the top 3 representative works from topic 6.**

Topic label	Titles of top 3 publications	Method/Approach
6_construction_infrastructure_infrastructures_building	Research on power engineering solutions based on NB-IoT technology (Yang <i>et al.</i> , <sup>[61]</sup> )	Adopted the latest generation of 5G narrowband Internet of Things (NB-IOT) technology to establish an intelligent construction site management system for electrical construction.
	Information needs for infrastructure building information modeling: A review (Zaid <i>et al.</i> , <sup>[62]</sup> )	They emphasized the essential development of BIM for infrastructure projects. Various information needs throughout the infrastructure construction were identified through observation.
	Research on Application of Digital Twin in Railway Construction (Gu <i>et al.</i> , <sup>[63]</sup> )	Listed out and discussed applications of the digital twin in the construction industry. Appropriate schemes based on these were proposed for typical railway construction scenarios.

to individual nations within the region about whom to approach for fostering collaborative ties. The additional information about the key SDGs to which the region has contributed or is interested can add value to such endeavors, as sustainability is viewed as a key component of national ecosystems and knowledge about shared interest in SDGs and ties that complement the weaknesses in particular SDGs can be attempted within the region. We also provided knowledge about key funding agencies in the region that can be well utilized by governments of nations where there is a shortage of funding for R&D in certain areas of mutual interest. Formation of the consortium of funding agencies and pooling of resources for sharing among the members can also be considered for ASEAN, East Asia and ASEAN and even for the whole Asia-Pacific region. While these are the general implications for strengthening national innovation systems (obtained by addressing RQs 1 to 4), more specific and focused technological as well as managerial implications for strengthening national innovation systems that are revealed while pursuing RQs 5 and 6 are discussed next.

The coevolution of some technologies (indicated by key topics analyzed in this work) is vital for realizing that Industry 5.0 will transform our future. Therefore, key decision-makers responsible for national innovation ecosystem management are recommended to integrate these technologies into the national innovation ecosystem systematically (i) by supporting research and developmental activities, (ii) by establishing regulatory frameworks under refined legal and ethical systems congruent with global standards and (iii) by ensuring a conducive environment for technopreneurs concerning but not limited to these relevant technologies. The following suggestions can be helpful in this regard.

Countries in the region that are struggling to reap benefits despite their efforts in nourishing the national innovation ecosystem might examine whether the firms are aware of the potential of digital marketing and based on the assessment, policies to handhold those firms, especially MSMEs, that are lacking in this regard should be framed. Programs to execute these policies should be systematically organized.

Countries in regions that are yet to recognize the potential and global interest and transition toward 3D printing/additive manufacturing should consider (i) research to unlock the potential of the technology to contribute to the national innovation ecosystem and to different SDGs and (ii) formulating policies that may nurture industrial players toward capability at par with global standards for ensuring their healthy involvement to ensure the socio-techno-economic and environmental benefits offered by the technology to the national innovation ecosystem.

The coevolution of many technologies points toward Industry 5.0. Manufacturing in the Industry 5.0 era will witness significant participation from robotic systems and network robot technology will play a vital role in this industry. While the timely interest in this technology by some countries is appreciable, heavy investment and fostering activities to promote innovative research, development, manufacturing, production and diffusion of those innovations are recommended for the countries in the region to capitalize on the opportunities offered by this game-changing technology. Manipulator robots and digital twin applications can be a particular focus for countries that have not begun their journey in this direction.

While some countries in the region are found to recognize the current relevance (Industry 4.0 era) and futuristic relevance (Industry 5.0 era) of digital twin technology, discrepancies might also exist in this regard. Countries are recommended to draw insights from existing studies in other countries, conduct their research to understand the potential of the technology, key application areas where the technology can impact most, requirements to extricate the full benefit of the technology and challenges that might be encountered. As a starting point, inspiration can be drawn from specific contributions from research within the region, such as the relationship between DT and cyber-physical systems, core components of DT and applications in Industry 5.0. These themes can be the primordial focus of research and innovation activities in their journey toward strengthening their national innovation ecosystem.

As blockchain technology is another vital game changer that has already started impacting many firms, countries in the region are recommended to research the impact of blockchain technology on enterprises at higher levels rather than concentrating on a few themes. Specific contributions from the region in the form of the applicability of blockchains in intelligent manufacturing are highly promising. This should be especially noted for fostering, as it can be crucial for the future of national innovation ecosystems of the countries within the region and potentially impact multiple SDGs.

According to existing studies in some countries, good-quality products (smartphones) with affordable prices are most sought by consumers. Additional demand is there if they come from firms with commendable brand images. Countries with weak

manufacturing and distribution systems in terms of smartphones need to conduct in-depth studies in this regard and make judicious decisions on whether to increase or decrease imports of these kinds of products or to encourage firms within the country to engage in indigenous smartphone manufacturing and promote brand image building through systematic training programs if necessary. The success of China (an East Asian country) in this regard and the recent progress of India (a SAARC country) through reforms such as 'Digital India',<sup>[65]</sup> 'Make in India',<sup>[66]</sup> must be well studied and best practices can be adopted.

Technologies such as digital twins are taking over infrastructure construction management, bypassing BIMs and at least some of the countries within the region have recognized this and are working to attain a competitive edge to seize the opportunities that may be revealed in due course. Other countries in the region should also seriously consider investing in this technology to restructure their national innovation ecosystems so that firms can be adequately equipped and achieve competence to contribute to developmental projects for nation-building processes that can transform cities, countries and, ultimately, the planet into a smart one.

