

Kasdi Merbah University – Ouargla

Faculty of Economic, Commercial and Management Sciences
Department of Management Sciences



Dissertation Submitted in Partial Fulfillment of the Requirements for the Academic
Master's Degree in the Field of:
ECONOMIC, MANAGEMENT AND COMMERCIAL SCIENCES
Specialization: **Management**

Evaluating the Efficiency of the Algerian National Innovation System: A Comparative Analysis Using the SBM-DEA Model (2015–2024)

Presented by:

- Hiba BENTARFA

Defended and approved in: 23/05/2026

Board of Examiners:

- Pr. Bachir BENCHOUHA	(Professor- University Kasdi Merbah-Ouargla)	President
- Pr. Abderraouf HADJADI	(Professor- University Kasdi Merbah-Ouargla)	Supervisor
- Pr. Nedjmi SAIDAT	(Professor- University Kasdi Merbah-Ouargla)	Examiner

Academic Year: 2025/2026

Kasdi Merbah University – Ouargla

Faculty of Economic, Commercial and Management Sciences
Department of Management Sciences



Dissertation Submitted in Partial Fulfillment of the Requirements for the Academic
Master's Degree in the Field of:
ECONOMIC, MANAGEMENT AND COMMERCIAL SCIENCES
Specialization: **Management**

**Evaluating the Efficiency of the Algerian National
Innovation System: A Comparative Analysis Using the
SBM-DEA Model (2015–2024)**

Presented by:

- Hiba BENTARFA

Defended and approved in: 23/05/2026

Board of Examiners:

- Pr. Bachir BENCHOUHA	(Professor- University Kasdi Merbah-Ouargla)	President
- Pr. Abderraouf HADJADI	(Professor- University Kasdi Merbah-Ouargla)	Supervisor
- Pr. Nedjmi SAIDAT	(Professor- University Kasdi Merbah-Ouargla)	Examiner

Academic Year: 2025/2026



DEDICATION



To my constant support, My father

To the source of endless love and sanctuary, My mother

To the unwavering presence, My brothers and sisters

And to all those who find joy in my happiness and have
shared the most beautiful moments of my life

My extended family, young and old

BENTARFA Hiba . _____

ACKNOWLEDGEMENTS

In the name of Allah, the Most Gracious, the Most Merciful

All praise is due to Allah, who has guided us and facilitated the paths of knowledge and learning

In recognition of the favor and in appreciation of the gratitude, I extend my deepest gratitude and sincere appreciation to Pr. ABDERRAOUF Hadjadj, for his invaluable guidance, continuous support, and the insightful directions he provided throughout this research

I would also like to extend my sincere thanks to Mr. SOFIANE Soualah Mohammad for his significant contribution, continuous encouragement, and constructive feedback, which significantly contributed to enhancing this study

We pray to Allah that this work is sincerely dedicated to His sake and that it may serve the advancement of knowledge and benefit its seekers

BENTARFA Hiba . _____

Abstract

This study aims to evaluate the efficiency and analyze the performance gaps of the Algerian National Innovation System (NIS) in its functional transition from Knowledge Accumulation to Economic Value Generation and Technological Sovereignty, while measuring its resilience against global shocks. To achieve this, a quantitative evaluative methodology has been applied based on the Slacks-Based Measure (SBM-DEA) model, applied to a purposive sample of 16 countries (developed and emerging) over the period 2015–2024. The analysis utilizes two Innovation Inputs: Total Scientific Documents and Total Patent Applications, against three Innovation Outputs: Total Patent Grants, Total Trademark Registrations, and Foreign-oriented Patent Families. The findings mainly reveal a fundamental efficiency gap and a state of Path Dependency, where the system remains trapped in Decreasing Returns to Scale due to structural bloat. The results further confirm a Knowledge Paradox and a Negative Memory Effect, evidenced by a failure to recover from global shocks and a functional disconnection between academic research and industrial valorization. Consequently, the study concludes that reaching the efficiency frontier requires a strategic functional redesign and global alignment, identifying the UAE model as the primary benchmark for transitioning from a technology consumer to a value-generating producer.

Keywords: National Innovation System (NIS), evaluating efficiency, SBM-DEA Model, Knowledge Accumulation, Economic Value Generation, Scientific Documents, Patents, Slack Value.

المخلص:

تهدف هذه الدراسة إلى تقييم كفاءة وتحليل فجوات الأداء للنظام الوطني للابتكار في الجزائر خلال تحوله الوظيفي من مرحلة تراكم المعرفة إلى مرحلة توليد القيمة الاقتصادية والسيادة التكنولوجية، مع قياس مدى مرونة النظام أمام الصدمات العالمية. لتحقيق ذلك، تم تطبيق منهج تقييم كمي يستند إلى نموذج قياس الكفاءة القائم على الفجوات (SBM-DEA)، حيث طبق على عينة شملت 16 دولة (متقدمة وناشئة) خلال الفترة الممتدة من 2015 إلى 2024. استخدم التحليل مدخلين للابتكار: (إجمالي الأبحاث العلمية وإجمالي طلبات براءات الاختراع)، مقابل ثلاثة مخرجات: (إجمالي براءات الاختراع الممنوحة، إجمالي العلامات التجارية المسجلة، وعائلات براءات الاختراع الموجهة للخارج). أظهرت النتائج بشكل رئيسي وجود فجوة كفاءة جوهرية وحالة من الاعتماد على المسار، حيث يظل النظام محاصراً في حالة تناقص عائد الحجم نتيجة للتضخم الهيكلي. كما تؤكد النتائج وجود فجوة معرفية وأثر ذاكرة سلبية، يتجلى في الفشل في التعافي من الصدمات العالمية ووجود انفصال وظيفي بين البحث الأكاديمي والتنمية الصناعي. وبناء على ذلك، تخلص الدراسة إلى أن الوصول إلى حد الكفاءة يتطلب إعادة تصميم وظيفي إستراتيجي وتوافقاً مع المعايير العالمية، مع تحديد النموذج الإماراتي كمرجع أساسي للتحويل من مستهلك للتكنولوجيا إلى منتج مولد للقيمة.

الكلمات المفتاحية: نظام وطني للابتكار، تقييم كفاءة، نموذج قياس كفاءة قائم على فجوات، تراكم معرفة، توليد قيمة اقتصادية، أبحاث علمية، براءات، قيمة فجوة.

Table of Contents

Dedication	V
Acknowledgements	VI
Abstract	VII
Table of Contents	VIII-X
List of Tables	XI
List of Figures	XII
List of Appendices	XIII
List of Abbreviations	XIV
Introduction	a-e
Chapter 1 Theoretical and Empirical Literature of the National Innovation System	1-35
Preface	1
1. Theoretical Literature of the National Innovation System	2-12
1.1. The National Innovation System	2-09
1.1.1. Historical Evolution of the National Innovation System	2
1.1.2. Definitions of the National Innovation System	3
1.1.3. Typologies of the National Innovation Systems	4
1.1.4. Importance of the National Innovation System	6
1.1.5. Indicators for Evaluating the National Innovation System	9
1.2. The National Innovation System of Algeria	9-12
1.2.1. The Strategic Shift Towards a Knowledge-Based Economy	9
1.2.2. Actors of the Algerian National Innovation System	11
1.2.3. Functional Dynamics and Integration Mechanisms of the Algerian NIS	12
2. Literature Review of the National Innovation System	13-34
2.1. National Studies	13-14
2.2. International Studies	14-29
2.3. Positioning the Current Study Within Previous Studies	30-34
2.3.1. Comparison Between the Current Study and Previous Studies	30
2.3.2. Contributions of Previous Studies to the Current Study	33

2.3.3. Distinctive Features of the Current Study	34
Chapter 1 Summary	35
Chapter 2 Evaluating the National Innovation System in Algeria: An Applied Comparative Study Using Data Envelopment Analysis Methodology	36-67
Preface	36
1. Data Envelopment Analysis (DEA) Methodology	37-42
1.1. Conceptual Framework and Operational Foundations of DEA	37
1.2. DEA Assumptions	37-38
1.2.1. Returns to Scale	37
1.2.2. Model Orientation	38
1.3. DEA Models	38-41
1.3.1. The CCR Model	38
1.3.2. The BCC Model	39
1.3.3. The Slacks-Based Measure (SBM) Model	40
1.3.4. The Hybrid Model	41
1.3.5. The DEA game model	41
1.3.6. The Network DEA Model	41
1.4. Dynamic/Time-Series DEA	41-42
1.4.1. The Window Analysis	41
1.4.2. The Malmquist Productivity Index (MPI)	42
1.4.3. The Dynamic SBM (DSBM)	42
2. Methodology of the Current Study and Data Description	43-46
2.1. Selected DEA Model	43-44
2.2. Indicators of the Study	44-45
2.3. Data Sources and Study Period	45-46
2.4. Study Sample (Selected Countries)	46
3. Application of the DEA Model to the Study Sample (2015–2024)	47-66
3.1. Descriptive Analysis and General Comparison	47-54
3.1.1. Evolution of Average Efficiency and Individual Trajectories	47
3.1.2. Spatiotemporal Efficiency Mapping (Heatmap Analysis)	51
3.1.3. Comparative Efficiency Ranking (2015 vs. 2024)	52
3.2. Structural Decomposition of Inefficiency and Determinants of Failure	54-57

3.2.1. Structural Slack Deconstruction and Failure Trajectories	54
3.2.2. Scale Dynamics and Returns to Scale (RTS) Analysis	56
3.3. In-depth Analysis of the Algerian Innovation System and Benchmarking	57-61
3.3.1. Temporal Efficiency Trajectory and the Impact of Decree 1275	57
3.3.2. Structural Comparison with the Benchmark	59
3.3.3. Dynamic Resilience and Global Quality Positioning	60
3.4. Strategic Roadmap	61-63
3.5. General Conclusion	63-65
3.5.1. Synthesis of Results	63
3.5.2. Theoretical Validation: Do the Results Support the Integration Mechanisms?	63
3.6. Discussion and Comparative Analysis with Previous studies	65-66
3.6.1. Convergent studies	65
3.6.2. Divergent Studies	66
Chapter 2 Summary	67
Conclusion	68-72
References	73-74
Appendices	75-86

List of Tables

Table N°	Table Title	Page
Table 1.1	National Innovation System Assessment Indicators	9
Table 1.2	Comparative Analysis of DEA-Based Innovation Studies	30
Table 1.3	Comparative Analysis of Econometric Innovation Studies	31
Table 1.4	Comparative Analysis of Indicator-Based Innovation Studies	32
Table 2.1	Primal and Dual Correspondences of the input-oriented CCR model Equation	38
Table 2.2	Primal and Dual Correspondences in BCC Model (Linear Programming Form)	40
Table 2.3	Target Projections and Slack Adjustments for Algeria	62

List of Figures

Figure N°	Figure Title	Page
Figure 1.1	Theoretical Framework of the SBM-DEA Model	E
Figure 1.2	Historical Evolution of National Innovation System	3
Figure 1.3	Typologies of National Innovation System	6
Figure 1.4	Importance of National Innovation System	8
Figure 1.5	Actors of Algerian National Innovation System	11
Figure 1.6	Integration Mechanisms of Algerian NIS	12
Figure 2.1	Evolution of the Sample's Efficiency (2015–2024)	48
Figure 2.2	Comparative Efficiency Trajectories: Algeria vs. Global Frontier and Peer Group (2015–2024)	50
Figure 2.3	Spatiotemporal Heatmap of Innovation Efficiency Scores (2015–2024)	51
Figure 2.4	Comparative Efficiency Ranking of National Innovation Systems (2015 vs. 2024)	53
Figure 2.5	Cumulative Structural Slack Composition of the Algerian NIS (2015–2024)	54
Figure 2.6	Distribution of Countries by RTS Nature (2024)	56
Figure 2.7	Evolution of Algeria's Technical Efficiency Scores and the Impact of Decree 1275 (2015–2024)	58
Figure 2.8	Comparative Radar Chart of Innovation Efficiency between Algeria and UAE (2024)	59
Figure 2.9	Comparative Efficiency Trajectories and Innovation Recovery Paths (2020–2024)	60
Figure 2.10	Evidence-based Functional Integration Model of the Algerian NIS (Post-DEA Diagnostic)	64

List of Appendices

Appendix N°	Appendix Title	Page
1	Frequency of Innovation Input Indicators in Previous DEA-based Studies	75
2	Frequency of Innovation Output Indicators in Previous DEA-based Studies	75
3	Raw Data Matrix for Innovation Inputs and Outputs (2015–2024)	76
4	2015- DEA-SBM model outputs	80
5	2016- DEA-SBM model outputs	80
6	2017- DEA-SBM model outputs	80
7	2018- DEA-SBM model outputs	81
8	2019- DEA-SBM model outputs	81
9	2020- DEA-SBM model outputs	81
10	2021- DEA-SBM model outputs	82
11	2022- DEA-SBM model outputs	82
12	2023- DEA-SBM model outputs	82
13	2024- DEA-SBM model outputs	83
14	Comparative Efficiency Scores: Algeria vs. Global Frontier and Peer Group (2015–2024)	83
15	Comparative Efficiency Scores of National Innovation Systems (2015 vs. 2024)	84
16	Annual Slack Values for Innovation Inputs and Outputs in Algeria (2015–2024)	84
17	Returns to Scale Analysis: Individual Country Classifications and Aggregate Distribution (2024)	85
18	Comparative Matrix of Innovation Inputs and Outputs: Algeria vs. UAE (Benchmark) – Raw and Normalized Data (2024)	85
19	Comparative Efficiency Scores and Innovation Recovery Paths (2020–2024)	86
20	Efficiency Benchmarks and Reference Peers for Algeria (2024)	86

List of Abbreviations

NIS	National Innovation System	ANDRU	The National Agency for the Development of University Research
R&D	Research and Development	CTI	Centres Techniques Industriels (Industrial Technical Centers)
GII	Global Innovation Index	DZA	Algeria
PCT	Patent Cooperation Treaty	CHE	Switzerland
WIPO	World Intellectual Property Organization	USA	United States of America
STTS	Scientific and Technical Training Sphere	IRN	Iran
RDS	Research and Development Sphere	NOR	Norway
PS	Productive Sphere	MAR	Morocco
IS	Institutional Sphere	EGY	Egypt
DN-DEA	Dynamic Network DEA	ARE	United Arab Emirates
SBM	Slacks-Based Measure	IRQ	Iraq
MPI	Malmquist Productivity Index	JOR	Jordan
DSBM	Dynamic SBM	SYC	Seychelles
DEA	Data Envelopment Analysis	MUS	Mauritius
DMUs	Decision Making Units	ZAF	South Africa
RTS	Returns to Scale	NAM	Namibia
CRS	Constant Returns to Scale	SEN	Senegal
IRS	Increasing Returns to Scale	CMR	Cameroon
DRS	Decreasing Returns to Scale		
INAPI	Institut National Algérien de la Propriété Industrielle (National Algerian Institute of Industrial Property)		
ANVREDET	The National Agency for the Valorization of the Results of Research and Technological Development		

INTRODUCTION

Preface

In the era of the Fourth Industrial Revolution, which is driven by rapid digitalization, artificial intelligence, and unprecedented technological disruptions, the National Innovation System (NIS) has emerged as the fundamental determinant of sustainable economic growth and global competitiveness. This emergence is due to the fact that modern economic value is no longer dictated by traditional physical labor or the mere accumulation of capital, but rather by the capacity to generate, process, and capitalize on advanced knowledge, which forces nations to rebuild their economic foundations around continuous innovation. Consequently, transitioning toward a knowledge-based economy is no longer a strategic luxury but an existential necessity for nations seeking to break free from resource dependency and the volatile commodity price shocks that historically crippled rentier economies.

To operationalize this macro-level transition, a system relies entirely on the seamless, functional synergy between four critical spheres: the Scientific and Technical Training Sphere (STTS), which acts as the primary engine for cultivating high-skilled human capital; the Research and Development Sphere (RDS), which generates novel ideas and basic scientific breakthroughs; the Institutional Sphere (IS), responsible for designing the regulatory frameworks, funding mechanisms, and intellectual property policies; and the Productive Sphere (PS), which absorbs these ideas and translates them into industrial outputs. While many nations have succeeded in building the formal infrastructure and physical structures of these four spheres, the real systemic challenge lies in the Efficiency of Transformation. This critical metric represents the ability to dynamically convert raw academic knowledge and scholastic outputs into protected, marketable, and internationally recognized technological assets, thereby closing the gap between academic theory and market reality.

Despite Algeria's significant investments in human capital and scientific infrastructure, the Algerian National Innovation System appears to be trapped in a state of Functional Disconnection. While academic indicators show quantitative growth, the economic and industrial impact remains limited, raising critical questions about the efficiency of the conversion process.

Accordingly, based on the above, the research problem can be formulated in the following question:

Research Question

How efficient is the Algerian National Innovation System in transforming its scientific and technical inputs into internationally protected and industrially marketable outputs compared to a sample of developed and emerging economies in the period 2015-2024?

Based on the previously stated research problem and in order to gain a deeper understanding of the various aspects of the topic, we have chosen to break down The main problem into a number of sub-questions that this study seeks to answer, as follows:

Sub-Questions

1. To what extent has the Algerian Institutional Sphere (IS) succeeded in ensuring the legal security of innovations through integrative initiatives like Decree 1275, and how have inherited administrative residues and path dependency affected the system's efficiency compared to the sample countries?
2. To what extent does the Resource Curse contribute to creating a state of Innovation Slack within the Algerian National Innovation System, and how does this curse explain the superiority of resource-poor countries in the efficiency of knowledge transformation?
3. To what extent does Path Dependency on a rentier economy direct inputs toward pure academic research rather than applied innovation compared to the sample countries?
4. What is the volume of Slacks resulting from the weak transformation of academic inputs into protected outputs, and how has the isolated development of the four spheres led to fluctuations in efficiency levels compared to the sample countries?
5. To what extent do global shocks induce a state of Innovation Hysteresis within the Algerian system, and how does the robustness of functional linkages between the four spheres determine the speed of innovation recovery and systemic resilience compared to the sample countries?
6. Is the low efficiency in Algeria due to the Scale Trap, and does it suffer from a fragmentation of knowledge efforts where inputs (publications) are disproportionate to the required outputs (patents)?
7. To what extent do Algerian innovation outputs deviate from International Quality Standards (PCT) and Global Alignment, and how does the weak foreign-orientation affect technological sovereignty and the system's overall efficiency?
8. To what extent does the Algerian innovation system succeed in bypassing the Knowledge Accumulation stage (publications and applications) to reach the Economic Value Generation stage (Trademarks and International Patents), And do the results reflect a real Social/Economic Return on academic effort compared to the sample countries?
9. What are the Projections and the Benchmarks identified by the SBM model for Algeria to establish a roadmap toward full efficiency?

Research Hypotheses

- Hypothesis 1: A fundamental efficiency gap exists in Algeria due to low Pure Technical Efficiency, where the responsiveness to new integrative policies (Decree

1275) is impeded by administrative residues of a rentier economy. While these initiatives aim to improve scale efficiency and technological sovereignty, their impact remains slow and constrained by legacy structures compared to emerging nations.

- Hypothesis 2: The abundance of natural resources in Algeria and oil-producing countries (Iraq, Iran) leads to directing inputs toward non-innovative rentier sectors, causing the SBM Score to be more sensitive to raw material prices than to actual scientific effort.
- Hypothesis 3: The Algerian innovation system faces structural difficulties in altering its traditional trajectory, remaining trapped in a pattern of scientific publication production without the ability to pivot toward patenting at the same pace as diversified nations.
- Hypothesis 4: A Knowledge Paradox occurs in Algeria, reflected in high output slacks, where there is efficiency in the field of training and research, but it fails to achieve internationally protected outputs due to the functional disconnection between the four spheres, reflecting the weak link between knowledge accumulation and industrial valorization.
- Hypothesis 5: Algeria exhibits excessive sensitivity to external crises and a Negative Memory Effect, where the productive cycle takes longer to recover (Lag Effect) due to functional fragmentation. Unlike countries with diverse productive spheres and university-industry integration, the Algerian system suffers from a permanent erosion of innovative gains after each shock.
- Hypothesis 6: The Algerian innovation system suffers from Decreasing Returns to Scale, where failure to achieve efficiency is not due to a lack of resources, but rather a failure to reach the Critical Mass of technical outputs that allows it to transition from a technology consumer to a solution producer.
- Hypothesis 7: There is a Global Alignment Gap and a weak foreign-orientation; Algeria focuses on local protection (INAPI) with low-complexity outputs, while sample countries integrate into the global sphere (WIPO) with complex, internationally protected outputs, thereby enhancing their technological sovereignty and SBM scores.
- Hypothesis 8: The Algerian system shows efficiency in Knowledge Accumulation (STTS and RDS spheres) but suffers from a break in the value chain when transitioning to the Productive Sphere (PS), making the economic return on innovation weak and confined to local consumption, unlike sample countries that translate their international patents into global market shares.
- Hypothesis 9: Achieving full efficiency requires a Catch-up in Stages strategy, starting with reducing slacks in the productive sphere first (simulating Egypt and Morocco), then a functional redesign that focuses on international outputs as a priority to break the isolation between the research and productive spheres.

INTRODUCTION

Reasons for Choosing the Topic

The selection of this topic is driven by the following motives:

- The Contemporary Significance of the Topic: Given the rapid global shifts toward a knowledge-based economy and the acceleration of digital transformation, there is an urgent need to evaluate how Algeria's innovation system is responding to these challenges.
- A Desire for Academic Depth: a profound interest in exploring the dynamics of NIS.

Importance of the Study

The importance of this study lies in its move beyond descriptive analysis to a quantitative evaluative approach. It provides a first-of-its-kind decomposition of inefficiency in the Algerian NIS using the SBM model, identifying the specific Slacks that hinder technological sovereignty and global alignment.

Objectives of the Study

- Measuring the technical and scale efficiency of the Algerian NIS relative to 15 international benchmarks.
- Analyzing the Resource Curse and Path Dependency effects on innovation performance.
- Evaluating the impact of Decree 1275 on the efficiency trajectory.
- Identifying the optimal benchmark (Reference Set) for Algeria to emulate in its catch-up strategy.

Data Collection & Sources

- Theoretical Framework: Relies on a comprehensive review of academic books, peer-reviewed journals, international conference proceedings, and global innovation reports.
- Analytical Framework: Quantitative data was harvested from international databases (WIPO) And Scopus SJR For the period (2015-2024).

Research Methodology & Model

The study adopts a Quantitative Analytical Approach. To fulfill the evaluative objective, the Output-Oriented Slack-Based Measure (SBM) Model under Variable Returns to Scale (VRS) assumptions was utilized. This model is chosen for its ability to handle non-radial slacks, providing a more accurate measure of inefficiency than traditional DEA models.

Scope of the Study

- Spatial Scope: A comparative sample of 16 countries, including Algeria, developed nations (USA, Switzerland), and emerging/resource-based economies (UAE, Egypt, South Africa... etc.).

INTRODUCTION

- Temporal Scope: A ten-year period from 2015 to 2024, capturing the impact of global crises and recent national reforms.