## CONCLUSION

East Asian and ASEAN nations wholeheartedly embrace the United Nations Sustainable Development Goals (SDGs), evident in their substantial research output, contributing to 21% of global publications aligned with the SDGs since 2015. Analyzing 33,685 publications and associated citations from the region provides insights into significant contributions, leading countries and the funding landscape, highlighting the region's unwavering dedication to a sustainable future. China, which particularly excels in SDG 7, "Affordable and Clean Energy," leads in overall research output. Other notable contributors include Japan, Indonesia, the United States, South Korea, Malaysia, Taiwan, Thailand, Vietnam, the Philippines and Singapore, each tailoring contributions to unique socioeconomic needs and policy agendas. Funding is concentrated in major national agencies, such as the National Natural Science Foundation of China (NSFC), the Japan Society for the Promotion of Science (JSPS) and the National Research Foundation of Korea (NRF), underscoring the influential role of state policy in shaping research agendas vital for economic and social development. While funding patterns reveal potential underemphasis on social equity-related SDGs, there is a call for reassessing strategies to ensure more equitable resource distribution. The cocitation map underscores the interconnectedness of the SDGs, emphasizing the need for a holistic approach to sustainable development that addresses multiple dimensions simultaneously.

Policy implications advocate for the sustained prioritization of research and innovation, particularly in areas manifesting precise needs for sustainable development. There is an urgent need to

reassess funding strategies, advocating for a balanced distribution across all SDGs with an emphasis on social equity-related goals.

Overall, research spending will also be key to achieving the SDGs. Research spending in ASEAN countries varies, with Malaysia allocating 0.95% of GDP to R&D, although it decreased from 2015 levels. Singapore, once the most research-intensive region, reduced its research intensity to 1.89% in 2019. The Philippines doubled its research intensity to 0.32%, while Thailand has experienced rapid growth, increasing its share from 0.4% to 1.33% of GDP and encouraging innovation through tax rebates for firms. Overall, diverse approaches and challenges exist in fostering research and development across ASEAN nations.<sup>[67]</sup> Technology is the other key resource required to implement SDG 9. The ASEAN Plan of Action on Science, Technology and Innovation (APASTI) 2016-2025 Implementation Plan addresses supporting research and development (SDG 9. B), while ICT (SDG 9. C) is covered by ASEAN 2025.

Future research directions include exploring the efficacy of existing policies, conducting in-depth analyses of underrepresented SDGs and scrutinizing the impact of international collaboration on sustainable development. Furthermore, the coevolution of essential technologies for Industry 5.0 ushers in a transformative era, compelling national decision-makers to strategically integrate these innovations into their ecosystems. This integration necessitates unwavering support for research, establishing regulatory frameworks aligned with global standards and creating a conducive environment for technopreneurs. Recommendations span addressing digital marketing awareness for Micro, Small and Medium Enterprises (MSMEs), embracing 3D printing with global standards, investing in network robot technology and delving into the applications and impact of digital twin technology in the industry 5.0 landscape. Moreover, the critical need to explore the broader implications of blockchain technology, research consumer preferences for smartphones and prioritize the adoption of digital twin technology in infrastructure construction management is paramount for flourishing in the dynamic landscape of Industry 5.0. This strategic integration, grounded in research and supported by policy measures, positions countries to foster innovation, competitiveness and sustainable development. Policymakers, researchers and stakeholders can leverage these insights to refine strategies and expedite progress toward a more sustainable and inclusive world.

The study has limitations, including potential data bias within the Dimensions Database and a temporal scope limited to 2015-2023, potentially overlooking recent developments. BER Topic modeling's algorithmic constraints and challenges in generalizing findings from SDG 9 to other areas are noted. The sample size of 32,968 documents included in SDG 9 analysis may not comprehensively cover research on industry, innovation

and infrastructure. The potential limitations of VOS viewer for large datasets are acknowledged. Despite these constraints, this study lays the groundwork for future research, guiding a nuanced exploration of SDG-related topics for sustainable development.

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## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

## ABBREVIATIONS

**SDG:** Sustainable Development Goals; **ASEAN:** Association of Southeast Asian Nations; **PRSIMA:** Preferred Reporting Items for Systematic reviews and Meta-Analyses; **BER Topic:** BERT\*-Based Topic Modelling; **\*BERT:** Bidirectional Encoder Representations from Transformers; **BRI:** Belt and Road Initiative; **SAARC:** South Asian Association for Regional Cooperation; **AI:** Artificial Intelligence; **ML:** Machine Learning; **NLP:** Natural Language Processing; **UMAP:** Uniform Manifold Approximation and Projection; **NSFC:** National Natural Science Foundation of China; **NRF:** National Research Foundation (South Korea); **MSIT:** Ministry of Science and ICT\*\* (South Korea); **\*\*ICT:** Information and Communication Technologies; **MOST:** Ministry of Science and Technology (China); **CAS:** Chinese Academy of Sciences; **JSPS:** Japan Society for the Promotion of Science; **CSC:** China Scholarship Council; **MSME:** Micro, Small and Medium Enterprises; **FDM:** Fused Deposition Modeling; **SEM:** Scanning Electron Microscopy; **AM:** Additive Manufacturing; **COVID-19:** Coronavirus disease 2019; **HRC:** Human-Robot-Collaboration; **PID:** Proportional Integral Derivative (controllers); **SPSS:** Statistical Package for Social Sciences; **AMOS:** Analysis of Moment Structures; **PLS:** Partial Least Squares; **APASTI:** ASEAN Plan of Action on Science, Technology and Innovation; **QREI:** Quality and Reliability Engineering International; **VNR:** Voluntary National Reviews.

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