Research Challenges

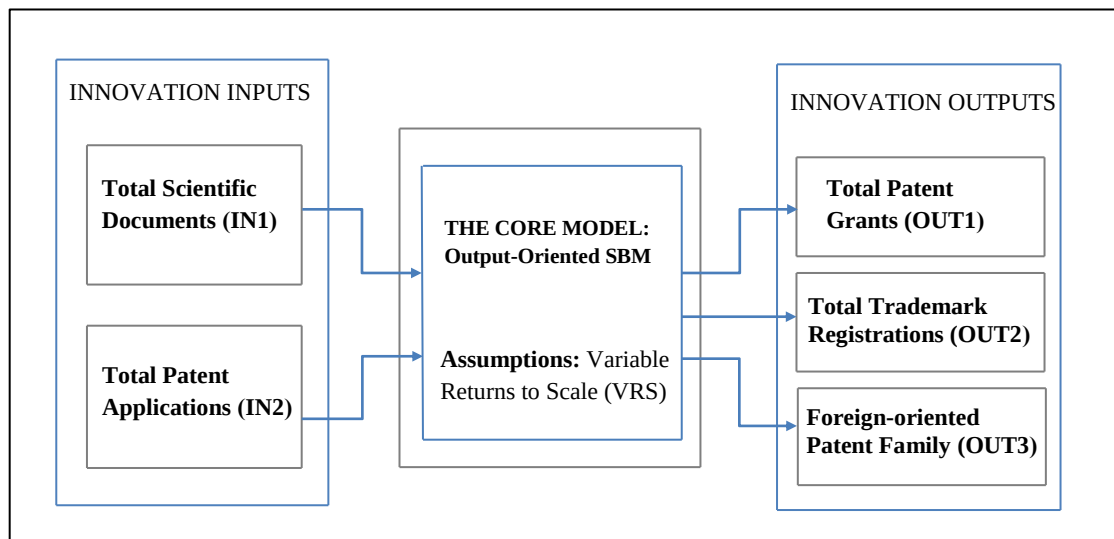
- Identification and Specification of Study Indicators.

Selection of the Country Sample based on Data Availability for the period 2015–2024

Research Model

The research model illustrates the functional flow of the Algerian National Innovation System. It employs a non-radial Slacks-Based Measure (SBM) to evaluate the efficiency of transforming innovation inputs (In1, In2) into their respective outputs (Out1, Out2, Out3).

Figure 1.1: Theoretical Framework of the SBM-DEA Model



Source: Compiled by the researcher

Chapter 1

Theoretical and Empirical Literature of the National Innovation System

Preface

The National Innovation System (NIS) is the fundamental pillar upon which nations build their competitive strategies, as innovation does not operate in isolation from the surrounding institutional and regulatory environment. A deep understanding of this system requires deconstructing its components and studying the interactive relationships between its various actors, ranging from government policies to research and development (R&D) outputs.

Accordingly, this chapter aims to provide a theoretical foundation for the core concepts of this system, while highlighting the reality of the Algerian Innovation System through the following sections:

1. Theoretical Literature of the National Innovation System

2. Literature Review of the National Innovation System

1. Theoretical Literature of the National Innovation System

Innovation is no longer merely a technical option, it has become a strategic driver that relies on the synergy between institutions, universities, and research centers within what is known as the National Innovation System. The efficiency of this system determines a country's ability to transform knowledge into economic value, making it the fundamental pillar for achieving competitive advantage and sustainable growth in the global knowledge-based economy. Accordingly, we will attempt here to address the typologies and importance of this system, while highlighting the reality of the Algerian context.

1.1. The National Innovation System

1.1.1. Historical Evolution of the National Innovation System

The nascent foundations of the National Innovation System concept emerged decades before its formal appearance as a technical term. Its intellectual roots can be traced back to the work of the German economist Friedrich List (1841). In his book "The National System of Political Economy", List emphasized that a nation's development does not rely solely on trade exchange, but rather on the construction of productive forces and the advancement of the state's mental and institutional capital. This perspective established the cornerstone for the idea that innovation is a process inherently linked to national boundaries and state policies. (Johnson, Edquist, & Lundvall, 2003)

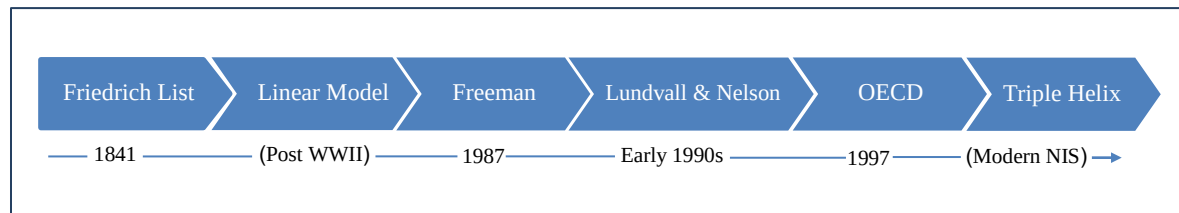
These ideas remained largely dormant until the post-World War II era, during which the "Linear Model of Innovation" prevailed. This model posited that innovation begins with basic research and automatically culminates in a commercial product. However, by the 1970s and 1980s, this vision began to erode in the face of the success of the Japanese experience. This success prompted Christopher Freeman (1987) to formally coin the term for the first time in his study of Japan. He defined the system as a network of institutions in the public and private sectors whose activities and interactions initiate, import, modify, and diffuse new technologies, asserting that the secret lies in social and political organization rather than in technology alone.

Later in the early 1990s, specifically between 1992 and 1993, the concept crystallized and expanded through two complementary trajectories. The first was led by Lundvall, who focused on "interactive learning" and characterized innovation as a social process rooted in the relationship between the producer and the user. The second trajectory was spearheaded by Richard Nelson, who concentrated on institutional setups and the comparison of national systems among major industrial nations, which led to the consolidation of the concept as a robust analytical tool. (Lundvall, 2015; Johnson, Edquist, & Lundvall, 2003)

By the late 1990s the concept transitioned from academic circles to international bodies. The OECD (1997) institutionalized the term transforming it into an operational framework for measuring "knowledge-based economies". This adoption led to the global diffusion of the concept, and developing nations began attempting to adapt this framework to understand their technological gaps. This evolution eventually led to modern models that discuss open systems and the synergy between university, industry, and government (Triple Helix) to confront the challenges of globalization. (Feinson, (n.d.))

Through tracing this trajectory, we conclude that the National Innovation System was not merely a new label, but a fundamental shift in understanding the drivers of economic growth, as Innovation is no longer a laboratory coincidence but rather a product of institutional interaction. The historical evolution has proven that the system does not succeed through the mere importation of technology, but through the state's ability to create linkages between education, research, and the market. Which The true measure is not the existence of institutions themselves, but the efficiency of interaction among them.

Figure 1.1: Historical Evolution of National Innovation System



Source: Compiled by the researcher

1.1.2. Definitions of the National Innovation System

Classical definitions

"The network of institutions in the public- and private-sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (**Freeman, 1987**)

"The elements and relationships which interact in the production, diffusion and use of new, and economically useful knowledge... and are either located within or rooted inside the borders of a nation state" (**Lundvall, 1992**)

"A national system of innovation is the system of interacting private and public firms (either large or small), universities, and government agencies aiming at the production of science and technology within national borders. Interaction among these units may be technical, commercial, legal, social, and financial, in as much as the goal of the interaction is the development, protection, financing or regulation of new science and technology" (**Niosi et al, 1993**)

"That set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies" (**Metcalfe, 1995**) . (Feinson, (n.d.))

Classically, the National Innovation System is defined as a local institutional fabric comprising public and private actors (including firms, universities, and government agencies) operating within national borders to establish interactive relationships aimed at the

production, importation, and diffusion of new technologies. This system provides the regulatory framework that bridges scientific research and governmental policies to transform scientific knowledge into economically useful applications.

Modern Definitions

"A network of interacting policies, institutions, and organizations whose holistic functionality depends on the quality of Cooperation between the various component parts" (Manzini, 2012)

"A unity of enterprises of various patterns of ownership that individually or through interaction with each other provide the formation and dispersion of innovation technologies within a definite state, it encourages the implementation of the derived technologies into production and development of new products saleable in the world market" (Garifullin and Ablaev, 2015)

"The institutions, human capital and interactions among them that facilitate the creation and diffusion of knowledge" (Maloney, 2017)

"An innovation system encompasses all the organizations and institutions involved in the innovation process and the national innovation system gives special attention to those institutions and organizations which are located in or rooted in a nation state" (Chaminade et al, 2018) . (Dworak, Grzelak, & Roszko-Wójtowicz, 2022)

Modernly, the National Innovation System is viewed as a holistic functional system that hinges on the quality of cooperation between policies, institutions, and individuals (human capital). Beyond the creation and dissemination of knowledge, this system emphasizes the dynamics of interaction that ensure the transformation of innovations into marketable products within the global market. It underscores that the overall effectiveness of the system is fundamentally dependent on the quality of coordination among its constituent components.

Based on the classical and modern definitions presented above, the National Innovation System **can be defined** as a set of interconnected institutions, organizations, policies, and actors operating within a nation state whose interactions and cooperation facilitate the creation, development, diffusion, and use of scientific and technological knowledge, there by supporting the innovation process and its application within the national economy.

1.1.3. Typologies of the National Innovation System

The classification of National Innovation Systems (NIS) varies significantly based on the criteria used to analyze their institutional and economic performance. According to academic literature and international frameworks (such as Albuquerque, Edquist, and the OECD), these systems can be categorized into four primary dimensions:

Classification by System Maturity and Technological Frontier

Scholars, notably Albuquerque (1999), distinguish between systems based on their position relative to the global technological frontier:

Mature NIS: Typical of advanced economies such as the United States, Switzerland, Norway, and Germany, these systems focus on radical innovation and basic research, supported by high R&D intensity and strong industry-university linkages.

Catching-up NIS: As observed in the development of Iran and the United Arab Emirates, these systems prioritize the absorption and adaptation of foreign technologies to bridge the gap with global leaders.

Non-mature/Developing NIS: These are often fragmented systems found in developing nations like Algeria, Morocco and Egypt, where innovation is primarily incremental and relies heavily on imitation and learning by doing due to weak institutional support. (Albuquerque, 1999)

Regional and Strategic Models

The evolution of systems is deeply rooted in historical and geographical contexts, leading to the emergence of specific regional models:

The East Asian Model: Characterized by strong government intervention and export-oriented growth, focusing on rapid technological integration into global value chains.

The Transition (Resource-Based) Model: Found in economies like Algeria, Iran, Iraq and Norway (as an advanced case), where the challenge lies in reorienting older competencies (or resource-based wealth) toward market-driven and knowledge-based needs. (Lundvall, Joseph, Chaminade, & Vang, 2009; Edquist, 1997)

Institutional Interaction Modes

Beyond strategic goals, systems differ in how their internal actors (universities, firms, and government) interact:

Interconnected Subjects Mode: Represents a high-functioning system with strong collaboration and interactive learning, as observed in Switzerland, Norway, and the United States. (Johnson, Edquist, & Lundvall, 2003)

Independent Subjects Mode: Where actors operate in isolated islands (Silos), a common characteristic in the systems of Algeria, Iraq, and Iran, often leading to what is known as the valley of death between research and application. (Feinson, (n.d.))

Narrow vs. Broad Perspectives

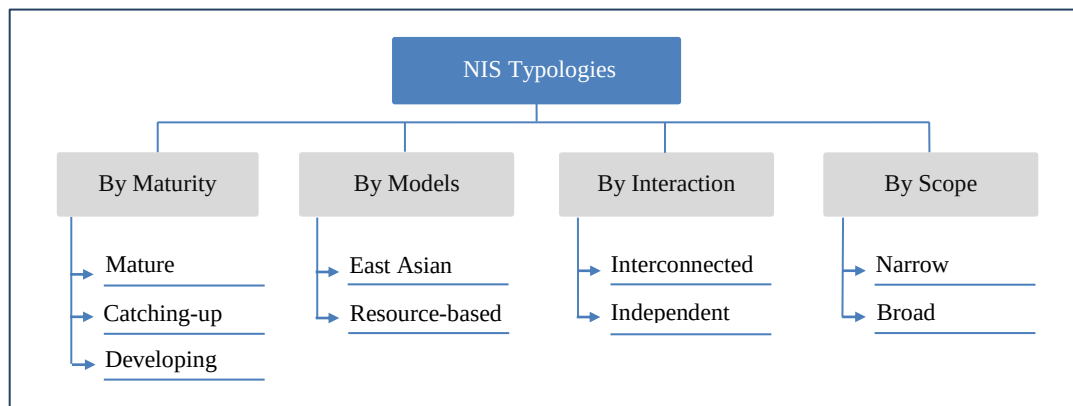
As highlighted by Lundvall et al., the scope of a national system can be viewed through two lenses:

Narrow NIS: Focuses strictly on formal R&D organizations, this is often the primary focus in Algeria, Cameroon and Namibia.

Broad NIS: Which encompasses the wider socio-economic environment, including the education system, financial regulations, and labor markets that indirectly influence a nation's innovative capacity, this is the stage reached by Switzerland, Norway, and the U.S., and which the United Arab Emirates is aggressively pursuing through its strategic reforms. (Lundvall, Joseph, Chaminade, & Vang, 2009)

The diversity of National Innovation Systems demonstrates that there is no one-size-fits-all model. However, The transition from a narrow R&D focus to a broader institutional perspective highlights that innovation is a social process and an interactive learning mechanism driven by the synergy between maturity, strategic policy, and institutional interconnectedness. And for comparative purposes, understanding these typologies is crucial, as it reveals how a nation's path dependency and its ability to bridge the gap between scientific research and market application determine its competitive position in the global knowledge economy.

Figure 1.2: Typologies of National Innovation System



Source: Compiled by the researcher

1.1.4. Importance of the National Innovation System

The National Innovation System is a fundamental analytical framework adopted by international organizations, such as the OECD, to examine how internal institutional networks contribute to the economic and social development of nations. Its importance is manifested in the following points:

Economic Growth and Competitiveness

Economic Performance: Innovation capacity is closely linked to economic performance, as high levels of innovation are often coupled with an increase in GDP per capita.

Global Competitiveness: The system affects a country's ability to effectively diffuse knowledge among institutions, which enhances its competitive position in the global economy.

Knowledge-Based Economy: The NIS provides the structural foundation that enables economies to move beyond dependence on natural resources or agriculture, transitioning toward high-value knowledge-based industries. (OECD, 2005)

Strategic Resilience and Sustainable Development

Sustainable Development: National innovation capacity constitutes an essential mechanism for achieving the goals of the 2030 Agenda for Sustainable Development.

Crisis Management: An efficiently functioning innovation system enhances a state's ability to maintain domestic productive capacities and respond effectively to global crises, such as the COVID-19 pandemic. (Li, Wu, Zhang, & Yang, 2023)

Economic Diversification: For developing and emerging economies, the NIS serves as a strategic tool for economic diversification and reducing over-reliance on natural resources. (Feinson, (n.d.))

Knowledge and Human Capital Development

Technological Catch-up: A nation's ability to absorb, adapt, and apply external technologies (often referred to as Absorptive Capacity) is significantly strengthened by the presence of an effective innovation system. (Feinson, (n.d.))

Institutional Cooperation: The system facilitates interaction between academic research institutions and private sector firms, narrowing the gap between scientific knowledge production and its commercial applications.

Human Capital Formation: The system contributes to the development of highly skilled human resources and research talent, which are essential elements for creating quality job opportunities and supporting long-term economic development. (Lundvall, 2010)

Policy Effectiveness

Policy Coordination: The NIS framework allows governments to align and coordinate diverse policy areas, such as education, R&D, and trade, within a coherent strategic vision.

Institutional Framework: The system works to establish the legal and institutional structures necessary to encourage sustainable private investment in innovation and technological progress. (OECD, 2005)

Enhancing Open Innovation (Firm-level)

Knowledge Permeability: Unlike traditional closed models, the NIS framework encourages Open Innovation, where firms accelerate their internal innovations by integrating external knowledge, technologies, and R&D from universities and startups (Outside-In process).

Commercialization of Knowledge Spillovers: The system enables companies to commercialize internal ideas or unused patents and transfer them to the market or other industries, ensuring that scientific knowledge does not remain stagnant within a single organization (Inside-Out process).

Collaborative Ecosystems: An effective system fosters a culture of co-innovation, where firms, research labs, and government bodies create value together through strategic alliances, reducing costs and risks associated with radical technological development. (Chesbrough & Bogers, 2013)

The importance of the National Innovation System lies not only in the isolated performance of its components but in the efficiency of their integration across the macro (policies) and micro (institutions) levels. Advanced economies use this system to maintain global leadership, while emerging economies harness it as a strategic tool for technological catch-up and economic diversification. It is also observed that by bridging the gap between national policies and open innovation at the firm level, the NIS is able to transform scientific research into a tangible engine for global competitiveness and sustainable economic growth.

Figure 1.3: Importance of National Innovation System



Source: Compiled by the researcher

1.1.5. Indicators for Evaluating the National Innovation System

The evaluation of a National Innovation System requires a multidimensional approach that encompasses various socio-economic and institutional factors. The table below presents the seven pillars of the Global Innovation Index (GII), which represent the core metrics for measuring a nation's innovative capacity. These pillars provide a comprehensive view of the innovation landscape, ranging from the foundational institutional environment to the final knowledge and creative outputs.

Table 1.1: National Innovation System Assessment Indicators

Main Indicators	Sub-Indicators	Individual Indicators (examples)
Institutions	Institutional environment, Regulatory environment, Business environment	Operational stability for businesses, Government effectiveness, Policy stability for doing business
Human capital and research	Education, Tertiary education, Research and development (R&D)	Expenditure on education, Researchers, Gross expenditure on R&D
Infrastructure	Information and communication Technology (ICT), General infrastructure, Ecological Sustainability	ICT access, Logistics performance, Gross capital formation
Market sophistication	Credit, Investment, Trade, diversification and market scale	Finance for startups and scaleups, Market capitalization, Domestic market scale
Business sophistication	Knowledge workers, Innovation linkages, Knowledge absorption	GERD performed by business, University-industry R&D collaboration, State of cluster development
Knowledge and technology outputs	Knowledge creation, Knowledge impact, Knowledge diffusion	PCT patents by inventor origin, Scientific and technical articles, High-tech exports
Creative outputs	Intangible assets, Creative goods and Services, Online creativity	Trademarks by origin, Industrial designs by origin, Creative goods exports

Source: Compiled by the researcher based on the Global Innovation Index. (WIPO, Global Innovation Index 2025 Innovation at a Crossroads, 2024, pp. 267-288)

1.2. The National Innovation System of Algeria

1.2.1. The Strategic Shift Towards a Knowledge-Based Economy

Algeria is adopting a strategic vision to move away from its traditional oil-dependent economy toward a new development model based on innovation and knowledge. This approach focuses on making startups and applied scientific research the main drivers of economic transformation. It aims to create a supportive environment for digital creativity and encourage entrepreneurship among young people. This effort goes beyond simple technical updates; it seeks to build stronger links between universities and the economic sector. By focusing on digital services and improving the investment climate, Algeria aims to attract high-value projects, turning knowledge into a key economic asset for sustainable development and technological independence. (Ministre, 2021)

To implement this vision, Algeria has adopted new educational policies to strengthen the developmental role of universities and their contribution to a knowledge-based economy,

Ministerial Decree No. 1275 known as the Startup-Certificate / Patent-Certificate initiative, is a key tool in this transformation, It seeks to bridge the gap between academic research and the economic sector by turning theoretical knowledge and scientific publications into practical, legally protected innovations, This decree encourages students and researchers to file patent applications and value their scientific results, ensuring that innovative ideas become high-value projects that support sustainable development, This path not only increases national intellectual property but also creates an integrated innovation environment that links university outputs with the needs of national development. (وزير التعليم العالي والبحث العلمي، 2022؛ بلصير، 2025)

1.2.2. Actors of the Algerian National Innovation System

To describe the actors of the Algerian NIS, the focus is placed here on the organizations and institutions related to science and technology, as well as upstream institutions, such as the education and training system, and downstream actors, such as industry.

A striking feature of the Algerian NIS is the existence of systemic elements without a direct link to science and technology but which contribute to promoting knowledge, skills, and qualifications for technological development, These include, for illustrative purposes, infrastructures like technopoles or industrial technical centers, or incentive mechanisms such as business upgrading or the creation of innovative startups.

The proposal by Bes (1995) to decompose the NIS into three spheres is expanded here to four to account for the influence of the institutional structure. They are detailed below:

The Scientific and Technical Training Sphere (STTS): Consisting of public or private education and higher teaching establishments, the content of programs and means implemented, as well as the stock of trained students.

The Research or Research and Development Sphere (RDS): It concerns applied research conducted by scientific and technological research structures (public and private laboratories or research centers).

The Productive Sphere (PS): The most externally oriented (commercial exchanges, technology transfers), it groups the structures and industrial relations between companies. It is here that the economic value of innovation is materialized, notably through the registration of trademarks which protect the identity of products on the market.

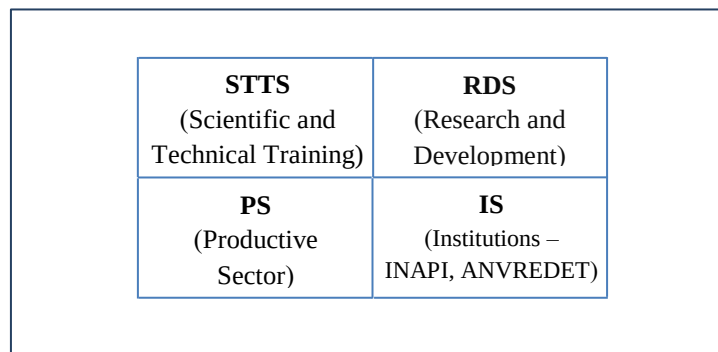
The Institutional Sphere (IS): It includes public institutions and regulatory bodies, such as INAPI, which guarantees the legal security of inventions through the issuance of patents.

In Algeria, most institutions for the regulation and promotion of innovation fall within the public domain, Even intermediate structures (CTI, technopoles, and financing systems) supporting technological development do not escape this state control, From the examination of the upstream institutions of the Algerian NIS, two central actors emerge whose role is to ensure the animation and coordination of scientific and technological activities, These are the National Agency for the Development of University Research (ANDRU) and the National Agency for the Valorization of the Results of Research and Technological Development

(ANVREDET), to which INAPI is added as a key actor in industrial property, responsible for maintaining a link between the research sphere and the productive sphere.

The R&D sphere is strongly embedded in the scientific and technological research system and, weakly, in the productive system. This is explained by the low propensity of private companies to undertake R&D activities and the lack of private R&D laboratories. Another explanatory element is the strong information asymmetry (lack of communication, development in isolation) that characterizes the various actors in the Algerian NIS. Between the two major spheres of the NIS, namely the STTS (education and research system) and the productive sphere (innovative enterprise), there are intermediate structures (CTI, technopoles, etc.) responsible for narrowing the gap between research and industry. The State, for its part, works to promote research and technological development by creating an adequate institutional framework and guaranteeing the transfer of knowledge and technology between the STTS, the PS, and the RDS. (Amdaoud, 2016)

Figure 1.4: Actors of Algerian National Innovation System



Source: Compiled by the researcher

1.2.3. Functional Dynamics and Integration Mechanisms of the Algerian NIS

The integration within the Algerian NIS is based on a functional sequence where the four spheres exchange roles to transform a raw idea into a protected industrial product. This integration can be analyzed through the following interconnected stages:

Knowledge Production and Technical Alignment (STTS-RDS Integration)

The first level of integration occurs between the Scientific and Technical Training Sphere (STTS) and the Research Sphere (RDS). In the Algerian context, particularly with the implementation of Decree 1275, the university (STTS) serves as the incubator for human capital, while the research centers (RDS) provide the technical infrastructure. According to Lundvall (2010), the effectiveness of an NIS depends on interactive learning here, the integration is achieved when academic programs are aligned with research priorities, ensuring that scientific outputs are not merely theoretical but possess a high potential for industrial application. (Lundvall, 2010)

Institutional Protection as a Bridge to Industry (IS-PS Integration)

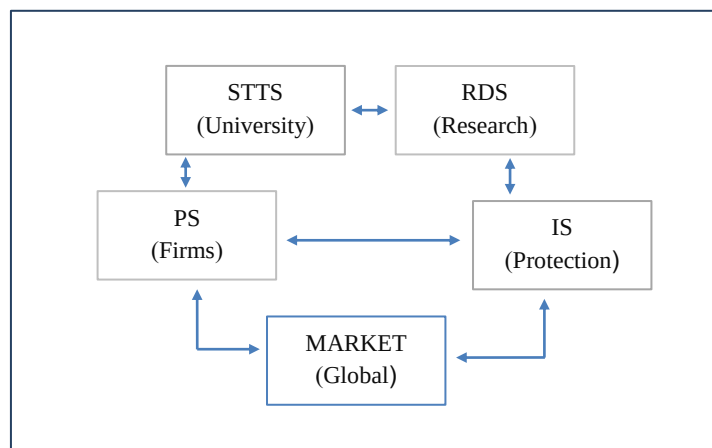
The second level of integration involves the Institutional Sphere (IS) and its role in securing the Productive Sphere (PS). This is a critical functional link. INAPI does not work in isolation but acts as a validator for the industry. When the Institutional Sphere grants a patent, it creates a legal certainty that allows the Productive Sphere to adopt the innovation. This mechanism is essential for Industrial Sovereignty; it ensures that the industrial sector can rely on national technical solutions, turning intangible research into tangible economic assets that strengthen the domestic market.

Outward-Looking Dynamics and Global Market Access

The final stage of integration is the transition from domestic production to international market positioning. This is where the synergy of the four spheres reaches its peak. Drawing upon the internationalization theory of Carlsson (2006), which emphasizes that the NIS becomes internationalized through cross-border knowledge flows and institutional alignment, it can be inferred that the NIS is integrated globally when its internal actors (from the STTS, RDS, and PS) utilize international frameworks like WIPO to protect their innovations. (Carlsson, 2006)

In this sense, the move toward outward-looking trajectories (such as seeking international protection for inventions) is the logical conclusion of the integration process. It proves that the national system has successfully coordinated its training, research, and industrial sectors to produce an output that meets global standards. Thus, the integration of the four spheres serves as the necessary foundation for Algeria to bridge the gap between national knowledge creation and international industrial competitiveness.

Figure 1.5: Integration Mechanisms of Algerian NIS



Source: Compiled by the researcher

2. Literature Review of the National Innovation System

The National Innovation System has garnered particular importance, representing a global trend through which countries seek to build an integrated framework that brings together institutions, universities, and research centers to develop a sustainable technological dynamics suited to their needs. In response to international shifts, countries and institutions strive to activate the roles of this system to keep pace with rapid transformations and enhance competitive advantage, especially within the knowledge economy, which is considered the most competitive economic model. This necessitates evaluating the efficiency of these systems to ensure their ability to transform scientific resources into added-value innovation outputs. Accordingly, we will attempt here to present several previous studies related to this topic, followed by an evaluation to identify the relationship between them and the current study, these have been categorized into national and international studies, arranged from the most recent to the oldest.

2.1. National Studies

2.1.1. Nadia Kharkhache, "Indicators of National Innovation System: The Importance of Improving Its Levels to Enhance the Building of Knowledge Economy - A Comparative Study between Algeria and Some Countries", Journal of the Institute of Economic Sciences, Ferhat Abbas University - Setif, Vol. 26, No. 02, 2023.

Through this study, the researcher sought to identify the problem of the weak performance of the National Innovation System indicators in Algeria and to examine the significance of improving these indicators in supporting the establishment of a knowledge-based economy, in comparison with selected developed and developing nations. The researcher employed a comparative analytical approach, utilizing innovation system indicators—specifically innovation input indicators (human resources in R&D and R&D expenditures) and innovation output indicators (scientific publications and patents)—as an analytical tools to evaluate the level of the national innovation system. The study sample included Algeria, the United States of America, Germany, France, South Korea, China, Egypt, Tunisia and Morocco covering the period 2018-2022.

The researcher reached the following key results:

- Algeria recorded one of the weakest and lowest levels of national innovation system indicators compared to the countries included in the study;
- The low level of innovation indicators negatively affects Algeria's ability to build a knowledge-based economy;
- Developed countries demonstrated superior performance in both innovation inputs and outputs.

The study concluded that improving the levels of national innovation system indicators is essential to support the transition toward a knowledge economy in Algeria, and the failure to enhance these indicators will continue to limit competitiveness and economic development.

2.1.2. Amina Zerdoudi and Moubarak Bouacha, "National Innovation Systems: A Comparison between Maghreb Countries and Emerging Countries", Journal of Humanities, University of Constantine 2, Vol. A, No. 43, June 2015.

This study addressed the variation in the performance of National Innovation Systems among the Maghreb countries compared to selected emerging economies, focusing on their ability to transform innovation inputs into measurable outputs and support economic development. The researchers employed a comparative analytical approach using cross-sectional comparisons of national innovation system indicators to evaluate performance gaps between the Maghreb countries and emerging economies. The analytical tools included a descriptive and analytical assessment of innovation inputs (R&D expenditure, human capital, and institutional and financial resources) and outputs (patents, scientific publications, and technological outcomes). The study sample included Algeria, Tunisia, Morocco, South Korea, Brazil and India for the period 2005-2014.

The most important results reached:

- Maghreb countries show weak performance in innovation outputs despite the available resources;
- Emerging economies outperform Maghreb countries in the efficiency of transforming innovation inputs into technological outputs;
- The results indicate that structural and institutional constraints in the Maghreb region limit the effectiveness of innovation systems and hinder synergy between research centers and the productive sector.

This study highlighted that strengthening the components of the National Innovation System and improving coordination between institutions are essential for Maghreb countries to enhance performance and bridge the gap with emerging economies. The study also emphasized that a successful transformation requires moving from isolated scientific efforts to integrated innovation policies that facilitate knowledge commercialization and technology transfer.

2.2. International Studies

2.2.1. Davor Vlačić et al., "The Efficiency of CEE Countries Innovation System", Transactions on Maritime Science, Vol. 14, No. 03, 25 July 2025.

This study aimed to investigate the efficiency of Central and Eastern European (CEE) countries (Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, and Slovenia) in transforming Research and Development (R&D) resources into innovation outputs. It sought to identify inefficiencies within the government, business, and higher education sectors while tracking changes in innovation productivity over time. The study adopted a quantitative efficiency analysis using Data Envelopment Analysis (BCC model) and the Malmquist Productivity Index (MI) covering the period 1998-2019, to evaluate both static efficiency and temporal changes and to decompose productivity growth into efficiency change (the catch-up

effect) and technological change (frontier shift). Inputs included sector-specific R&D expenditures, while outputs focused on technological and productive outcomes.

The study reached the following key findings:

- There are significant inefficiencies in transforming R&D inputs into innovation outputs across many CEE countries;
- Changes in productivity are primarily driven by improvements in efficiency (the catch-up effect) rather than shifts in the technological frontier;
- Structural and institutional weaknesses continue to limit the effectiveness and Return on Investment (ROI) of R&D inputs.

The study demonstrated that CEE countries can primarily enhance innovation performance by improving the efficiency of R&D resource allocation rather than merely increasing expenditure, and that achieving an optimal balance between public, private, and academic R&D investment is crucial for a more productive innovation system.

2.2.2. Robert D. Atkinson et al., "Understanding and Comparing National Innovation Systems: The U.S., Korea, China, Japan, and Taiwan", Joint Report by Chey Institute and ITIF, February 2025.

This study addressed the variations in National Innovation Systems between major advanced and emerging economies, and how institutional structures, policy frameworks and industrial specialization shape innovation performance and economic competitiveness. The study relied on comparative, qualitative and quantitative analysis, combining historical policy analysis and indicator-based comparison of National Innovation Systems. The analytical tools included a comparative NIS framework, the Global Innovation Index (GII), and Sectoral Location Quotients for the United States, Korea, China, Japan and Taiwan in the period 2010-2020, using human capital, R&D investment, and institutional frameworks as inputs, and technological outputs, industrial specialization, and productive outcomes as outputs.

The most important findings extracted from the study are as follows:

- Korea and Taiwan demonstrated strong innovation performance driven by human capital and manufacturing capabilities;
- The United States showed weaknesses in advanced industrial production despite its high innovation capacity;
- China's National Innovation System focuses on rapid technological catch-up and expanding the technical frontier, while Japan faces a decline in competitive advantages across several advanced sectors.

The study demonstrated that the success of a National Innovation System is contingent upon the presence of strong human capital and strategic synergy between industrial structures and innovation policies, and that international collaboration is imperative to enhance innovation outputs in an era characterized by global technological specialization and supply chain interdependence.

2.2.3. Gonalo Rodrigues Brs and Margarita Robaina, "National innovation systems and sustainable environmental performance: A cross country analysis", Environmental Challenges, Vol. 16, 5 July 2024.

Through this study, the researchers sought to understand the relationship between National Innovation Systems and sustainable environmental performance, with focus on the extent to which strong innovation systems contribute to achieve better outcomes and enhancing climate change resilience. They relied on a cross-country quantitative empirical analytical approach to test the relationship between innovation system indicators and environmental performance metrics, using econometric modeling as analytical tool. The variables included National Innovation System indicators (R&D, technological capacity, and institutions), environmental performance indicators, and cross-sectional data from 2021/2022 for 130 countries.

The researchers reached the following key findings:

- Strong National Innovation Systems are positively associated with improved environmental sustainability outcomes;
- Innovation activities serve as a fundamental pillar in supporting clean technologies and enhancing environmental efficiency;
- The results show that institutional support significantly strengthens the environmental impact of innovation, ensuring that technological progress aligns with sustainability requirements;
- Innovation acts as a key driver for sustainable development by providing the necessary tools for resource optimization.

We note that the study emphasized that effective National Innovation Systems play a major role in fostering sustainable environmental performance, and that the integration of institutional quality and technological advancement is the key to success in addressing global environmental challenges.

2.2.4. Abdel Latef Anouze et al., "Reevaluating national innovation systems: An index based on dynamic-network data envelopment analysis", Socio-Economic Planning Sciences, Vol. 95, 24 June 2024.

The study aimed to identify the shortcomings in current innovation system evaluation methods, and sought to develop a more dynamic, and process-oriented assessment for National Innovation Systems. The study relied on Dynamic Network Data Envelopment Analysis (DN-DEA), specifically the SBM-DNDEA model, to measure the efficiency of the innovation system over time. The methodology involved constructing an efficiency index based on Global Innovation Index (GII) data for the period 2016-2021, using sub-processes for knowledge development and commercialization, and panel data for 33 countries (a group of oil-producing countries and leading innovation benchmark countries).

The study reached the following key findings:

- National Innovation System efficiency remains relatively stable over time;

- South Korea and Sweden emerged as the top-performing countries in terms of overall systemic efficiency;
- The results revealed a functional divide, where different countries lead in distinct sub-processes, for example, excellence in knowledge generation versus excellence in commercialization.

The study demonstrated that Dynamic Network Data Envelopment Analysis provides a more comprehensive and accurate evaluation of innovation systems, offering valuable insights for designing targeted innovation policies.

2.2.5. Larysa Antoniuk et al., "Evaluating the National Innovation Systems of EU Countries through Innovation Indicators", Proceedings of the 7th International Conference on Economics and Social Science (ICESSE), Romania, 13-14 June 2024.

This study addressed how to evaluate and compare the performance of The National Innovation Systems across EU countries, and the extent to which differences in innovation indicators can explain the variations in national innovation performance. The study adopted a quantitative comparative methodology based on the analysis of secondary statistical data for EU member states, using innovation indicators derived from Eurostat, the variables related to R&D activities, patents, and innovation inputs, along with composite indicators for the year 2023, while employing Cluster Analysis, Graph Visualization, and descriptive and comparative statistical techniques as primary analytical tools.

The most important findings extracted:

- There are significant disparities among EU countries regarding national innovation performance;
- Countries with strong patent-related indicators tend to consistently demonstrate higher levels of overall national innovative capacity;
- The efficiency and structure of innovation indicators, particularly Digitalization, play a crucial role in shaping national innovation outputs.

This study highlighted that the effectiveness of the National Innovation Systems in the EU is closely linked to the quality and intensity of innovation indicators, specifically those related to patents and digital transformation, and that improving the institutional and regulatory conditions supporting innovation is essential for enhancing national innovation performance.

2.2.6. Ivica Nikolić et al., "Analysis of Innovation in EU Countries", International May Conference on Strategic Management (IMCSM24), Republic of Serbia, Vol. 20, No. 2, May 2024.

This study analyzed the variations in innovation performance among European Union countries and sought to identify the key factors that explain differences in national innovation outputs and relative performance levels. The study adopted a quantitative comparative analytical approach based on innovation indicators for the year 2023. Innovation input indicators included R&D expenditure and human resources in science and technology, while

output indicators included patents and measures of technological and non-technological innovation, using descriptive statistical analysis (cluster analysis) and comparative indicator assessment as analytical tools.

The study reached the following key findings:

- There are substantial differences among EU member states in terms of innovation performance;
- Northern and Western European countries consistently outperform EU members in the South and East;
- Innovation results are closely linked to R&D investment intensity and the quality of human capital.

The study emphasized that narrowing innovation gaps within the EU requires long-term investment in research, human capital, and institutional support, and that the structural nature of these disparities necessitates a formulation of tailored strategies that go beyond simple financial injection to address core institutional weaknesses in innovation-lagging regions.

2.2.7. Veronika Cabinova et al., "Evaluating Innovation Efficiency in EU Countries: the DEA Approach", Marketing and Management of Innovations, Vol. 15, No. 4, 2024.

This study aimed to identify the problem of unequal innovation efficiency across EU countries and to examine the efficiency of member states in transforming innovation-related inputs into tangible outputs, adopting a quantitative comparative efficiency-based approach. The variables included innovation inputs represented by R&D expenditures and human resources, while outputs included patents, high-technology exports, and scientific publications for the period 2018-2021, using Data Envelopment Analysis (basic output-oriented DEA models) to analyze 27 EU countries.

The most important findings reached:

- The results show significant differences in innovation efficiency among EU member states;
- Some countries have the ability to achieve high innovation outputs with relatively limited resources, such as Romania and Malta;
- Several countries show notable inefficiency despite massive investments in innovation and high input levels;
- The results indicate that high rankings in innovation performance do not necessarily mean high efficiency in resource utilization.

We note that the study concluded that innovation performance in the EU is determined not only by the volume of invested resources but by the efficiency of transforming these resources into measurable innovation outputs, and that improving the transformation process within national innovation systems is crucial for enhancing overall productivity and economic impact.

2.2.8. Muhammad Hamid Nasir and Sen Zhang, "Evaluating innovative factors of the global innovation index: A panel data approach", *Innovation and Green Development*, Vol. 3, 26 September 2023.

Through this study, the researchers sought to identify the dynamic relationship between innovation inputs, outputs, efficiency, and their collective impact on the Global Innovation Index (GII) ranking. Aiming to determine how these relationships vary across different countries and income levels. The study adopted a quantitative panel data analytical approach covering 105 countries, using Panel-Corrected Standard Errors (PCSE), Panel Quantile Regression (PQR), and Two-Stage Least Squares (2SLS) as advanced measurement tools for variables represented by GII scores, input and output indices, the efficiency index, and instrumental variables (ICT and high-tech trade) for the period 2013-2021.

The researchers reached the following key findings:

- Innovation input and output indices significantly and positively affect the Global Innovation Index;
- Innovation efficiency contributes positively to the overall score, albeit to a lesser extent compared to inputs and outputs;
- The strength and significance of these relationships vary across different income levels and innovation performance indicators;
- The results remain robust across various econometric techniques.

This study highlighted that innovation performance at the global level depends heavily on the interaction between innovation inputs, outputs, and efficiency. The study also emphasized that policy strategies must consider structural differences and income levels among countries and should not be generic.

2.2.9. Maxim Polyakov et al., "Determining the key factors of the innovation gap between EU countries", *Problems and Perspectives in Management*, Vol. 21, No. 3, 15 August 2023.

The study aimed to identify the innovation indicators most influential in explaining the differences in innovation performance among EU member states, and to determine the structural drivers of the regional innovation gap by adopting a two-stage empirical analytical approach, combining cluster and functional classification techniques. The main tools used included K-means cluster analysis, the Decision Tree method, and data mining techniques, using 22 relative indicators, including R&D funding, researcher intensity, and high-tech manufacturing output for the year 2022.

The study reached the following key findings:

- The possibility of effectively classifying EU countries into four innovation clusters;
- The study identified five pivotal indicators that most strongly explain the variation in performance: researchers, business-financed GERD (Gross Domestic Expenditure on R&D), joint ventures and strategic alliances, software spending, and high-tech manufacturing;

- The results show that the intensity of technological collaboration and industrial structure are the primary determinants of a country's rank in the innovation index.

We note that the study demonstrated that the innovation gap within the EU is primarily attributed to differences in research capacities, business R&D funding, high-tech industrial structure, and the intensity of technological collaboration, and that policy interventions targeting these specific factors can effectively promote convergence among member states and strengthen the European innovation system.

2.2.10. Evelina Maria Oliveira Coutinho and Manuel Au-Yong-Oliveira, "Factors Influencing Innovation Performance in Portugal: A Cross-Country Comparative Analysis Based on the Global Innovation Index and on the European Innovation Scoreboard", Sustainability, Vol. 15, No. 13, 03 July 2023.

Through this study, the researchers sought to investigate the key factors influencing innovation performance in Portugal compared to Ireland, Belgium, and the Czech Republic, using international innovation benchmarks. The study relied on a quantitative comparative analytical approach, conducting benchmarking of Portugal against Ireland, Belgium, and the Czech Republic using standardized innovation indicators. The Global Innovation Index (GII) and the European Innovation Scoreboard (EIS) were utilized for variables represented in innovation input indicators (human capital and R&D expenditure) and innovation output indicators for the period 2019-2022.

The most important findings reached:

- Portugal demonstrates a moderate innovation performance compared to the benchmarked countries;
- Structural factors and limited efficiency in transforming inputs into outputs constrain this performance;
- The results show that Portugal's innovation potential is hindered by systemic bottlenecks that prevent the full realization of returns from its investments.

The study emphasized that innovation performance in Portugal can be enhanced by improving the alignment of innovation policies and the more effective use of innovation inputs. And that for moderate performers, the priority must be optimizing transformation efficiency to ensure that resources achieve the maximum possible technological and economic value.

2.2.11. Meda Andrijauskienė et al., "European Union Innovation Efficiency Assessment Based on Data Envelopment Analysis", Economies, Vol. 11, No. 6, 09 June 2023.

This study investigated the efficiency of European Union countries in transforming innovation inputs into outputs, and identifying relative efficiency gaps among member states. The study adopted a quantitative efficiency assessment from a comparative EU-wide perspective as its methodology, using Data Envelopment Analysis (DEA) for innovation inputs (R&D expenditures, human capital in innovation, and innovation infrastructure) and outputs (patent-related indicators and innovation performance outcomes) covering the period 2000-2020.

The study reached the following key findings:

- There are strong disparities in innovation efficiency across EU countries;
- Only a limited number of countries operate on the efficiency frontier;
- Possessing a strong infrastructure or massive R&D budgets does not inherently guarantee full efficiency in outputs;
- The variations between countries are primarily attributed to the effectiveness of the transformation process rather than the absolute volume of inputs.

The study concluded that policy efforts should focus on improving the effectiveness of innovation systems rather than merely increasing innovation inputs, and that reaching the efficiency frontier requires structural reforms that ensure synergy between human capital and financial resources to generate tangible innovation impacts.

2.2.12. Adisu Fanta Bate et al., "The determinants of innovation performance: an income-based cross-country comparative analysis using the Global Innovation Index (GII)", Journal of Innovation and Entrepreneurship, Vol. 12, No. 20, 2023.

This study analyzed how the determinants of innovation performance vary across countries with disparate income levels, and whether the driving factors of innovation remain constant or change based on a country's economic capacity. The study adopted a cross-country (63 countries) quantitative comparative analytical approach with a classification of countries by income level. The primary tools included the Global Innovation Index (GII) and econometric and comparative statistical analysis of innovation input and output index variables for the year 2020.

The most important findings reached:

- The determinants of innovation performance vary substantially and systematically across different income groups;
- High-income countries benefit more from advanced institutional frameworks and specialized knowledge generation;
- Low-income countries face structural and resource-related constraints;
- The results show that adopting a uniform policy approach is ineffective in promoting innovation performance equally across all countries.

We note that the study concluded on the necessity for innovation policies to be income-specific, as a one-size-fits-all approach does not enhance innovation performance equally among nations. The study also emphasized that strategic priorities must be formulated to suit the specific economic context and resource constraints of each country, to ensure that innovation investments lead to the desired developmental outcomes.

2.2.13. Edyta Dworak and Maria Magdalena Grzelak, "The innovation gap of national innovation systems in the European Union", Comparative Economic Research. Central and Eastern Europe, Vol. 26, No. 1, 2023.

Through this study, the researchers sought to evaluate whether differences in innovation levels across EU countries are determined by the type of National Innovation System (advanced vs. developing systems), and to measure the innovation gap relative to the EU average. They adopted a quantitative assessment of innovation levels as a methodology, using Hellwig's Synthetic Measure of Development (SMD), arithmetic mean calculations, and innovation gap ratio analysis of innovation-related statistical indicators from Eurostat and OECD synthetic innovation index values for the years 2010 and 2021.

The researchers reached the following key findings:

- Innovation levels vary significantly among EU countries;
- Countries with developing national innovation systems demonstrate a measurable innovation gap compared to the EU average;
- Innovation performance is closely and strictly linked to the structural type of the National Innovation System.

We note that the study demonstrated that the level of innovation in EU economies is determined by the structural characteristics of their National Innovation Systems, and that the developing systems remain below the EU average, confirming the existence of a structural innovation gap. This requires from these countries, in order to achieve convergence, to focus policy interventions on structural upgrades to the National Innovation System architecture to enhance systemic efficiency.

2.2.14. Svetlana V. Ratner et al., "The Efficiency of National Innovation Systems in Post-Soviet Countries: DEA-Based Approach", Mathematics Journal, Vol. 10, 02 October 2022.

This study aimed to evaluate the efficiency of National Innovation Systems in post-Soviet countries, and to identify the differences in innovation performance among these economies using a quantitative efficiency framework. The study adopted a cross-country quantitative comparative analysis using Data Envelopment Analysis and output-oriented efficiency models, for input variables (R&D resource-related inputs, human capital in science and technology) and outputs (patent activity-related outputs and technological results) covering the period 2011-2018.

The study reached the following key findings:

- There are significant disparities in the efficiency levels of National Innovation Systems among post-Soviet countries;
- Only a limited number of countries operate near the efficiency frontier, while the vast majority lag significantly behind;

- Most countries demonstrate systemic inefficiencies due to weak institutional frameworks and inadequate transformation of innovation inputs into tangible outputs;
- Structural and institutional constraints are the primary factors hindering the effective utilization of innovation resources in these transition economies.

The study concluded that the National Innovation Systems in the majority of post-Soviet countries are inefficient, reflecting deep-rooted structural and institutional constraints. This suggests that mere resource allocation is insufficient without a robust institutional environment capable of bridging the gap between innovation inputs and socio-economic outcomes.

2.2.15. Han Lu et al., "Assessing the Dual Innovation Capability of National Innovation System: Empirical Evidence from 65 Countries", Systems, Vol. 10, No. 23, 23 February 2022.

Through this study, the researchers sought to investigate the dual innovation capability of National Innovation Systems in generating and commercializing innovation, aiming to understand how countries balance knowledge production and economic value creation. The researchers adopted a cross-country quantitative empirical analysis using composite indicators supported by statistical analysis, for variables of innovation input indicators, innovation production, and commercialization indicators covering 65 countries over the period 2010–2018.

The researchers reached the following key findings:

- Countries vary substantially in their capability to generate innovation versus commercializing it;
- Some countries achieved good performance in knowledge production but suffer from weak commercialization efforts;
- The results show that balanced innovation capability (achieving synergy between innovation and application) leads to stronger overall national performance.

This study highlighted that adopting a dual perspective of innovation capability is essential, as innovation success depends on both knowledge creation and commercialization. It also emphasized that for a National Innovation System to be globally competitive, policymakers must ensure the alignment of institutional support for R&D with robust mechanisms for market translation and technological diffusion.

2.2.16. Edyta Dworak et al., "Comparison of National Innovation Systems in the European Union Countries", Risks Journal, Vol. 10, No. 6, 29 December 2021.

This study investigated whether variations in the structure and development levels of National Innovation Systems explain the differences in innovation performance among European Union countries, and specifically tested the capability of these systems to generate high-value and sustainable innovation outputs. The researchers relied on a quantitative comparative cross-country analysis within the EU as a methodology, using composite indicators (to classify countries according to their innovation performance), Hellwig's Synthetic Measure of

Development (SMD), and linear ordering techniques, for innovation-related indicators (R&D expenditures, human resources in science and technology, patent activity, and knowledge-based outputs), for the years 2010 and 2019.

The most important findings reached:

- EU countries can be effectively classified into distinct groups according to the maturity of their National Innovation Systems;
- There are substantial and persistent structural disparities in innovation performance between Western and Northern European countries (the most advanced) and Southern and Eastern European countries;
- The results show that innovation performance exhibits a strong state of path dependency over time, meaning that institutionally advanced systems consistently maintain their competitive advantage.

We note that the study demonstrated that excellence in innovation outputs is not accidental but rather the result of close integration between advanced institutional frameworks and the capability to transform resources into internationally protected knowledge assets, which further widens the gap between mature and developing systems.

2.2.17. Ibrahim Alnafrh, "Efficiency evaluation of BRICS's national innovation systems based on bias-corrected network data envelopment analysis", *Journal of Innovation and Entrepreneurship*, Vol. 10, N. 26, 2021.

In this study, the researcher addressed the shortcomings in previous researches that treated National Innovation Systems as a single-stage process, aiming to measure the efficiency of innovation systems in BRICS economies by decomposing the innovation process into interconnected sub-processes and identifying their deficiencies. The researcher relied on a quantitative comparative efficiency analytical approach using two-stage Bias-corrected Network Data Envelopment Analysis (Network DEA), comprising the Knowledge Production Process (KPP) and the Knowledge Commercialization Process (KCP), to analyze input and output variables related to R&D activities, human capital, patent indicators, and commercialization outputs for the period 2014-2016.

The researcher reached the following key findings:

- Evaluating the National Innovation System as a multi-stage process provides deeper insights into systemic inefficiencies compared to single-stage models;
- The overall efficiency of National Innovation Systems varies substantially among BRICS countries;
- Systemic failures in BRICS economies are primarily concentrated in the commercialization stage rather than the knowledge generation stage.

The study concluded that the efficiency of an innovation system is determined by its transformative capacity across different stages, Which in BRICS countries, the systemic gap lies in the failure to commercialize, confirming that the accumulation of scientific outputs

does not translate into economic growth without effective mechanisms to bridge the lab-to-market divide.

2.2.18. Irena Łacka and Łukasz Brzezicki, "The Efficiency and Productivity Evaluation of National Innovation Systems in Europe", European Research Studies Journal, Vol. 24 , Special Issue 3, 2021.

Through this study, the researchers sought to address the shortcomings in traditional innovation rankings by examining the efficiency and productivity of National Innovation Systems in Europe, focusing on the relationship between innovation inputs and economic outputs rather than relying solely on innovation performance levels. The study adopted a quantitative longitudinal analysis as a methodology, using the Slacks-Based Measure (SBM-DEA) model, the Super-SBM model, and the Malmquist Index (MI-SBM) to measure efficiency levels and productivity changes over time. The variables included sub-input indicators (human resources, research systems, innovation-friendly environment, finance and support, firm investments, innovators, linkages, and intellectual assets) and output indicators (employment impacts and sales impacts) for a sample of 27 European countries from 2012 to 2019.

The study reached the following key findings:

- The average efficiency level of European National Innovation Systems was approximately 70%;
- Countries that joined the European Union after 2004 frequently achieved higher efficiency levels compared to older members;
- Productivity growth was primarily driven by improvements in managerial efficiency rather than shifts in the technological frontier;
- The results show that smaller or less developed National Innovation Systems can achieve relatively higher economic returns through the efficient use of limited resources.

This study highlighted that improving efficiency plays a more decisive role than resource expansion in enhancing innovation productivity, and that achieving high innovation outputs depends heavily on the transformative capacity of the system.

2.2.19. Naser Ali Azimi et al., "Efficiency of the National Innovation System of Iran and Selected Countries", Quarterly Journal of Economic Research, Vol. 21, No. 2, 2021.

The study aimed to investigate the relative efficiency of the Iranian National Innovation System compared to selected countries, focusing on the effectiveness of transforming innovation inputs into outputs, and analyzing the functional gap between the stages of innovation generation and commercialization it. The study adopted a quantitative efficiency measurement approach, using Relational Two-Stage Data Envelopment Analysis and efficiency decomposition techniques, for input variables represented by R&D expenditure, human capital, and institutional quality indicators, and output variables represented by patents, scientific publications, and innovation-related economic indicators for the period 2011-2016.

The study reached the following key findings:

- Iran demonstrates low innovation efficiency compared to many of the benchmark countries included in the study;
- Systemic inefficiency is primarily attributed to institutional and structural weaknesses rather than a mere lack of resources;
- Some countries achieve significantly higher innovation outputs with inputs similar to or lower than those used in Iran.

The study concluded that improving institutional quality and resource allocation efficiency is more important than increasing innovation inputs to enhance the performance of the National Innovation System in Iran. It emphasized also that the transition toward a knowledge-based economy requires a strong enabling environment capable of bridging the gap between scientific production and commercial application.

2.2.20. Slobodan Cvetanović et al., "National Innovation Capacity and Economic Progress of Countries", Economic Themes, Vol. 59, No. 3, 2021.

This study analyzed whether national innovation capacity is significantly linked to the level of economic development measured by GDP per capita, and how variations in innovation capacity explain the economic gaps between countries, particularly between EU and Western Balkan countries. The study relied on a quantitative empirical analytical approach based on correlation and comparative assessment, using the Innovation Capacity Index (ICI) and statistical correlation analysis between this index and GDP per capita according to Purchasing Power Parity (PPP). The variables included research capacity, technology and innovation efficiency, and knowledge absorption and diffusion for the year 2020.

The most important findings reached:

- There is a strong positive correlation between national innovation capacity and GDP per capita;
- Countries with high innovation capacity tend to achieve higher and more sustainable levels of economic development;
- The results showed that despite the importance of innovation, some countries reach high levels of GDP due to factors other than innovation capacity, indicating fundamental structural differences.

This study showed that building national innovation capacity is a key determinant of long-term economic development, although it is not the sole driver of growth, and that economic progress requires a process of institutional learning to effectively absorb and diffuse knowledge throughout the economy as all.

2.2.21. Arkadiusz Michał Kowalski, "Dynamics and Factors of Innovation Gap Between the European Union and China", Journal of the Knowledge Economy, Vol. 12, 13 November 2020.

The researcher sought to study the size and evolution of the innovation gap between China and the European Union average, identifying the factors leading to convergence or divergence in national innovation performance. The researcher relied on an empirical statistical analytical approach of innovation indicators during the period 2008–2018, using comparative statistical analysis and convergence analysis based on various innovation indicators. The variables included inputs represented by R&D expenditures, human capital, and PhD graduates, and outputs represented by international patent applications (PCT), trademark applications, scientific publications, and innovation impacts.

The researcher reached the following key findings:

- While the EU maintains overall innovation leadership, China shows significantly higher growth rates in key innovation indicators, indicating a clear convergence process;
- The results identified (R&D) investment, strategic Science, Technology and Innovation policies, industrial cluster development, and Foreign Direct Investment (FDI)-based technology transfer as key drivers of China's rapid catch-up process;
- The results show that the innovation gap between the two regions has been steadily diminishing since 2008.

We note that the study concluded that although the EU remains ahead in terms of overall innovation performance, the dynamic structural improvements in China are steadily narrowing the innovation gap, suggesting a long-term convergence process.

2.2.22. Eva Jurickova et al., "Efficiency measurement of National Innovation Systems of the European Union countries: DEA Model Application", Journal of International Studies, Vol. 12, No. 4, 2019.

This study investigated the efficiency of European Union countries in transforming innovation inputs into outputs, and identifying the scope of technical efficiency and inefficiency within their National Innovation Systems. The study adopted a non-parametric quantitative efficiency analysis using Data Envelopment Analysis, specifically the output-oriented CCR model under the constant returns to scale (CRS) assumption. The inputs included the number of researchers (Full-Time Equivalent - FTE) and R&D expenditures, while the outputs focused on the number of patent applications submitted to the European Patent Office (EPO) and the number of scientific articles published in journals indexed in SCI and SSCI for the period 2005-2016.

The study reached the following key findings:

- The results showed that only a few EU countries are technically efficient;
- Many leading innovation countries suffer from inefficiency in the utilization of innovation inputs;

- The results show that high innovation performance does not necessarily imply high efficiency in resource utilization.

The study concluded that most EU countries do not use their innovation resources efficiently, even when demonstrating strong innovation performance, and that improving the performance of National Innovation Systems requires a shift in focus from increasing inputs to enhancing the transformation efficiency of R&D expenditures and research personnel.

2.2.23. Rongping Mu et al., "National Innovation Capacity Index: A Cross-Country Comparative Analysis", Innovation and Development Policy, Vol. 2, 2019.

This study addressed the problem of how to measure and compare national innovation capacity through a composite indicator that monitors the ability of countries to produce and commercialize innovation. The study adopted a quantitative indicator-based comparative methodology by constructing a composite index to assess national innovation capacity across 40 countries, using the National Innovation Capacity Index (NICI) for variables related to innovation inputs (R&D expenditure, human capital), variables related to institutions and policies, and innovation output indicators for the period 2006-2015.

The most important findings reached:

- There are substantial and systematic differences in innovation capacity across countries;
- Countries with stronger institutional frameworks and higher R&D investments demonstrate superior capability in generating and sustaining innovation;
- National innovation capacity is closely linked to long-term economic competitiveness.

The study concluded that national innovation capacity can be systematically measured through a composite index, and that institutional quality and continuous investment in innovation are the primary determinants of high performance. It also emphasized that for an innovation system to be productive, it must bridge the gap between knowledge creation and commercial application through a robust institutional environment.

2.2.24. Eva Jurickova et al., "Efficiency of innovation system in the Czech Republic: Comparison with other European countries", New Trends and Issues Proceedings on Humanities and Social Sciences, Vol. 4, No. 10, The 6th World Conference on Business, Economics and Management (BEM-2017), 04-06 May 2017.

This study aimed to investigate the efficiency of the National Innovation System in the Czech Republic compared to other European Union countries, in transforming innovation inputs into measurable outputs. The study adopted a cross-country comparative quantitative analytical approach, using Data Envelopment Analysis under the Constant Returns to Scale (CRS) assumption. The inputs variables included the number of researchers and R&D expenditure, while the outputs focused on Number of granted patents and Gross domestic product for the year 2015.

The researchers reached the following key findings:

- The Czech Republic is classified as having medium efficiency compared to other EU countries;
- Key weaknesses were identified in intellectual assets and research-related outputs;
- The results showed that high-performing countries demonstrate a superior capability of transforming research inputs into legally protected and marketable intellectual property;
- The efficiency gap can be reduced by prioritizing intellectual property results and strengthening national research capacity.

The study highlighted that improving intellectual property results and enhancing research capacity are crucial for raising the efficiency of the National Innovation System. It also emphasized that for medium-efficiency countries, the focus must shift from increasing R&D resources to improving the mechanisms that transform those resources into tangible and protected innovation assets.

2.2.25. Rana P. Maradana et al., "Does innovation promote economic growth? Evidence from European countries", Journal of Innovation and Entrepreneurship, Vol. 6, No. 1, 2017.

This study investigated whether innovation contributes substantially to economic growth across 19 European countries, and examined the nature of the relationship between innovation indicators and economic performance. The study adopted a quantitative empirical analytical approach using a panel data framework, where researchers utilized panel data econometric models to assess the relationship in the period 1989-2014. The variables included innovation indicators (patent activity, R&D-related measures, performance metrics) and economic growth measured by GDP and GDP per capita.

The most important findings reached:

- Innovation has a statistically significant positive impact on economic growth in the surveyed European countries;
- Patent-related indicators and R&D investment play an important role in explaining economic growth variations between countries;
- The impact of innovation varies significantly across countries based on specific structural and institutional factors.

The study concluded that innovation is a key driver of economic growth in Europe, but its effectiveness depends on National Innovation Systems and the capability to transform innovation activities into productive economic outcomes. And that policymakers must consider structural contexts to ensure that R&D efforts lead to tangible macroeconomic returns.

2.3. Positioning the Current Study Within Previous Studies

2.3.1. Comparison Between the Current Study and Previous Studies

To facilitate a rigorous comparative analysis, previous studies are categorized into three groups based on their methodological frameworks. The current study is included in the DEA-based group for direct comparison as follows:

Groupe 1: Comparison with DEA-Based Studies

Table 1.2: Comparative Analysis of DEA-Based Innovation Studies

Studies	Indicators	Study Sample	Methodological Tool	Time Period	Research Objective
Current Study	- Total Scientific Documents - Total Patent Applications - Total Patent Grants - Total Trademark Registrations - Foreign-oriented Patent Family by Origin	16 countries	Output-Oriented Slack-Based Measure (SBM) Model under Variable Returns to Scale (VRS) Assumptions	2015-2024	To evaluate the efficiency and analyze the performance gaps of the Algerian NIS in its functional transition from Knowledge Accumulation to Economic Value Generation and Technological Sovereignty, while measuring the system's resilience against global shocks in comparison to a sample of emerging and developed economies
Study of Davor Vlačić et al., 2025	- Sector-specific R&D expenditures - Technological and Productive Outcomes	Central and Eastern European (CEE) countries	Data Envelopment Analysis (BCC model) & Malmquist Productivity Index (MI)	1998-2019	To investigate innovation efficiency in CEE countries and track productivity changes over time across different sectors
Study of Abdel Latef Anouze et al., 2024	- Knowledge Development sub process - Commercialization sub-process	33 countries	Dynamic Network DEA (SBM-DNDEA)	2016-2021	To identify the shortcomings in current innovation system evaluation methods, and to develop a more dynamic and process-oriented assessment for NIS
Study of Veronika Cabinova et al., 2024	- R&D expenditures - Human resources - Patents - High-tech exports - Scientific Publications	27 EU countries	Data Envelopment Analysis (basic output-oriented DEA models)	2018-2021	To identify unequal innovation efficiency and examine the member states efficiency in transforming inputs into tangible outputs
Study of Meda Andrijauskienė et al., 2023	- R&D expenditures - Human capital - Innovation infrastructure - Patents - Innovation Performance Outcomes	European Union countries	Data Envelopment Analysis	2000-2020	To investigate the efficiency of EU countries in transforming inputs into outputs and identify relative efficiency gaps
Study of Svetlana V. Ratner et al., 2022	- R&D resources - Human capital in S&T - Patent activity	Post-Soviet countries	Data Envelopment Analysis (DEA) - Output-oriented models	2011-2018	To evaluate NIS efficiency in post-Soviet countries and identify innovation performance differences

	- Technological Results				using a quantitative framework
Study of Ibrahim Alnafrah, 2021	- R&D - Human Capital - Patents - Commercialization Outputs	BRICS countries	Two-stage Bias-corrected Network DEA	2014-2016	To measure NIS efficiency by decomposing the process into sub-processes (KPP & KCP) and identifying deficiencies in BRICS economies
Study of Irena Łącka and Łukasz Brzezicki, 2021	- sub-input indicators (Human resources, Research systems, ...etc) - Employment and sales impacts	27 European countries	SBM-DEA, Super-SBM, and Malmquist Index (MI-SBM)	2012-2019	To evaluate NIS efficiency and productivity in Europe and address traditional ranking shortcomings by focusing on input-output relationships
Study of Naser Ali Azimi et al., 2021	- R&D expenditure - Human capital and institutional quality indicators - Patents - scientific publications - Economic indicators	Iran and selected countries	Relational Two-Stage DEA & Efficiency Decomposition	2011-2016	To investigate Iran's NIS efficiency compared to other nations and analyze the functional gap between innovation generation and commercialization
Study of Eva Jurickova et al., 2019	- Number of researchers (FTE) - R&D expenditures - EPO Patents - SCI/SSCI scientific Articles	EU countries	DEA (Output-oriented CCR model under CRS)	2005-2016	To investigate NIS efficiency in EU countries and identify technical efficiency and inefficiency levels
Study of Eva Jurickova et al., 2017	- Number of Researchers - R&D expenditure - Number of granted patents - Gross domestic Product	Czech Republic and other EU countries	DEA (under CRS assumption)	2015	To investigate the efficiency of the Czech Republic's NIS in transforming inputs into outputs compared to EU countries

Source: Compiled by the researcher

Groupe 2: Comparison with Econometric and Statistical Studies

Table 1.3: Comparative Analysis of Econometric Innovation Studies

Studies	Indicators	Study Sample	Methodological Tool	Time Period	Research Objective
Study of Gonçalo Rodrigues Brás and Margarita Robaina, 2024	- NIS Indicators: R&D, Tech Capacity, Institutions - Environmental Indicators: Performance metrics	130 countries	Econometric Modeling	2021/2022	To examine the relationship between NIS and sustainable environmental performance and climate change resilience
Study of Muhammad Hamid Nasir and Sen Zhang, 2023	- GII scores - Input/Output indices - Efficiency index ICT - High-tech trade	105 countries	Panel Data Econometrics (PCSE, PQR, 2SLS)	2013-2021	To identify the dynamic relationship between innovation inputs, outputs, and efficiency and their impact on GII rankings across income levels
Study of Maxim Polyakov et al., 2023	- 22 relative indicators (R&D funding, Researcher intensity,	EU member states	K-means Cluster Analysis, Decision Tree, & Data	2022	To identify the innovation indicators most influential in explaining the

	High-tech output, ...etc)		Mining		differences in innovation performance among EU member states, and determine the structural drivers of the regional innovation gap
Study of Adisu Fanta Bate et al., 2023	- Innovation input and output index variables (based on GII)	63 countries	Econometric and Comparative Statistical Analysis	2020	To analyze how innovation determinants vary across countries based on their income levels and economic capacity
Study of Slobodan Cvetanović et al., 2021	- Research capacity - Technology and Innovation efficiency - knowledge absorption and diffusion	EU and Western Balkan countries	Statistical Correlation & Comparative Assessment	2020	To analyze the link between national innovation capacity and economic development (GDP) and explain economic gaps
Study of Arkadiusz Michał Kowalski, 2020	- R&D expenditures - Human capital - PhDs - PCT patents - Trademarks - Publications - Innovation impacts	China and the European Union	Comparative Statistical & Convergence Analysis	2008–2018	To study the evolution of the innovation gap between China and the EU and identify factors of convergence or divergence
Study of Rana P. Maradana et al., 2017	- Innovation: Patents, R&D measures, performance metrics - Growth: GDP and GDP per capita	19 European countries	Panel Data Econometric Models	1989-2014	To investigate if innovation contributes to economic growth and examine the nature of the relationship between them

Source: Compiled by the researcher

Groupe 3: Comparison with Indicator-Based and Descriptive Studies

Table 1.4: Comparative Analysis of Indicator-Based Innovation Studies

Studies	Indicators	Study Sample	Methodological Tool	Time Period	Research Objective
Study of Robert D. Atkinson et al., 2025	- Human Capital - R&D Investment - Institutional Frameworks - Tech Outputs - Industrial Specialization - Productive Outcomes	U.S., South Korea, China, Japan, Taiwan	comparative NIS framework, the Global Innovation Index (GII) and Sectoral Location Quotients	2010-2020	To address NIS variations and examine how institutions, policies, and industrial specialization shape performance and competitiveness
Study of Larysa Antoniuk et al., 2024	- R&D activities - Patents and innovation inputs, along with composite indicators	EU member states	Cluster Analysis, Graph Visualization & Descriptive Statistics	2023	To evaluate and compare EU innovation systems and explain performance variations through innovation indicators
Study of Ivica Nikolić et al., 2024	- R&D expenditure - Human resources in S&T - Patents - Tech and non-tech	EU countries	Descriptive Statistical Analysis & Comparative Indicator Assessment	2023	To analyze innovation performance variations and identify factors explaining differences in outputs and performance across EU

	Innovation				countries
Study of Evelina Maria Oliveira Coutinho and Manuel Au-Yong-Oliveira, 2023	- Human capital - R&D expenditure - Innovation output Indicators	Portugal, Ireland, Belgium, and the Czech Republic	Benchmarking (Based on GII and EIS)	2019-2022	To investigate factors influencing Portugal's innovation performance through benchmarking against other nations
Study of Edyta Dworak and Maria Magdalena Grzelak, 2023	- Statistical indicators from Eurostat and OECD synthetic innovation index	European Union countries	Hellwig's Synthetic Measure of Development and arithmetic mean calculations	2010, 2021	To evaluate innovation levels based on NIS types (advanced vs. developing) and measure the innovation gap relative to the EU average
Study of Nadia Kharkhache, 2023	- R&D Human Resources - R&D Expenditure - Scientific Publications - Patents	Algeria, USA, Germany, France, South Korea, China, Egypt, Tunisia, Morocco	Comparative Analytical Approach	2018-2022	To identify the weak performance of Algeria's NIS and its role in building a knowledge economy compared to selected nations
Study of Han Lu et al., 2022	- Innovation inputs - Innovation production - Commercialization Indicators	65 countries	Composite Indicators & Statistical Analysis	2010-2018	To investigate the dual innovation capability (generation & commercialization) and how countries balance knowledge production and economic value
Study of Edyta Dworak et al., 2021	- R&D expenditures - Human resources in S&T - Patents - Knowledge-based Outputs	EU countries	Hellwig's Synthetic Measure (SMD) & Linear Ordering	2010, 2019	To investigate if NIS structure and development levels explain innovation performance differences and test the capability to generate sustainable outputs
Study of Rongping Mu et al., 2019	- R&D expenditure - Human capital - Institutions/Policies - Innovation outputs	40 countries	National Innovation Capacity Index (NICI)	2006-2015	To measure and compare national innovation capacity by monitoring the ability to produce and commercialize innovation
Study of Amina Zerdoudi and Moubarak Bouacha, 2015	- R&D Expenditure - Human Capital - Institutional /Financial Resources - Patents - Scientific Publications - Tech Outcomes	Algeria, Tunisia, Morocco, South Korea, Brazil, India	Comparative Analytical Approach (Descriptive & Analytical Assessment)	2005-2014	To assess the performance variation and the ability to transform innovation inputs into outputs among Maghreb and emerging economies

Source: Compiled by the researcher

2.3.2. Contributions of Previous Studies to the Current Study

The existing studies provided a comprehensive framework that guided the design of the current study in the following aspects:

Establishing the Methodological Trend: Previous research (e.g., Anouze et al., 2024; Andrijauskienė et al., 2023) has demonstrated that Data Envelopment Analysis (DEA) is the

most robust and objective tool for measuring National Innovation System efficiency. By reviewing these works, the current study adopts DEA to overcome the limitations of descriptive rankings, benefiting from the non-parametric nature of the model which does not require a pre-defined functional form.

Core Innovation Metrics and Re-conceptualization: The reviewed studies (e.g., Kharkhache, 2023; Bate et al., 2023; Zerdoudi & Bouacha, 2015) were instrumental in identifying the primary variables for National Innovation Systems. Based on the frequency analysis of indicators used in previous DEA-based studies (See Appendix.1 and Appendix.2), there is a clear consensus on the importance of metrics such as Scientific Publications and Patents. While these variables are traditionally viewed as outputs, the current study introduces a functional re-classification—supported by the high frequency of their usage in previous DEA-based studies—by defining them as Innovation Inputs to better reflect the process of generating high-value outcomes.

Setting Benchmarking Standards: Cross-country comparative studies provided a roadmap for selecting peer countries. This enabled the current study to move beyond isolated analysis toward a strategic benchmarking approach, using established global and regional leaders as reference points.

2.3.3. Distinctive Features of the Current Study

While this research aligns with the academic interest in innovation efficiency, it introduces several unique features compared to the 27 reviewed studies:

Precision via the Non-Radial SBM Approach: Unlike many previous studies that relied on radial models like CCR or BCC (e.g., Jurickova, 2017; 2019; 2024), this study adopts the Slacks-Based Measure (SBM). This provides a higher level of precision by directly accounting for specific inefficiency gaps in each indicator, offering a realistic Roadmap for improvement that radial models fail to provide.

Accountability for Scale Heterogeneity (VRS): While several studies assume Constant Returns to Scale (CRS), the current research adopts the Variable Returns to Scale (VRS) assumption. This is crucial given the heterogeneous nature of the 16-country sample (comparing global giants like the USA with emerging economies like Seychelles), ensuring that efficiency scores are not biased by the size of the national economy.

Diversification of the Comparative Sample: The current study expands the analytical scope by including a specifically curated sample of 16 countries. This sample is more heterogeneous than the typical EU-centric or BRICS-focused studies, as it simultaneously compares global leaders, oil-dependent economies, and emerging African innovators.

Integration of High-Granularity Quality Metrics: Unlike the majority of reviewed studies that use basic patent/publication counts, this research integrates advanced qualitative indicators such as Foreign-oriented patent families and Madrid System trademarks. This allows for measuring the international competitiveness and commercial value of innovation, rather than just its domestic quantity.

CHAPTER 1. Summary _____

From the analysis presented throughout this chapter, it is evident that the National Innovation System is not merely a static institutional structure, but a dynamic functional network whose sustainability depends on the quality of interaction among its actors. It has been established that a nation's success in transitioning toward a knowledge-based economy does not rely solely on the volume of R&D investments, but rather on the ability to build robust bridges between educational institutions, research centers, and the productive sector under a coherent institutional and regulatory framework.

Furthermore, it should be noted that the Algerian experience, through recent strategic shifts (such as Ministerial Decree 1275), reflects a growing recognition of the need to activate the system's transformative capacity—the ability to convert academic knowledge into legally protected and industrially marketable innovations. The ultimate goal is to ensure the transition from a closed innovation system dependent on technical imports to an integrated and functionally efficient system that contributes to economic diversification and global competitiveness. This transition necessitates moving beyond theoretical description toward a quantitative evaluation to measure the actual efficiency of this conversion process.

Chapter 2

Evaluating the National Innovation System in Algeria: An Applied Comparative Study Using Data Envelopment Analysis Methodology

Preface

After reviewing the core theoretical concepts of the National Innovation System and highlighting the reality of the Algerian Innovation System in the previous chapter, this chapter seeks to evaluate the efficiency of this system through a comparative study between Algeria and a group of countries. The objective is to measure the ability of these systems to transform their knowledge-based inputs into outputs of economic and competitive value during the period (2015–2024).

This chapter is divided into the following sections:

1. Data Envelopment Analysis (DEA) Methodology
2. Methodology of the Current Study and Data Description
3. Application of the DEA Model to the Study Sample (2015–2024)

1. Data Envelopment Analysis (DEA) Methodology

The increasing complexity of the global economic environment has intensified the need for robust analytical frameworks, to evaluate the performance of National Innovation Systems. Given that, innovation processes involve multiple interrelated resources and diverse outcomes, traditional statistical methods (which often focus on average behavior and central tendencies), frequently fall short of capturing the full spectrum of relative efficiency. Consequently, Data Envelopment Analysis (DEA) has emerged as a vital non-parametric analytical tool. By leveraging linear programming, DEA provides a sophisticated mechanism for identifying best-practice frontiers, allowing for a comprehensive assessment of how effectively inputs are transformed into tangible innovative outputs.

1.1. Conceptual Framework and Operational Foundations of DEA

Data Envelopment Analysis is a relatively new, non-parametric approach, for evaluating the performance of a set of peer entities called Decision Making Units (DMUs), which convert multiple inputs into multiple outputs. The characterization of the unit of assessment as "decision making", implies that it has control over the process it employs to convert its resources into outcomes.

Thanassoulis also explains that in DEA the resources are typically referred to as "inputs" and the outcomes as "outputs". Which the identification of the inputs and the outputs in an assessment of DMUs is as difficult as it is crucial. The inputs should capture all resources which impact the outputs, While The outputs should reflect all useful outcomes on which we wish to assess the DMUs. Further, any environmental factors which impact the transformation of resources into outcomes should also be reflected in the inputs or the outputs. (Cvetkoska, 2011)

1.2. DEA Assumptions

1.2.1. Returns to Scale

Two basic models are used in DEA, leading to the identification of two different frontiers:

Constant Returns to Scale - CRS: The CRS model assumes that a change in the inputs results in a proportional change in the outputs. This means that if a DMU doubles its inputs, its outputs will also double.

Variable Returns to Scale - VRS: The VRS model assumes that a change in the inputs does not result in a proportional change in the outputs. This implies that if a DMU doubles its inputs, its outputs can less than double (decreasing returns to scale), double (constant returns to scale), or more than double (increasing returns to scale).

1.2.2. Model Orientation

A DEA model can be input or output oriented:

Input Orientation: In an input orientation, DEA model minimizes inputs for a given level of outputs. In other words, a unit is technically efficient if it is possible to reduce its inputs without reducing its outputs.

Output Orientation: In an output orientation, DEA model maximizes outputs for a given level of inputs. In other words, a unit is technically efficient if it is possible to increase its outputs without increasing its inputs. (Huguenin, 2012)

1.3. DEA Models

According to Cooper et al., DEA models are categorized based on their orientation and the underlying assumption of returns to scale:

1.3.1. The CCR Model (Charnes, Cooper, and Rhodes)

This model is built on the assumption of Constant Returns to Scale (CRS), there are two versions of this model:

Input-Oriented CCR Model: One version of a CCR model aims to minimize inputs while satisfying at least the given output levels.

Output-Oriented CCR Model: The output-oriented model attempts to maximize outputs without requiring more of any of the observed input values.

According to Cooper et al., the dual input-oriented CCR model (Envelopment form) is expressed as:

$$\begin{aligned}
 (DLP_o) \quad & \min_{\theta, \lambda} \quad \theta \\
 \text{Subject to} \quad & \theta x_o - X\lambda \geq 0 \\
 & Y\lambda \geq y_o \\
 & \lambda \geq 0
 \end{aligned}$$

Table 2.1: Primal and Dual Correspondences of the input-oriented CCR model Equation

Constraint (LP_o)	Dual variable (DLP_o)	Constraint (DLP_o)	Primal variable (LP_o)
$vx_o = 1$	θ	$\theta x_o - X\lambda \geq 0$	$v \geq 0$
$-vX + uY \leq 0$	$\lambda \geq 0$	$Y\lambda \geq y_o$	$u \geq 0$

Where

θ : a scalar variable (This represents the efficiency score).

λ : an $n \times 1$ vector of variables (These are the intensity variables or weights assigned to DMUs).

X : the $m \times n$ matrix of input data ($X = [x_1, \dots, x_n]$).

Y : the $s \times n$ matrix of output data ($Y = [y_1, \dots, y_n]$).

x_o : the $m \times 1$ input vector for DMU_o .

y_o : the $s \times 1$ output vector for DMU_o .

v : the $m \times 1$ vector of multipliers for inputs.

u : the $s \times 1$ vector of multipliers for outputs. (Cooper, Seiford, & Tone, 2007)

1.3.2. The BCC Model (Banker, Charnes, and Cooper)

This model extends the CCR model by accommodating Variable Returns to Scale (VRS), According to Cooper et al.:

1. The BCC model distinguishes between Technical Efficiency and Scale Efficiency by adding a convexity constraint to the mathematical formulation;
2. Like the CCR model, the BCC model can also be: Input-oriented (focusing on maximal movement toward the frontier via input reductions) or Output-oriented (focusing on maximal movement toward the frontier via output expansions).

Its expressed in the input-oriented BCC model (Envelopment form) as:

$$\begin{aligned}
 (BCC_o) \quad & \min_{\theta_B, \lambda} \quad \theta_B \\
 \text{Subject to} \quad & \theta_B x_o - X\lambda \geq 0 \\
 & Y\lambda \geq y_o \\
 & e\lambda = 1 \\
 & \lambda \geq 0
 \end{aligned}$$

Table 2.2: Primal and Dual Correspondences in BCC Model (Linear Programming Form)

Envelopment form constraints	Multiplier form Variables	Multiplier form Constraints	Envelopment form Variables
$\theta_B x_o - X\lambda \geq 0$	$v \geq 0$	$vx_o = 1$	θ
$Y\lambda \geq y_o$	$u \geq 0$	$-vX + uY - u_o e \leq 0$	$\lambda \geq 0$
$e\lambda = 1$	u_o		

Where

θ_B : The efficiency score for the BCC model.

u_o : a scalar (free in sign) that indicates the type of returns to scale.

e : a row vector with all elements equal to 1. (Cooper, Seiford, & Tone, 2007)

1.3.3. The Slacks-Based Measure (SBM) Model

According to Cooper et al. (2007), the SBM was introduced by Tone as a single scalar measure for additive models. This model is characterized by the following important properties:

Property 1 (P1) - Units Invariant: The measure is invariant with respect to the unit of measurement of each input and output item.

Property 2 (P2) - Monotone: The measure is monotone decreasing in each input and output slack.

This model is defined by the following fractional program:

$$\begin{aligned}
 (SBM) \quad & \min_{\lambda, s^-, s^+} \quad \rho = \frac{1 - \frac{1}{m} \sum_{i=1}^m s_i^- / x_{io}}{1 + \frac{1}{s} \sum_{r=1}^s s_r^+ / y_{ro}} \\
 \text{Subject to} \quad & x_o = X\lambda + s^- \\
 & y_o = Y\lambda - s^+ \\
 & \lambda \geq 0, s^- \geq 0, s^+ \geq 0
 \end{aligned}$$

Where

ρ : The SBM efficiency score.

s^-, s^+ : Vectors representing input and output slacks, respectively.

m, s : The number of inputs and outputs.

x_o, y_o : The input and output vectors of DMU_o .

X, Y : The input and output data matrices.

λ : A vector of intensity variables. (Cooper, Seiford, & Tone, 2007)

In addition to the basic radial and non-radial models, this study acknowledges advanced DEA structures as defined by Cooper et al.:

1.3.4. The Hybrid Model

This model solves the Hybrid measure of efficiency under the constant (variable) returns-to-scale assumptions. (Cooper, Seiford, & Tone, 2007)

1.3.5. The DEA game model

This model is utilized for consensus-making and the allocation of shared resources among DMUs. (Cooper, Seiford, & Tone, 2007)

1.3.6. The Network DEA Model

This model deals with the internal structure of DMUs. It considers the divisions of a DMU as well as the intermediate products. (Cooper, Seiford, & Tone, 2007)

In addition to the primary DEA models, the Super-efficiency model is utilized as a supplementary tool for ranking DMUs that are identified as efficient (score = 1.0). As defined by Cooper et al., this approach is achieved by eliminating the data on the DMU_o to be evaluated from the solution set, which allows its efficiency score to exceed 1.0. This technique is primarily used to rank the efficient DMUs and eliminate the ties that occur in standard models like CCR, BCC, or SBM. (Cooper, Seiford, & Tone, 2007)

1.4. Dynamic/Time-Series DEA

As previously discussed, most Conventional DEA models deal with efficiency under static conditions. However, this can be misleading in certain contexts, such as innovation systems, where dynamic settings may involve an intensive use of resources intended to produce beneficial results in future periods. Therefore, we will present here non-parametric DEA models designed to evaluate performance under dynamic and time-dependent situations.

1.4.1. The Window Analysis

This model is a time-dependent DEA technique. It treats a DMU in each different period as if it were a separate unit. Accordingly, the performance of a DMU in a particular period is contrasted with its own performance in other periods as well as to the performance of other DMUs in the same periods.

This model is defined as following:

$$n(k - p + 1)p$$

Where n is the number of DMUs, k is the number of periods, p is the window length ($1 \leq p \leq k - n$), $w = k - p + 1$ is the number of windows, and np is the number of DMUs in each window. The total no. of "different" DMUs is $n(k - p + 1)p$. (Cooper, Seiford, & Tone, 2007)

1.4.2. The Malmquist Productivity Index (MPI)

The Malmquist Productivity Index is an index representing Total Factor Productivity (TFP) growth of a Decision Making Unit (DMU), in that it reflects progress or regress in efficiency (catch-up) along with progress or regress of the frontier technology between two periods of time (frontier-shift) under the multiple inputs and multiple outputs framework.

The Malmquist index (MI) is computed as the product of (Catch-up) and (Frontier-shift), i.e.,

$$MI = (Catch-up) \times (Frontier-shift)$$

$$MI = \left[\frac{\delta^1((x_o, y_o)^2)}{\delta^1((x_o, y_o)^1)} \times \frac{\delta^2((x_o, y_o)^2)}{\delta^2((x_o, y_o)^1)} \right]^{1/2}$$

Where MI represents the Malmquist productivity index, $(x_o, y_o)^1$ and $(x_o, y_o)^2$ denote the inputs and outputs of DMU_o in periods 1 and 2, respectively. The term $\delta^1((x, y)^1)$ is the efficiency score of DMU_o in period 1 measured by the frontier in period 1, and $\delta^2((x, y)^2)$ is the efficiency score in period 2 measured by the frontier in period 2. The Catch-up effect is the efficiency change, while the Frontier-shift effect represents the technological change (innovation). (Cooper, Seiford, & Tone, 2007)

1.4.3. The Dynamic SBM (DSBM)

This model is an extension of the Slacks-Based Measure (SBM) designed to handle time-series data. It is characterized by its ability to incorporate carry-over activities between consecutive periods. As a non-radial approach, it can deal with inputs/outputs individually, contrary to the radial approaches that assume proportional changes in inputs/outputs.

Furthermore, according to the characteristics of carry-overs, they are classified into four categories, i.e. desirable, undesirable, free and fixed:

Desirable (good) link: This indicates desirable carry-over, e.g. profit carried forward and net earned surplus carried to the next term. In the DSBM framework, desirable links are treated as outputs and link value is restricted to be not less than the observed one. Comparative shortage of links in this category is accounted as inefficiency.

Undesirable (bad) link: This belongs to undesirable carry-over, e.g. loss carried forward, bad debt and dead stock. In the DSBM framework, undesirable links are treated as inputs and its value is restricted to be not greater than the observed one. Comparative excess in links in this category is accounted as inefficiency.

Discretionary (free) link: This corresponds to carry-over that DMU can handle freely. Its value can be increased or decreased from the observed one. The deviation from the current value is not directly reflected in the efficiency evaluation, but the continuity condition between two terms explained in the next section exerts an indirect effect on the efficiency score.

Non-discretionary (fixed) link: This indicates carry-over that is beyond the control of DMU. Its value is fixed at the observed level. Similarly to free link, fixed link affects the efficiency score indirectly through the continuity condition between two terms.

According to Tone & Tsutsui, the Output-oriented DSBM model is expressed as:

$$1/\tau_o^* = \max \frac{1}{T} \sum_{t=1}^T w^t \left[1 + \frac{1}{S + ngood} \left(\sum_{i=1}^s \frac{w_i^+ s_{it}^+}{y_{iot}} + \sum_{i=1}^{ngood} \frac{s_{it}^{good}}{z_{iot}^{good}} \right) \right]$$

Where τ_o^* is the overall efficiency during the period, T, w^t is the weight assigned to period, t, s is the number of outputs, $ngood$ is the number of desirable (good) carry-overs, s_{it}^+ are the output slacks, s_{it}^{good} are the slacks for desirable carry-overs, y_{iot} is the observed output of DMU_o in period t , and z_{iot}^{good} is the observed desirable carry-over. (Tone & Tsutsui, (n.d))

2. Methodology of the Current Study and Data Description

This section outlines the methodology employed to evaluate the efficiency of the National Innovation System in Algeria relative to the selected sample. It describes the specific DEA model used, defines the input and output indicators, details data sources, the study period, and the rationale behind the sample selection

2.1. Selected DEA Model

This study employs the Output-Oriented Slack-Based Measure (SBM) Model under Variable Returns to Scale (VRS) assumptions, justified by the following methodological grounds:

Non-Radial Precision via SBM: Unlike traditional radial models (CCR/BCC) that assume proportional changes in inputs and outputs, the SBM model is non-radial and directly deals with Slacks. This provides a more objective and precise measurement of efficiency by accounting for the specific individual improvements required for each indicator.

Variable Returns to Scale (VRS) Assumption: The VRS (BCC-based) assumption is selected to account for the heterogeneous nature of the National Innovation Systems in the sample. Since the countries vary significantly in size, economic capacity, and resource endowment, VRS ensures that DMUs are compared against peers of similar scale, preventing efficiency bias.

Output Orientation: Since national innovation policies primarily aim to maximize outputs given available resources, this orientation is the most suitable for evaluating NIS efficiency.

2.2. Indicators of the Study

Despite the large number of indicators used to assess the performance of national innovation systems, the present study focuses on a limited set of indicators that are most relevant to the objectives of the research.

Input Indicators

Total Scientific Documents: This indicator represents the total number of scholarly documents, including primary articles, reviews, and conference papers. (SCImago, (n.d))

the Scientific documents serve as a fundamental driver of knowledge production. Previous studies, such as Kharkhache (2023), have demonstrated that this indicator accurately reflects the scale of investment in Research and Development.

Total Patent Applications (Direct and PCT National Phase Entries): An Application is the procedure for requesting IP rights at an office. This indicator specifically combines two paths:

Direct filings: Applications filed directly with national or regional patent offices.

National phase under the PCT: This refers to the phase that follows the international phase of the PCT procedure and which consists of the entry and processing of the international application in the individual countries or regions in which the applicant seeks protection for an invention. (WIPO, 2025)

This indicator represents the Innovation Effort deposited within the system. In this SBM-VRS model, applications are treated as a fundamental input representing the intermediate stage of the innovation process. It reflects the intensity of a country's transition from academic research to applied technical solutions.

Output Indicators

Total Patent Grants (Direct and PCT National Phase Entries): A Grant refers to a set of exclusive rights legally accorded to the applicant when a patent is issued, This indicator measures the number of applications (whether filed directly or through the PCT national phase) that have successfully passed the examination and were granted legal protection.

Total Trademark Registrations (Direct and via the Madrid System): A Trademark is a sign used to distinguish the goods or services of one undertaking from those of another, This indicator includes Registrations (exclusive rights legally accorded when a mark is issued) obtained through two routes:

Direct filings: At the relevant national or regional office(s).

Madrid System: The system for the international registration of trademarks.

Foreign-oriented Patent Family by Origin: This indicator focuses on Patent Family by the Origin of the applicant (the country of residence of the first-named applicant), It comprises a special subset that includes only those patent families with at least one filing office that differs from the office of the applicant's country of origin, This measures high-value inventions aimed at international markets. (WIPO, 2025)

Outputs reflect the legal and economic value of innovation. The Foreign-oriented patent families indicator serves as a qualitative addition, measuring global competitiveness and overcoming the limitations of studies focused solely on domestic quantity.

The study is restricted to 5 indicators to ensure the discriminatory power of the DEA model, as the number of DMUs must significantly exceed the sum of inputs and outputs to avoid efficiency inflation.

2.3. Data Sources and Study Period

The study utilizes data from WIPO IP Statistics Data Center and Scopus SJR (Scimago Journal & Country Rank) for the period 2015–2024. While this period offers the highest data availability compared to previous years, some missing values were identified within the input and output indicators for the sample countries. To ensure a balanced panel and maintain the discriminatory power of the SBM-VRS model, the following justifications and procedures were applied:

Contemporary Performance Analysis: This period captures the performance of NIS across a decade of shifting global innovation trends, allowing for a robust cross-sectional analysis of efficiency scores for each year.

Comparative Reliability: A 10-year span ensures that the efficiency scores obtained via the SBM-VRS model are not influenced by temporary annual fluctuations, providing a stable mean efficiency for a comprehensive ranking of the selected countries.

Data Completeness and Imputation: To address the issue of missing observations and ensure a continuous time series, the Arithmetic Mean Imputation method was employed. This technique replaces missing values with the average of available data for the same variable within the specific country's time series. This approach minimizes bias and prevents the exclusion of relevant DMUs due to isolated data gaps.

The imputation was calculated using the following formula:

$$\text{Arithmetic Mean} = \frac{\sum_{n=1}^k x_n}{k}$$

Where:

$\sum_{n=1}^k x_n$: represents the sum of all observed values for the specific indicator in a given country.

k : is the total number of years with available data (the sample size for that specific variable).

x_n : represents the value of the indicator in the year (n).

2.4. Study Sample (Selected Countries)

The study encompasses a sample of 16 countries: Algeria, Switzerland, the United States, Iran, Norway, Morocco, Egypt, the United Arab Emirates, Iraq, Jordan, Seychelles, Mauritius, South Africa, Namibia, Senegal, and Cameroon. This sample was selected based on the following criteria:

Global Benchmark Countries: Switzerland, the USA, and Norway are included as primary Peers to measure Algeria's technological gap. While Switzerland and the USA represent global innovation leaders, Norway provides a unique benchmark as a highly advanced economy that successfully managed its natural resources wealth through innovation.

Rapidly Evolving Systems & Economic Diversification: the United Arab Emirates, and Iran are chosen for their rapid growth and efforts to diversify their economies away from natural resources — a challenge that is directly mirrored in the Algerian context.

Regional and Structural Comparability (MENA Region): Including Morocco, Egypt, Jordan, and Iraq, allows for a realistic assessment within the Middle East and North Africa (MENA) context. These countries share similar socio-economic characteristics with Algeria, providing a more balanced comparative framework.

Top-Performing and Emerging African Innovators: To evaluate Algeria's position within its continent, Mauritius, Seychelles, South Africa, and Namibia were included as leading innovation ecosystems. Additionally, Senegal, and Cameroon represent emerging African systems, providing a broader understanding of innovation dynamics across different African sub-regions (West and Central Africa).

3. Application of the DEA Model to the Study Sample (2015–2024)

This section will address the presentation and analysis of the SBM model results applied to the study sample during the period (2015-2024), while validating the formulated hypotheses. The presentation of the results will follow a gradual approach, moving from the general level (the study sample as a whole) to the specific level (a detailed analysis of the Algerian case). Subsequently, a comparison will be conducted between the results of this study and the findings of previous studies to ensure the reliability of the results and to provide an analytical depth that allows for positioning the Algerian innovation system within the regional and international context.

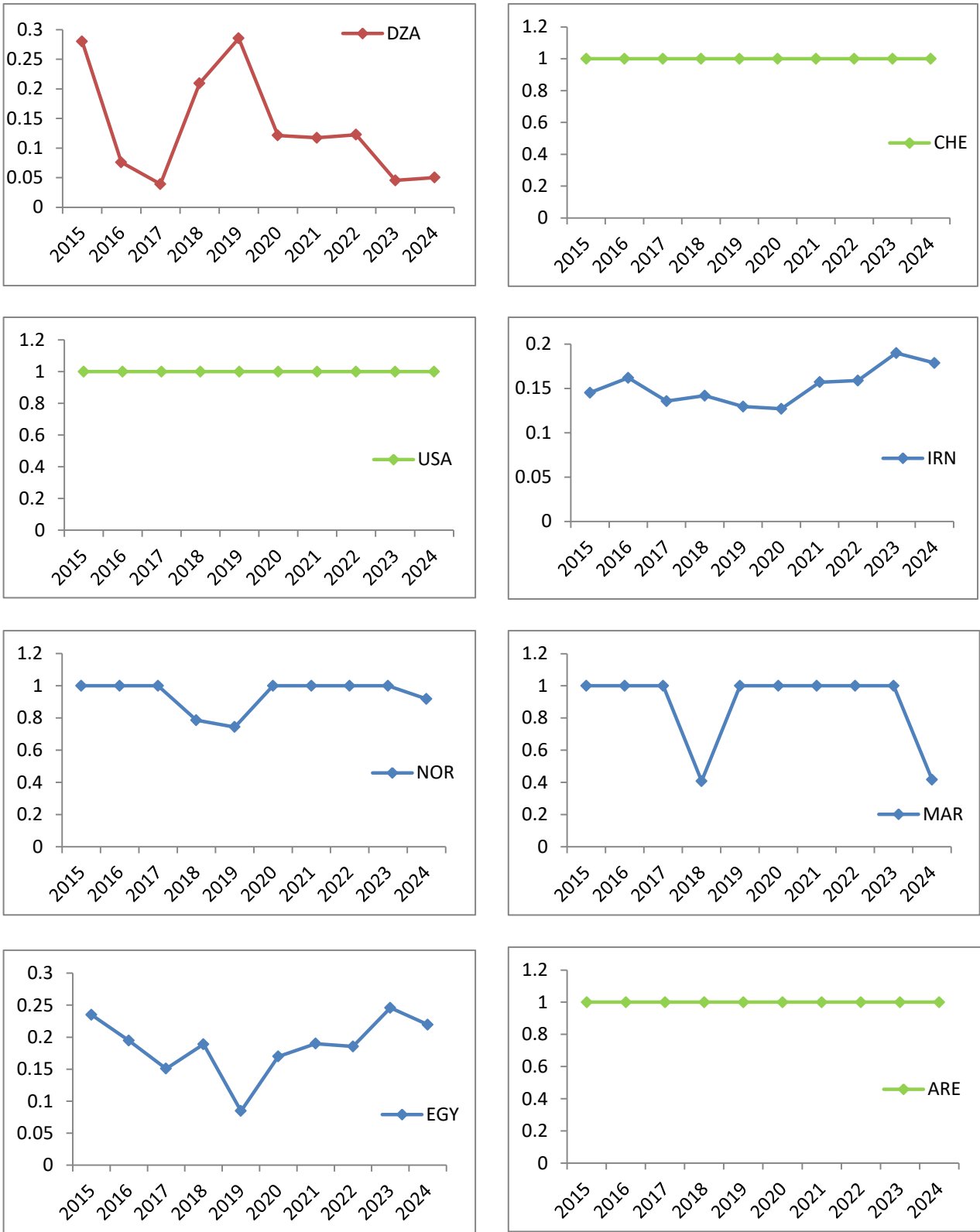
3.1. Descriptive Analysis and General Comparison

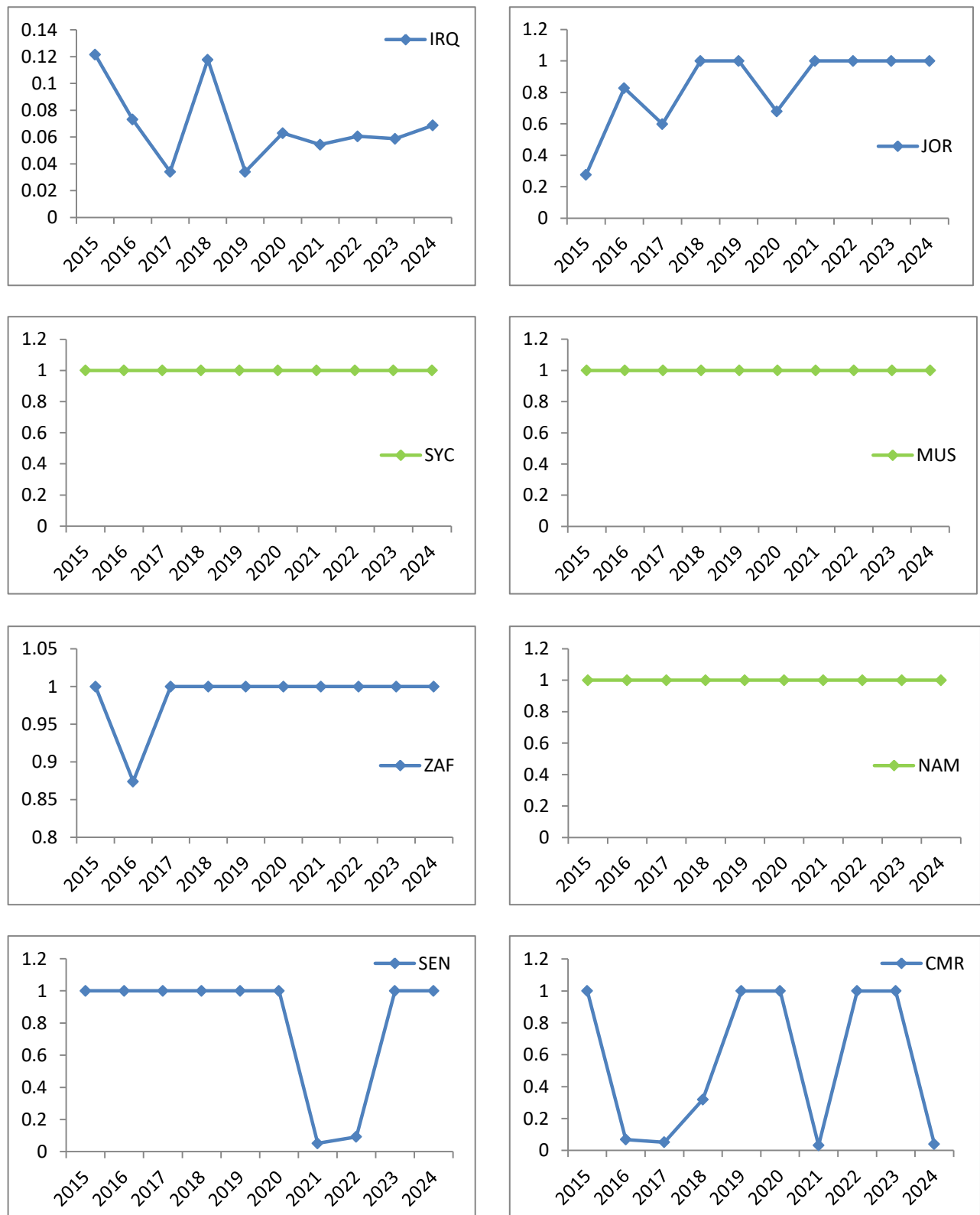
Academic practice in analyzing the efficiency of National Innovation Systems necessitates moving beyond static figures to track the behavior of these systems over time, thereby understanding their responsiveness to economic and geopolitical variables. This phase aims to provide a comprehensive panoramic view of the performance of the study sample, comprising 16 countries over the period (2015-2024). This is achieved by monitoring international rankings, efficiency stability, and identifying technological gaps between leading nations and those still hindered by path dependency. We will utilize a set of graphical tools that allow for temporal and spatial comparisons, paving the way for an in-depth analysis of Algeria in subsequent stages.

3.1.1. Evolution of Average Efficiency and Individual Trajectories

This section does not merely aim for descriptive presentation, rather, it seeks to deconstruct the phenomenon of performance fluctuation. We will compare the individual trajectory of each country—to highlight its specificity—with the Algerian trajectory, linking them to the Efficiency Frontier defined by the benchmark countries in the sample. This correlation allows us to test the sensitivity of these systems to global shocks, such as the OVID-19 pandemic and energy price volatility, and to determine whether the Algerian innovation system possesses sufficient resilience for rapid recovery or falls victim to long-term innovation hysteresis.

Figure 2.1: Evolution of the Sample's Efficiency (2015–2024)





Source: Compiled by the researcher based on DEA-SBM model outputs

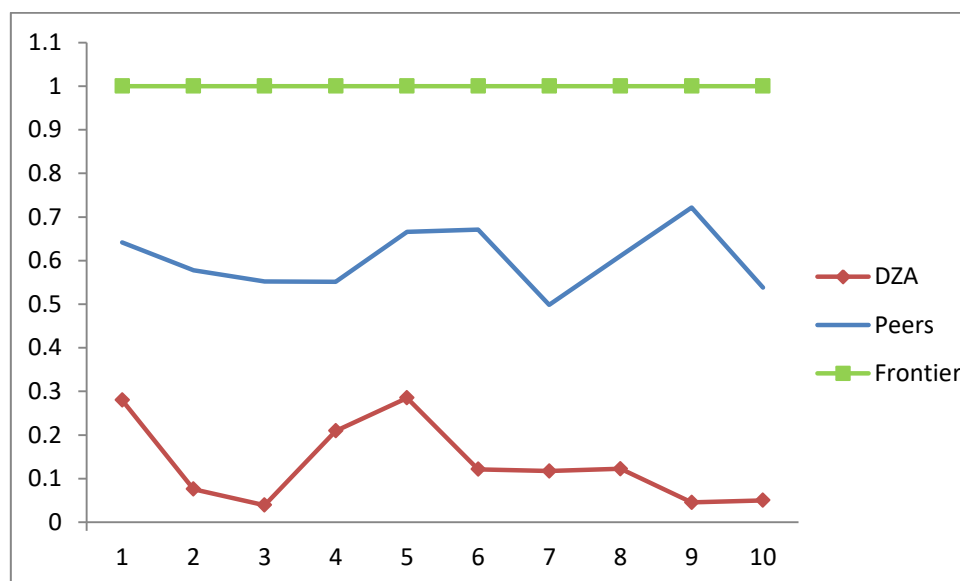
By extrapolating the individual trajectories of the National Innovation Systems efficiency for the study sample, a fundamental divergence in systemic behavior is observed. While

benchmark countries (Frontier), such as Switzerland (CHE), the United States (USA), and the United Arab Emirates (ARE), maintained absolute stability at the efficiency frontier (1.0), Algeria's (DZA) trajectory exhibited sharp fluctuations. This volatility reflects the immaturity of the linkages between research outputs and industrial transformation.

These fluctuations—notably the sharp declines recorded in 2016 (following the energy price shock) and 2021 (the delayed impact of the global pandemic)—validate **Hypothesis 5**. Global shocks, including COVID-19 and energy market volatility, have induced a state of Innovation Hysteresis and a Negative Memory Effect within the Algerian system. This phenomenon hindered a rapid return to 2019 efficiency levels, confirming that the system suffers from a permanent erosion of innovative gains due to functional fragmentation.

To deepen the understanding of the Algerian innovation system's positioning within the global competitive environment, the analysis shifts from individual descriptions to group comparisons. The following figure (Figure 2.2) illustrates the Algerian efficiency trajectory relative to the global efficiency frontier—represented by the benchmark countries—and the average performance of the peer group, which includes countries with similar developmental contexts. This visual correlation aims to measure the magnitude of the technological gap and determine the extent to which Algeria aligns with the general trends of the study sample.

Figure 2.2: Comparative Efficiency Trajectories: Algeria vs. Global Frontier and Peer Group (2015–2024)



Source: Compiled by the researcher based on DEA-SBM model outputs

The combined chart (Figure 2.2) reveals a dual efficiency gap that places the Algerian system in a critical position: a technological gap relative to the Frontier (Pioneers) and a performance gap relative to the Peer Group.

Based on these results, the following can be inferred:

Confirmation of Hypothesis 1: Algeria's trajectory remaining far below the technological frontier (1.0) demonstrates low pure technical efficiency and a resistance to institutional

change. The system fails to effectively bridge the gap between academic knowledge and internationally protected intellectual property, hampered by administrative residues.

Confirmation of Hypothesis 3: Algeria's trendline runs almost parallel to, but significantly below, the peer average. This confirms the existence of Path Dependency, where the system remains trapped in traditional production patterns that impede its ability to catch up with other emerging nations.

Confirmation of Hypothesis 6: Algeria's position below the peer average, despite possessing substantial human and academic resources, confirms that the system suffers from Decreasing Returns to Scale (DRS). This indicates that the core issue is not the volume of inputs, but rather the functional efficiency in directing these inputs toward globally demanded outputs.

Overall, the findings demonstrate that the Algerian innovation system suffers from structural weaknesses that fail to sustain innovative gains, making it highly vulnerable to global crises. This will be further detailed in the next stage through Slacks Analysis to precisely identify the points of failure.

3.1.2. Spatiotemporal Efficiency Mapping (Heatmap Analysis)

Following the analysis of temporal trajectories, we proceed to present the results using a Heatmap, which aims to monitor the spatial and temporal distribution of efficiency. This visual tool allows for the identification of countries that have maintained stability at the technological frontier versus those suffering from chronic fluctuations or path dependency. Furthermore, it provides visual evidence to test the impact of natural resource abundance on relative efficiency levels.

Figure 2.3: Spatiotemporal Heatmap of Innovation Efficiency Scores (2015–2024)

DZA	0.280	0.076	0.039	0.209	0.285	0.121	0.117	0.122	0.045	0.050
CHE	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
USA	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IRN	0.145	0.162	0.136	0.142	0.130	0.127	0.157	0.159	0.190	0.179
NOR	1.000	1.000	1.000	0.786	0.744	1.000	1.000	1.000	1.000	0.919
MAR	1.000	1.000	1.000	0.407	1.000	1.000	1.000	1.000	1.000	0.417
EGY	0.235	0.195	0.151	0.189	0.084	0.170	0.190	0.185	0.246	0.220
ARE	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
IRQ	0.121	0.073	0.034	0.118	0.034	0.063	0.054	0.061	0.059	0.069
JOR	0.277	0.828	0.598	1.000	1.000	0.679	1.000	1.000	1.000	1.000
SYC	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
MUS	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
ZAF	1.000	0.874	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
NAM	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SEN	1.000	1.000	1.000	1.000	1.000	1.000	0.052	0.092	1.000	1.000
CMR	1.000	0.069	0.052	0.319	1.000	1.000	0.031	1.000	1.000	0.040
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024

Source: Compiled by the researcher based on DEA-SBM model outputs

The Heatmap provides a critical visual diagnostic of the innovation efficiency patterns across the study period. By observing the color intensity, we can draw the following conclusions regarding the research hypotheses:

Confirmation of Hypothesis 2 (The Resource Curse): The map reveals a striking color dualism. Countries with high natural resource dependence, specifically Algeria (DZA), Iraq (IRQ), and Iran (IRN), are predominantly characterized by light yellow/pale zones, indicating chronically low efficiency. In contrast, countries with diversified economies or managed resource wealth like Switzerland (CHE), USA, and the UAE (ARE) maintain a solid dark blue block (Score = 1.0). This supports the Resource Curse hypothesis, where abundant rentier resources lead to a lack of urgency in optimizing innovation inputs.

Confirmation of Hypothesis 3 (Path Dependency): The horizontal consistency of the pale color in the Algerian row (DZA) over the ten-year period proves the existence of Path Dependency. Despite minor fluctuations (e.g., in 2015 and 2019), the system fails to achieve a structural color shift toward the frontier (Dark Blue). This confirms that the Algerian innovation system remains trapped in institutional rigidities that hinder rapid efficiency jumps.

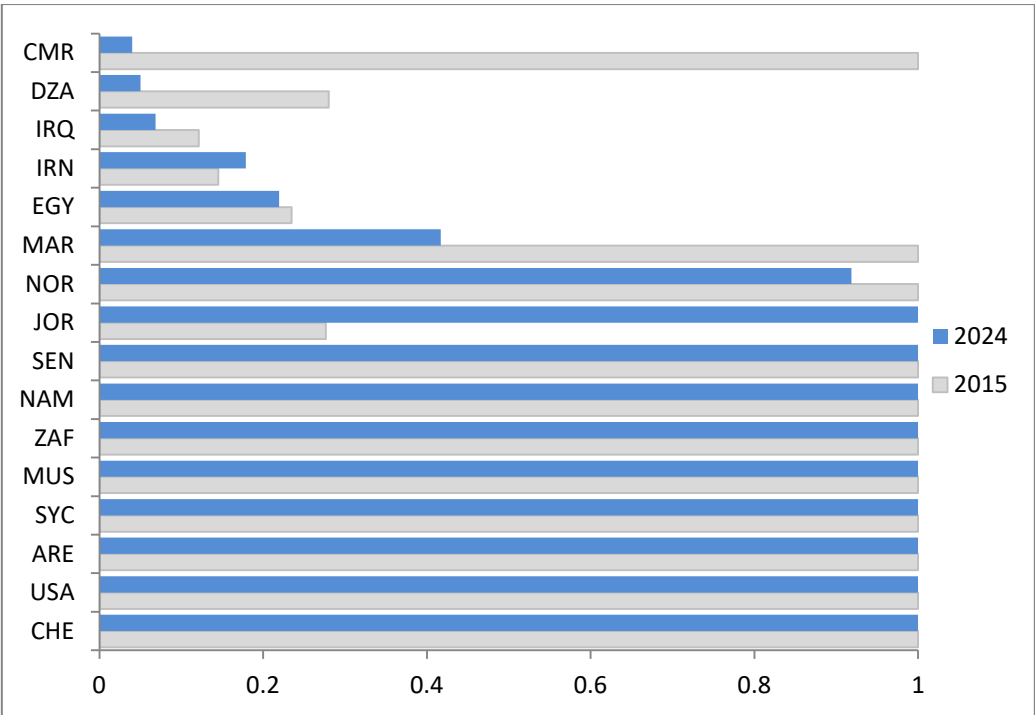
Sensitivity to External Shocks (Hypothesis 5): The map clearly shows the Hysteresis effect in several countries following 2020. For instance, Cameroon (CMR) and Senegal (SEN) exhibit a sudden transition to pale colors in 2021/2022, a pattern mirrored in Algeria's continued low performance. This visual evidence confirms that some systems in the sample lack the institutional memory or resilience to sustain efficiency during global crises.

Identification of Benchmarks: Countries like Jordan (JOR) and Morocco (MAR) show a dynamic pattern, transitioning from pale to dark blue in certain years. These instances serve as Policy Lessons for Algeria, suggesting that focused interventions can indeed break the path dependency, a point that will be further explored in the Slacks analysis.

3.1.3. Comparative Efficiency Ranking (2015 vs. 2024)

This Section provides a comparative ranking of the sample countries at the beginning (2015) and the end (2024) of the study period. By utilizing a Clustered Bar Chart, we can visually track the Catch-up Effect—or the lack thereof—for the Algerian innovation system relative to its global and regional peers. This comparison is vital to assess whether recent national initiatives have succeeded in narrowing the efficiency gap.

Figure 2.4: Comparative Efficiency Ranking of National Innovation Systems (2015 vs. 2024)



Source: Compiled by the researcher based on DEA-SBM model outputs

The comparative ranking goes beyond mere efficiency scores to highlight the Catch-up Effect—or the lack thereof—within the sample. By contrasting the 2015 and 2024 results, we can observe critical shifts that validate new dimensions of the research hypotheses:

The Catch-up Gap (Confirmation of Hypothesis 7): The most striking result is the trajectory of Jordan (JOR) and South Africa (ZAF). While Jordan started with a low score in 2015, it successfully reached the Efficiency Frontier (1.0) by 2024. This success highlights a Global Alignment that Algeria (DZA) lacks. Algeria’s decline from 0.280 to 0.050 indicates a failure to align with international quality standards (WIPO/PCT), whereas peers managed to integrate their research output into global value chains.

Knowledge vs. Economic Value (Confirmation of Hypothesis 8): The ranking reveals that countries like Egypt (EGY) and Morocco (MAR), despite fluctuations, maintain a significantly higher efficiency floor than Algeria. This confirms that the Algerian system is trapped in the Knowledge Accumulation stage without transitioning to Economic Value Generation. While peers are translating their patents into market shares, the Algerian NIS remains localized and decoupled from industrial needs.

Efficiency Divergence (Comparison with Peers): In 2015, Algeria was ahead of or comparable to several regional peers. However, by 2024, a clear Efficiency Divergence has occurred. Algeria’s fall to the bottom of the ranking proves that the issue is not a lack of resources, but a systemic failure to modernize the functional linkages between the university and the productive sector, a gap that has widened despite local initiatives.

Institutional Resilience: The stability of Namibia (NAM) and Mauritius (MUS) at the frontier, compared to Algeria's volatility, suggests that smaller and more specialized innovation systems are more resilient to global shocks than large and fragmented systems. This further supports the Scale Trap argument, where Algeria's size becomes a burden rather than an advantage.

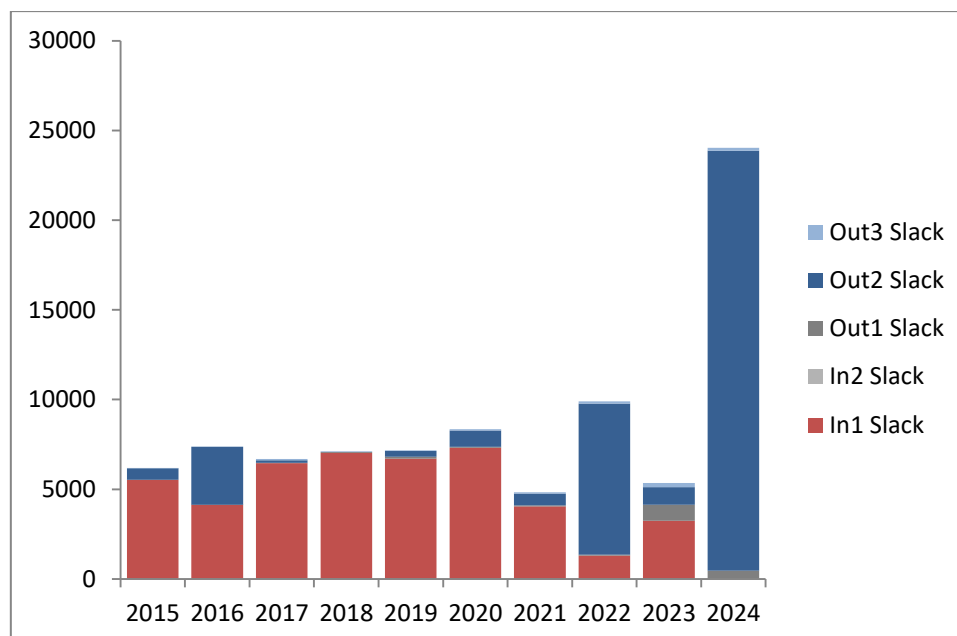
3.2. Structural Decomposition of Inefficiency and Determinants of Failure

Having assessed the relative efficiency trajectories and spatiotemporal patterns previously, this stage shifts from external benchmarking to internal structural diagnostics. The primary objective is to penetrate beyond aggregate efficiency scores to identify the specific Slacks that anchor the Algerian NIS below the Global Efficiency Frontier. By deconstructing the systemic imbalances, we aim to discern whether the recorded inefficiency is a product of managerial resource misallocation or a fundamental divergence in the nature of Returns to Scale.

3.2.1. Structural Slack Deconstruction and Failure Trajectories

This Section focuses on decomposing the total inefficiency into its primary constituents: input surpluses and output deficits. By projecting raw slack values onto a cumulative visual framework, we can pinpoint the variables most responsible for Algeria's deviation from Best Practice benchmarks. This approach allows us to move beyond the "What" (the efficiency score) to the "Why" (the root cause), specifically by testing the sensitivity of the system to functional decoupling.

Figure 2.5: Cumulative Structural Slack Composition of the Algerian NIS (2015–2024)



Source: Compiled by the researcher based on DEA-SBM model outputs

Input Redundancy and Academic Overhang (In1 - Scientific Documents): The Findings reveals a persistent dominance of Input Slacks (In1) during the 2015–2020 period, where surplus values consistently exceeded 7,000 units. Within the SBM-DEA framework, these slacks represent Structural Redundancy—indicating that the Algerian system could have sustained its output levels while significantly reducing its academic inputs. This provides definitive evidence of the system's inability to optimize its scientific output, where a massive volume of Scientific Documents (In1) fails to catalyze proportional technological breakthroughs, acting as a resource burden rather than a productive driver for industrial application.

The Explosion of the Output Gap (Commercialization and Quality Deficit): A radical shift in the failure trajectory is observed post-2022. The Output Expansion required to reach the efficiency frontier experienced an unprecedented explosion, particularly in Out2 (Trademarks), which reached a staggering deficit of 23,417.12 by 2024. This exponential growth in output slack signifies that the Algerian NIS is rapidly losing ground in the global race for knowledge commercialization. While the system manages a baseline of academic activity, it suffers from a Terminal Blockage in the transition from pure knowledge to protected commercial assets, failing to transform laboratory results into market-ready trademarks and international patents. (See Appendix.16)

Validation of Hypothesis 4 (Functional disconnection): The slack structure provides robust validation for the functional disconnection argument. The marginal slack in Out1 (Patent Grants)—which remains relatively low—contrasted with the massive deficits in Out2 (Trademarks) and Out3 (Foreign-oriented Patent Families), highlights a Scholarly-Industrial Paradox. The Algerian NIS is technically optimized for academic accumulation but remains functionally disconnected from the industrial and Productive spheres. This reflects a weak correlation between knowledge accumulation and industrial transformation, where the system produces scientific documents for the sake of academic record rather than for economic value.

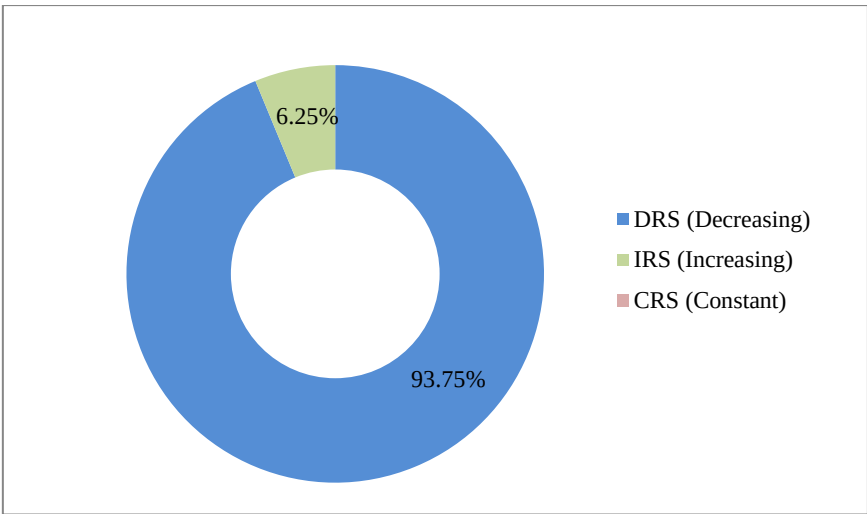
Validation of Hypothesis 8 (Value Generation Failure): The transition recorded in 2024—where In1 Slack (Scientific Documents) vanished while Out2 Slack (Trademarks) skyrocketed—illustrates a state of Exhaustive Inefficiency. In the final year of the study, despite utilizing its full input capacity, Algeria's performance gap widened to a historic peak. This confirms that the system is trapped in the Knowledge Accumulation stage without transitioning to Economic Value Generation. The resources are being fully consumed by the research and training fields, yet they fail to bridge the gap toward the production field (PS), leaving the economic return of innovation weak and confined to local consumption.

Validation of Hypothesis 7 (Technological Sovereignty): The persistent slacks in Out3 (Foreign-oriented Patents) compared to benchmarks prove that the Algerian system suffers from an Inward-looking orientation. The inability to reduce the gap in international protections (PCT/Madrid System) reflects a deficiency in Technological Sovereignty, as local innovations remain unprotected internationally, which further weakens the system's efficiency within the SBM model.

3.2.2. Scale Dynamics and Returns to Scale (RTS) Analysis

Following the structural diagnostic of slacks, this section investigates the Scale Efficiency of the studied National Innovation Systems. By examining the nature of Returns to Scale, we aim to determine the optimal operational size for each system. This analysis is crucial for distinguishing between systems that possess the capacity for expansion and those that have reached a stage of Systemic Saturation. Through this section, we provide evidence to evaluate the Scale Trap and determine whether inefficiency is a result of resource scarcity or an optimal scale divergence where the system's magnitude becomes a structural burden.

Figure 2.6: Distribution of Countries by RTS Nature (2024)



Source: Compiled by the researcher based on DEA-SBM model outputs

The results for the year 2024 reveal a striking dominance of the Decreasing Returns to Scale (DRS) pattern across almost the entire study sample. The classification, based on scale elasticity coefficients, leads to the following inferences:

The Dominance of Decreasing Returns (DRS) and the Scale Trap: The data indicates that 15 out of 16 countries (approximately 93.75% of the sample) are operating within the DRS zone (negative RTS values). This includes both inefficient countries, such as Algeria (DZA) with an RTS value of (-1.66), and high-performing countries like Switzerland (CHE) and the USA, which recorded values of (-0.08) and (-0.05) respectively.

The Case of Senegal (SEN): A significant observation is recorded for Senegal, which achieved absolute technical efficiency (Score = 1.0) yet registered a sharp negative RTS value of (-9.93). This paradox does not imply performance failure, rather, it indicates that Senegal is operating at an exhausted scale. The system has fully utilized the advantages of quantitative expansion, and any additional resource injection—without a radical structural redesign—will inevitably lead to a decline in efficiency. (See Appendix.17)

Algeria's Position: Algeria's positioning in the DRS zone (-1.66) provides validation for **Hypothesis 6**. The negative coefficient signifies that the Algerian NIS is suffering from Structural Bloat.

The Logic of Inefficiency: In this state, the core issue is not a lack of inputs, but rather the Systemic Inertia of the existing structures. Any further increase in the academic documentation (In1) under these negative values will mathematically dilute the overall efficiency. The system has reached a saturation point where its administrative and academic bulk hinders the rapid transformation of inputs into international protected outputs (Trademarks and PCT Patents).

The Exception (Increasing Returns to Scale (IRS)): Namibia (NAM) stands as the sole exception in the sample, exhibiting Increasing Returns to Scale with a positive value of 0.68. This suggests that Namibia's innovation system is still in its growth phase and possesses the Absorptive Capacity to benefit from increased investments. Unlike Algeria, Namibia needs to expand its input base to reach its optimal functional scale.

Validation of Hypothesis 6 (Scale Trap): The results confirm that the Algerian NIS (alongside peers like Egypt and Iraq) is trapped in a stage where size has become a liability. The system acts as a massive consumer of scientific resources that fails to reach the Critical Mass of technical solutions required to transition from a knowledge-accumulating system to a value-generating one.

The Efficiency Frontier Reality: Even for benchmarks like the UAE and South Africa, the negative RTS values suggest that the global innovation frontier is currently characterized by Diseconomies of Scale, where the cost of generating the next unit of high-quality innovation is increasing globally, placing a higher premium on functional integration rather than quantitative expansion.

3.3. In-depth Analysis of the Algerian Innovation System and Benchmarking

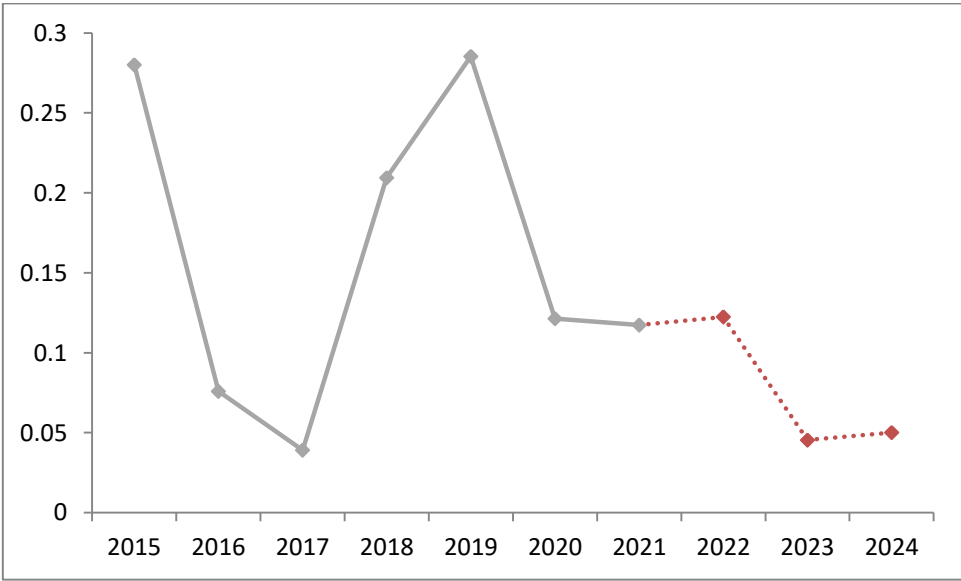
In this section, the study transitions to a micro-level analysis of the Algerian NIS, aiming to decode the underlying factors behind the fluctuations in efficiency levels. The analysis transcends mere numerical tracking to establish a causal link between the temporal efficiency trajectory and the structural and legislative shifts witnessed in Algeria. Particular emphasis is placed on measuring the system's responsiveness to new integrative policies and comparing Algeria's innovation footprint with nations defining the Efficiency Frontier. This comparative approach serves to precisely identify functional gaps and delineate a strategic roadmap toward innovation excellence.

3.3.1. Temporal Efficiency Trajectory and the Impact of Decree 1275

By integrating the temporal trajectory of efficiency scores with pivotal legislative milestones—specifically Decree 1275 (the Startup-Certificate /Patent-Certificate initiative)—this analysis seeks to identify the inflection point in performance, Aiming to determine whether the efficiency gains reflect a genuine response to integration policies between the

university and the productive sector, or if the system remains constrained by Path Dependency, hindering its ability to achieve qualitative leaps toward full technical efficiency.

Figure 2.7: Evolution of Algeria's Technical Efficiency Scores and the Impact of Decree 1275 (2015–2024)



Source: Compiled by the researcher based on DEA-SBM model outputs

The temporal trajectory of Algeria’s efficiency scores provides a critical basis for evaluating Hypothesis 1. While the period following the enactment of Decree 1275 (2021/2022) was expected to trigger an immediate upward trend, the empirical data reveals a more complex reality:

The Post-Decree Shock (2023): Instead of an immediate recovery, the score experienced a sharp decline in 2023, dropping to (0.045). This can be interpreted as a Adjustment Lag. The sudden shift toward the Startup/Patent model created a temporary disruption where the system’s inputs were redirected toward new administrative mechanisms that had not yet yielded matured outputs.

Institutional Inertia and Path Dependency: The slow response confirms the presence of Institutional Inertia as stated in the hypothesis. The Algerian NIS remains heavily influenced by its historical Path Dependency on the rentier economy model, where academic structures struggle to rapidly pivot from pure publication to commercialized innovation.

The 2024 Recovery Signal: The marginal improvement recorded in 2024 (moving from 0.045 to 0.050) indicates the beginning of a Timid Recovery. This suggests that the integrative efforts (Decree 1275) are starting to thaw the system's previous stagnation, but the efficiency growth is strictly constrained by inherited administrative residues.

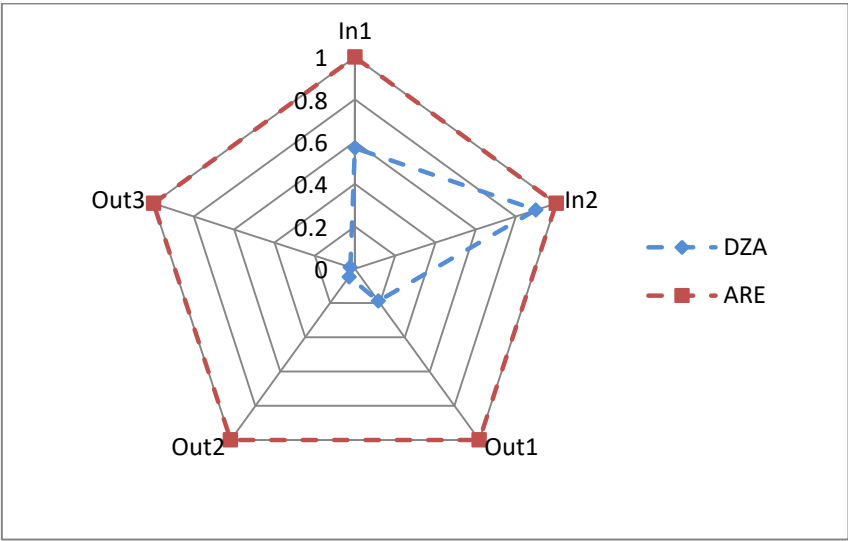
Hypothesis 1 Validation: The sharp decline in 2023 post-decree reflects an Adjustment Lag and Institutional Inertia. The Algerian NIS struggles to pivot from the rentier model, proving that responsiveness to integrative policies is impeded by administrative residues of a legacy

economy. The timid recovery in 2024 (0.050) marks the beginning of a slow transition constrained by these residues.

3.3.2. Structural Comparison with the Benchmark

By employing a Radar Chart, we compare the Algerian NIS against the most relevant international benchmark. This comparison is not merely numerical but structural, designed to uncover the functional architecture of efficiency and identify the specific output dimensions where the Algerian system diverges from global frontier performance.

Figure 2.8: Comparative Radar Chart of Innovation Efficiency between Algeria and UAE (2024)



Source: Compiled by the researcher based on DEA-SBM model outputs

Based on the Slacks-Based Measure (SBM) model results for 2024, the analysis identified three benchmark countries for Algeria: the United States (USA), the United Arab Emirates (ARE), and Seychelles (SYC). The United Arab Emirates (ARE) was selected as the primary reference for comparison in this figure for two strategic reasons:

Mathematical Weight: The UAE recorded the highest reference weight ($\lambda = 0.542$), making it the optimal model for Algeria to emulate mathematically.

Economic Logic: The convergence of economic conditions (resource-based economies) renders the UAE's transition toward a knowledge-based economy a gold standard that is both applicable and comparable to the Algerian context.

To highlight the disparities clearly, raw data for the year 2024 was transformed into Normalized Values ranging from (0) to (1). This process involved dividing each variable's value for both countries by the maximum value recorded in the entire sample for that specific variable. This normalization allowed for the integration of variables with widely divergent scales—such as scientific publications (in thousands) and patents (in tens)—into a single, coherent visual framework.

Interpretation of Results: The Radar Chart reveals a fundamental divergence in the innovation footprint between the two systems:

Input Alignment vs. Output Gap: Algeria shows significant convergence with the UAE in patent applications (In2), reaching over 89% of the benchmark value, and 57% in Scientific Publications (In1). This indicates that Algeria possesses the necessary knowledge base and research personnel.

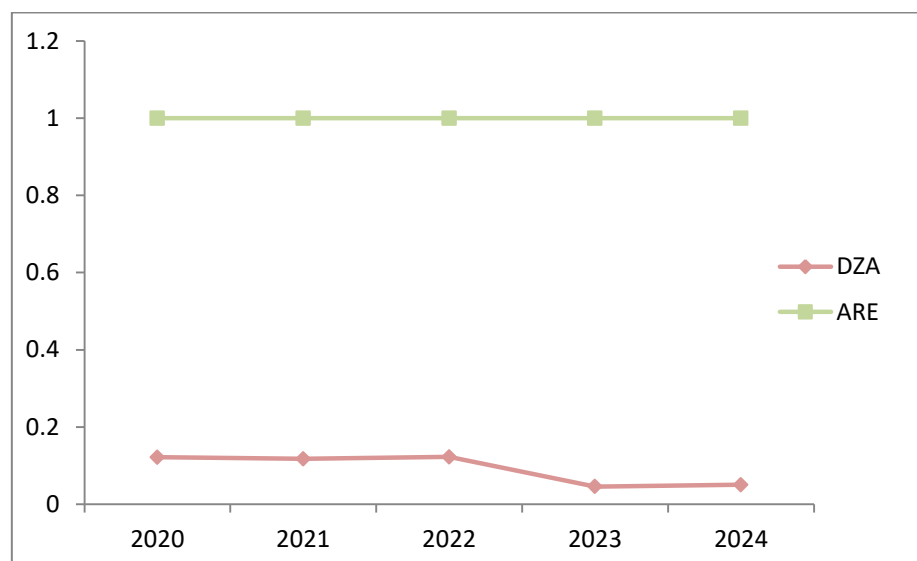
Contraction in Qualitative Outputs: A sharp disparity emerges when transitioning to outputs, Algeria's performance area dramatically contracts in International Patents (Out3) to a negligible ratio (0.02) and Local Patents (Out2) at (0.04), compared to the UAE, which touches the Efficiency Frontier (value of 1). (See Appendix.18)

Validation of Hypothesis 7: These findings confirm the validity of Hypothesis 7, indicating that Algeria suffers from a Global Alignment Gap. While the benchmark system successfully integrates into the global institutional sphere (WIPO) with high-quality, complex outputs, the Algerian system remains confined to low-complexity outputs and limited local protection. This leads to the erosion of the academic knowledge accumulation and a failure to convert it into international economic value.

3.3.3. Dynamic Resilience and Global Quality Positioning

Building upon the structural comparison, this section transitions from a static to a dynamic evaluation of the NIS. Efficiency is not merely a terminal score but a reflection of the system's ability to absorb shocks and its strategic alignment with global quality standards. we will examine Innovation Recovery to measure the resilience of the Algerian NIS against the benchmark after the 2020 global crisis.

Figure 2.9: Comparative Efficiency Trajectories and Innovation Recovery Paths (2020–2024)



Source: Compiled by the researcher based on DEA-SBM model outputs

Resilience Contrast and Recovery Dynamics: The comparative time-series analysis highlights a profound disparity in Systemic Resilience between the Algerian NIS and its benchmark. The United Arab Emirates (ARE) maintained a consistent position on the Efficiency Frontier (Score = 1.0) throughout the post-2020 period. This stability indicates a highly integrated system where functional linkages are robust enough to absorb global shocks without losing technical efficiency.

The Stagnation of the Algerian NIS: In contrast, Algeria's efficiency trajectory reflects a state of Structural Stagnation. The scores remained at critically low levels, fluctuating between 0.12 and 0.05. Notably, instead of showing a recovery or an upward trend post-pandemic, the Algerian system experienced a further decline in 2023 and 2024 (0.045 and 0.050 respectively). This downward drift indicates that the system is not only failing to catch up but is also losing the little ground it held. (See Appendix.19)

Validation of Hypothesis 5 (The Negative Memory Effect): These empirical results provide strong validation for Hypothesis 5. The Algerian system exhibits a clear Negative Memory Effect, every crisis or external shock seems to lead to a permanent erosion of innovation gains rather than a temporary setback. This is attributed to:

Weak University-Industry Linkages: The inability to re-mobilize research outputs into the productive sector during and after crises.

Functional Fragmentation: The lack of synergy between the four domains (STTS, RDS, IS, PS) prevents the system from achieving the Innovation Recovery seen in more diverse and integrated economies.

The widening gap between the two trajectories proves that the Algerian NIS lacks the Institutional Resilience required to return to the efficiency frontier. While the benchmark system operates with proactive flexibility, the Algerian system remains trapped in a low-efficiency equilibrium, confirming that structural reforms in functional integration are mandatory for any future catch-up strategy.

3.4. Strategic Roadmap

This phase represents the practical framework of the study, transitioning from the diagnostic assessment of inefficiency to the formulation of actionable policy targets. Utilizing the SBM-Projection results, this section identifies the ideal state that the Algerian NIS must attain to reach the efficiency frontier (Score = 1.0). By analyzing Slack Movements, we pinpoint specific areas of resource wastage (Input Excess) and performance deficits (Output Shortage). Furthermore, through Benchmark Analysis, these projections are grounded in the successful experiences of peer countries, providing a data-driven Catch-up Strategy that prioritizes international output quality as a catalyst for systemic transformation.

Table 2.3: Target Projections and Slack Adjustments for Algeria

Variables	Actual value	Projection	Slack
In1	13081	13081	0
In2	1122	1122	0
Out1	106	562.4356	456.4356
Out2	2076	25493.12	23417.12
Out3	4	169.1503	165.1503

Source: Compiled by the researcher based on DEA-SBM model outputs

Analysis of Projections and Slack Movements

The SBM-Projection results for Algeria (2024) reveal a critical Output Shortage rather than Input Excess. As shown in the table

Efficiency of Resource Utilization: The Slacks for In1 and In2 are zero, indicating that Algeria is utilizing its current input levels fully relative to its peer group, however, these inputs are failing to translate into proportional innovative outputs.

The Output Gap: The most striking finding is in Out3 (International Patents), where the system must jump from an actual value of 4 to a projected target of 169.15. This represents a massive required improvement, confirming that the current Algerian innovation output is severely under-performing compared to the global frontier.

Productivity Realignment: Significant gaps are also noted in Out1 (Patent grants) and Out2 (Trademarks), requiring a multi-fold increase to reach the efficiency frontier.

Analysis of Benchmarks

The model identifies a specific Reference Set for Algeria to emulate, characterized by the following Lambda (λ) weights:

The UAE Model (ARE - 0.54): The United Arab Emirates serves as the primary benchmark for Algeria. This suggests that Algeria's path to efficiency lies in adopting the UAE's strategy of high-value, internationally protected innovation.

The Seychelles Model (SYC - 0.45): This benchmark emphasizes efficiency in smaller, specialized innovation ecosystems, suggesting that Algeria can learn from Seychelles' ability to maximize impact with focused resources.

The USA Model (USA - 0.0008): While the weight is marginal, its presence indicates that Algeria's long-term targets are anchored in the highest global standards of innovation quality.

Validation of Hypothesis 9

The data provided by the SBM model fully supports **Hypothesis 9**, with some nuanced adjustments based on the results:

Shift from Quantity to Quality: The hypothesis predicted a need for functional redesign focusing on international outputs. The data confirms this, as the (Out3) gap is the most significant strategic challenge.

The Catch-up Mechanism: Instead of the predicted reliance on Egypt or Morocco (as initially hypothesized), the model strictly directs Algeria toward the UAE and Seychelles models. This implies that the Algerian strategy should not just focus on regional industrial production but must pivot towards Global Innovation Integration.

Breaking the Isolation: The required increase in (Out3) from 4 to 169 proves the existence of a "disconnect" between research inputs and international marketability. Achieving the future targets requires a policy shift that incentivizes the conversion of local research into internationally recognized intellectual property.

3.5. General Conclusion

3.5.1. Synthesis of Results

The evaluation of the Algerian National Innovation System (2015–2024) reveals a system characterized by Structural Stagnation and Functional disconnecting, where Algeria exhibits chronically low technical efficiency (0.045–0.12) significantly distanced from the Global Frontier (USA, ARE, CHE).

This underperformance is exacerbated by Innovation Hysteresis and a Negative Memory Effect, where global shocks—such as COVID-19 and energy volatility—lead to permanent erosion of gains rather than temporary setbacks.

Central to this failure is a Resource Paradox (Slacks), the transition from Input Redundancy in scientific papers to an Output Explosion in trademarks and international patents indicates a state of Exhaustive Inefficiency. By 2024, the system utilized its full input capacity but reached a historic peak in its performance gap, particularly in knowledge commercialization.

Furthermore, with a negative Returns to Scale (RTS) of (-1.66), the Algerian NIS is trapped in Structural Bloat, where its administrative and academic volume hinders the transformation of inputs into market-ready outputs. Consequently, while the implementation of Decree 1275 triggered a Post-Decree Shock (Adjustment Lag) in 2023, the timid recovery in 2024 confirms that legislative shifts face severe resistance from inherited Institutional Inertia.

3.5.2. Theoretical Validation: Do the Results Support the Integration Mechanisms?

The findings strongly support and necessitate the functional integration mechanisms proposed (STTS-RDS-PS-IS). The data confirms that the failure of the Algerian NIS is not a lack of Spheres but a failure of the Linkages between them:

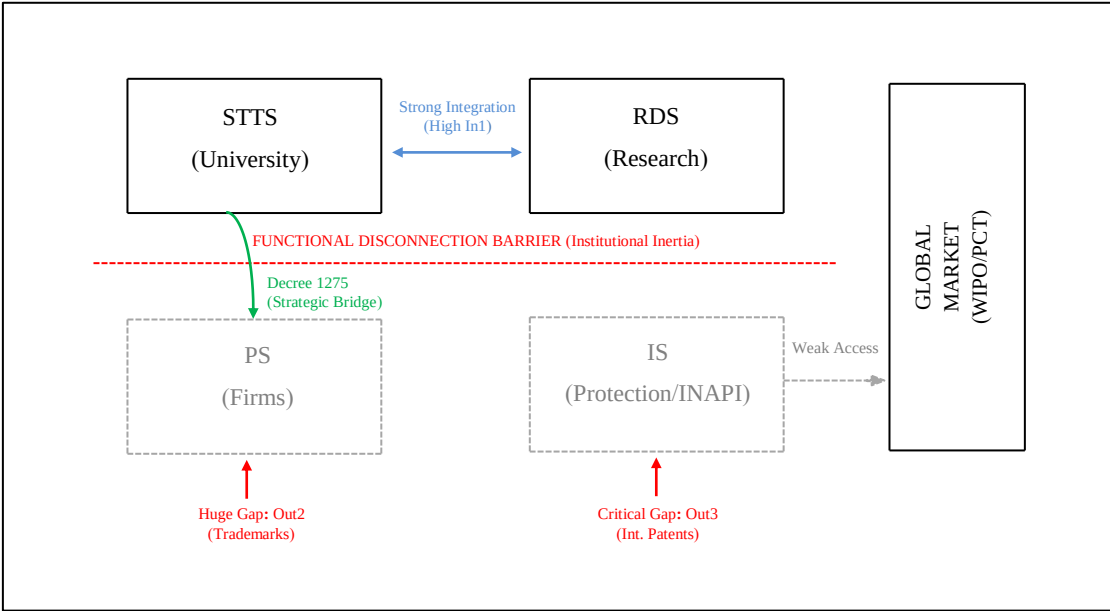
Validation of STTS-RDS Integration: The high volume of scientific documents (In1) contrasted with low industrial application proves that the integration between the Training and Research spheres is linear and academic. The proposed mechanism for Technical Alignment is the missing link to prevent this Academic Overhang.

Validation of IS-PS Integration: The massive Output Gap in trademarks and patents (Out2, Out3) validates the need for the Institutional Sphere (INAPI, ANVREDET) to act as a functional bridge. The results prove that without the Institutional Protection hypothesized, intangible research can not become tangible economic assets.

Validation of Outward-Looking Dynamics: The staggering gap in international patents (from 4 actual to 169 projected) proves that the system is Inward-looking. This confirms the validity of the conclusion that global integration via WIPO/PCT frameworks is the peak of the NIS process and the only way to break Path Dependency.

Based on the discussed Theoretical Validation, and to visualize the functional gaps and the proposed strategic remedies, the following Corrected Functional Integration Model (Figure 2.10) maps the transition from an Inward-looking academic system to an integrated economic powerhouse. This model serves as a structural translation of the statistical slacks identified in (In1, Out2, and Out3), positioning the Decree 1275 as the essential bridge to overcome the identified Academic Overhang.

Figure 2.10: Evidence-based Functional Integration Model of the Algerian NIS (Post-DEA Diagnostic)



Source: Compiled by the researcher based on the SBM-DEA analysis results and the proposed functional integration framework

This model illustrates the internal dynamics of the Algerian NIS under the light of our research findings. It highlights:

The Functional Barrier: A red-dashed line representing the Institutional Inertia that separates academic potential from industrial reality.

Strategic Bridging: The arrow representing Decree 1275 acts as a catalyst, specifically linking the Training Sphere (STTS) to the Productive Sphere (PS) to convert research into startups.

Output Slacks: The red arrows at the bottom quantify the failure to transform intangible assets into international patents and trademarks, explaining the Weak Access to the Global Market (WIPO/PCT frameworks).

3.6. Discussion and Comparative Analysis with Previous studies

This section provides a critical comparative analysis between our SBM-DEA results and a curated selection of 27 previous studies. The objective is to identify points of convergence that reinforce our findings and points of divergence that highlight the unique structural challenges and Institutional Inertia characterizing the Algerian case.

3.6.1. Convergent studies

The following studies reinforce our core finding that innovation failure is not a matter of resource scarcity but a fundamental efficiency crisis in the transformation process, explaining the Resource Paradox observed in Algeria:

Eva Jurickova et al. (2019): This study demonstrates a strong alignment with our results by proving that high innovation performance (as seen in input volumes) does not inherently translate into high technical efficiency. This directly supports our observation regarding the Academic Overhang in Algeria, where the massive accumulation of scientific publications (In1) fails to generate technical efficiency due to the systematic mismanagement of innovation inputs.

Ibrahim Alnafrh (2021): Utilizing a multi-stage perspective, Alnafrh's findings in BRICS economies mirror our Functional Disconnection thesis. His evidence that systemic failure is concentrated in the Commercialization Stage—rather than knowledge generation—provides a robust explanation for the massive output gaps we identified in trademarks and international patents (Out2, Out3). It confirms that Algeria's NIS is stalled at the transition from intangible research to marketable assets.

Naser Ali Azimi et al. (2021): Our results intersect with this study in identifying that systemic inefficiency is rooted in institutional and structural bottlenecks rather than a lack of R&D investment. This reinforces our hypothesis of an Inward-looking system, where the lack of institutional quality prevents the Algerian NIS from aligning with international efficiency frontiers.

3.6.2. Divergent Studies

The following studies highlight the disparity between Dynamic systems that overcome barriers and the Stagnant nature of the Algerian system:

Eva Jurickova et al. (2017) - The Case of Czechia: Unlike the Algerian experience, the Czech Republic successfully achieved moderate efficiency by prioritizing Intellectual Assets and legal protection. Our findings diverge here; despite the introduction of legislative catalysts such as Decree 1275, Algeria continues to suffer from deep-rooted Institutional Inertia that resists the transformation of research into protected and marketable intellectual property.

Davor Vlajčić et al. (2025): While Central and Eastern European countries exhibited a clear Catch-up effect by moving toward the technological frontier, our analysis reveals the opposite. Algeria suffers from Innovation Hysteresis (a negative memory effect), where the system drifts further away from the global frontier rather than converging with it, indicating a failure in the NIS's adaptive capacity.

Arkadiusz Michał Kowalski (2020): The fundamental divergence lies in the comparison with China's rapid Technological Convergence. While China leveraged strategic Science, Technology, and Innovation policies to bridge its innovation gap, the Algerian NIS remains trapped in Structural Bloat. This administrative and academic volume acts as a hindrance rather than a driver, creating a performance lag that legislation alone has yet to overcome.

CHAPTER 2. Summary ---

This chapter represented the core of the study, transitioning from the theoretical frameworks of National Innovation Systems to a rigorous quantitative diagnostic using the SBM-DEA methodology. By applying this model to a sample of 16 countries over the period 2015–2024, the study succeeded in mapping efficiency trajectories and identifying the structural gaps within the Algerian NIS.

The evaluation was based on a functional transformation model, utilizing Total Scientific Documents and Total Patent Applications as primary Innovation Inputs, while measuring performance through three key Innovation Outputs: Total Patent Grants, Total Trademark Registrations, and Foreign-oriented Patent Families. The analysis provided a detailed deconstruction of inefficiency through the study of Slacks and Returns to Scale (RTS), shifting the focus from mere resource availability to the actual capacity of functional conversion. Consequently, the analyzed results provided the necessary evidence-based foundation to formulate the strategic roadmap and finalize the research conclusions.

CONCLUSION

This research progressed from a broad theoretical conceptualization to a precise diagnostic of the Algerian case. The study initially established that the transition toward a knowledge-based economy is not merely a product of increasing R&D expenditures, but a result of the structural synergy between research institutions, the productive sector, and the regulatory framework.

At the heart of this investigation was the central research question: How efficient is the Algerian National Innovation System in transforming its scientific and technical inputs into internationally protected and industrially marketable outputs compared to a sample of developed and emerging economies during the 2015–2024 period?

To bridge the gap between theory and reality, the research transitioned into a quantitative evaluative phase using the Slacks-Based Measure (SBM-DEA) model. This methodology allowed for a rigorous benchmarking of Algeria's innovation efficiency against 15 international economies. By deconstructing inefficiency through the lens of structural slacks and returns to scale, the study moved beyond descriptive analysis to pinpoint the exact locations of functional blockage, ultimately providing a definitive answer to the research problem regarding Algeria's capacity for knowledge valorization and technological sovereignty.

Based on the hypotheses formulated at the beginning of this study, we will proceed to test their validity and review the most significant research findings. This will lead to providing strategic recommendations to the relevant authorities, while several research prospects emerge that could serve as scientific extensions of this work for future research.

Testing of Research Hypotheses

Based on the SBM-DEA model outputs and the analytical results from the period 2015–2024, the study's hypotheses are tested as follows:

Hypothesis 1: [Confirmed] The results confirm a fundamental efficiency gap (Score: 0.050). The Adjustment Lag observed after Decree 1275 (where the score dropped to 0.045 in 2023) proves that the system's responsiveness is impeded by Institutional Inertia and administrative residues of the rentier model, making the recovery slow and constrained.

Hypothesis 2: [Confirmed] The Resource Curse is validated through the Heatmap; oil-producing countries (Algeria, Iraq, Iran) consistently occupy the "Pale Zones" of low efficiency. This proves that the Algerian NIS is more sensitive to raw material price volatility than to actual scientific effort.

CONCLUSION

Hypothesis 3: [Confirmed] The horizontal consistency in Algeria's trajectory over 10 years proves a state of Path Dependency. The system remains trapped in a traditional pattern of producing scientific publications (In1) without the ability to pivot toward patenting at the same pace as diversified nations.

Hypothesis 4: [Confirmed] The Knowledge Paradox is evident; the slack analysis reveals that while Input Slacks (In1) were minimized, the deficit in qualitative outputs (Out2, Out3) skyrocketed. This confirms a Functional Disconnection where the link between knowledge accumulation and industrial valorization is broken.

Hypothesis 5: [Confirmed] The study proves that Algeria suffers from Innovation Hysteresis and a Negative Memory Effect. Global shocks (2016 and 2021) led to a permanent erosion of innovative gains. Unlike the UAE, Algeria's recovery is hindered by functional fragmentation between its spheres.

Hypothesis 6: [Confirmed] The Scale Trap is validated by a negative Returns to Scale (RTS) value of (-1.66). This Structural Bloat indicates that the system has reached a saturation point where size has become a liability, and additional inputs only dilute overall efficiency.

Hypothesis 7: [Confirmed] A Global Alignment Gap is proven; the Radar Chart shows that Algeria converges with the UAE in inputs but collapses in Foreign-oriented Patents (Out3) with a negligible ratio of 0.02. This reflects a deficit in technological sovereignty and a weak foreign-orientation.

Hypothesis 8: [Confirmed] A total Break in the Value Chain is confirmed. The Algerian system shows efficiency in Knowledge Accumulation but fails when transitioning to the Productive Sphere (PS), leaving the economic return on innovation weak and confined to local consumption.

Hypothesis 9: [Confirmed with Strategic Adjustments] Achieving full efficiency requires a Functional Redesign. The SBM-Projection identifies the UAE Model (Weight: 0.54) as the primary benchmark, shifting the strategy from regional catch-up to Global Innovation Integration, specifically by bridging the gap from 4 to 169 international patents.

Key Research Findings

Following the confirmation of the study's hypotheses, the following key findings were obtained:

- *The Scale Trap & Structural Bloat:* The Algerian NIS has reached its quantitative saturation point. The RTS of (-1.66) proves that the core issue is not resource scarcity but Systemic Inertia. Any further increase in inputs without structural redesign will mathematically dilute efficiency;
- *The Terminal Blockage in Knowledge Transfer:* There is a fundamental break between research and the market. The system acts as a Scientific Archive rather than an Innovation

CONCLUSION

Engine, where a massive volume of publications fails to catalyze technological breakthroughs;

- *The Adjustment Lag of Decree 1275*: The 2023 performance dip (0.045) reveals that new integrative policies face structural resistance. The system requires a Thawing Period to overcome inherited administrative residues before these policies yield matured outputs;

- *Technological Sovereignty Deficit*: The most critical failure is the Global Alignment Gap. Algeria's reliance on local protection (INAPI) with low-complexity outputs, compared to the 169-patent target in the global sphere (WIPO/PCT), indicates a loss of international competitiveness;

- *Innovation Hysteresis & Negative Memory*: Unlike resilient systems, the Algerian NIS does not rebound after crises. Every global shock (Energy or Health) leads to a permanent erosion of gains, suggesting that the system lacks Institutional Memory;

- *The Resource Curse Mechanism*: The SBM scores show that the innovation system is an indirect consumer of oil rents; efficiency levels fluctuate in tandem with energy markets rather than scientific productivity;

- *The UAE as a Gold Standard*: The benchmarking results prove that the UAE model is the most mathematically relevant for Algeria (Weight: 0.54). This implies that a Resource-Based Economy can successfully transition to a Knowledge-Based Economy through global institutional integration;

- *Input Redundancy vs. Output Explosion*: While Algeria eliminated slacks in Scientific Documents (In1) by 2024, the output gap (especially in Trademarks) experienced an unprecedented explosion, signaling a total loss of ground in the race for knowledge commercialization.

Recommendations

Based on the findings, the following recommendations are proposed:

- *Pivoting from Quantitative Expansion to Qualitative Redesign*: Since the system operates under Decreasing Returns to Scale (RTS: -1.66), policymakers must halt the Scale Trap of merely increasing the number of researchers or publications. Instead, funding should be redirected toward high-complexity outputs (International Patents and Trademarks) to improve the marginal return on scientific investment;

- *Bridging the Terminal Blockage through Functional Integration*: To address the Functional Disconnection, it is mandatory to activate the linkages between the Research Sphere (RDS) and the Productive Sphere (PS). This can be achieved by transforming university laboratories from Knowledge Archives into Innovation Hubs that prioritize the commercialization of research through the Startup-Certificate/Patent-Certificate (Decree 1275) framework;

CONCLUSION

- *Adopting the Global Alignment Strategy (The UAE Model):* Algeria should emulate the UAE benchmark ($\lambda = 0.54$) by shifting its institutional focus from local protection (INAPI) to the global institutional sphere (WIPO/PCT). Reducing the 169-unit gap in international patents (Out3) is the only mathematical and strategic pathway to reach the Global Efficiency Frontier;
- *Mitigating Innovation Hysteresis and Building Resilience:* To counter the Negative Memory Effect, the NIS requires Institutional Buffers—such as specialized venture capital and flexible regulatory sandboxes—that protect innovative gains during global shocks (like energy price volatility), ensuring a faster recovery and return to the efficiency trajectory;
- *Transitioning to Outward-Looking Technological Sovereignty:* Efficiency within the SBM model is currently weakened by the closure of the productive cycle within the local market. Incentivizing foreign-oriented innovation will ensure that local solutions are protected internationally, thereby securing both economic value and technological sovereignty.

Prospects for Future Research

While this study provided a macro-diagnostic of the Algerian NIS, several research prospects emerge that could serve as scientific extensions of this work:

- *Micro-Efficiency Analysis of University Incubators:* Future research could apply the SBM-DEA model at the micro-level to evaluate the individual efficiency of Algerian university incubators in implementing Decree 1275, identifying Best Practice units within the national territory;
- *Sector-Specific Innovation Metrics:* A deep-dive study into the efficiency of specific strategic sectors (e.g., Renewable Energy, Biotechnology, or Fintech) would provide a more granular understanding of where functional integration is succeeding or failing;
- *Innovation Resilience and Crisis Management:* Future studies should focus on developing an Innovation Resilience Index to measure the capacity of National Innovation Systems to withstand global shocks. This includes investigating the Institutional Memory required to prevent the Negative Memory Effect and ensure that external crises do not lead to a permanent erosion of innovative gains;
- *The Impact of Innovation Autonomy on Stability:* Research is needed to explore how decoupling the innovation system from Raw Material Rents (the Resource Curse) can act as a buffer against energy price volatility, transitioning the NIS from a Rent-Dependent model to an Innovation-Autonomous model;
- *The Impact of Digitalization on Integration Resilience:* Future studies could explore how the digital transformation of the Institutional Sphere (IS) can mitigate "Innovation Hysteresis" and the "Negative Memory Effect", providing a faster recovery mechanism during global crises;

CONCLUSION

- *Qualitative Assessment of Institutional Inertia:* Since the DEA model identifies "what" the inefficiency is, future studies could use Qualitative Methodology (Interviews and Surveys) to explore the "why" behind the Institutional Inertia and administrative resistance identified in this research;
- *Dynamic Network DEA (DN-DEA) Application:* To further deconstruct the Value Chain, future researchers could utilize Network DEA to separately measure the efficiency of the Knowledge Production Stage versus the Commercialization Stage, providing a dual-index of systemic performance.

REFERENCES

1. Albuquerque, E. D. (1999). National Systems of Innovation and Non-OECD Countries: Notes about a rudimentary and tentative “typology”. *Revista de Economia Política*, 602-620.
2. Amdaoud, M. (2016). La construction d'un système national d'innovation en Algérie: institutions et politique d'innovation. *Marché et organisations*, 49-91.
3. Carlsson, B. (2006). Internationalization of innovation systems: A survey of the literature. *Research Policy*, 56-67.
4. Chesbrough, H., & Bogers, M. (2013). Explicating Open Innovation: Clarifying an Emerging Paradigm for Understanding Innovation. In H. Chesbrough, W. Vanhaverbek, & J. West, *New Frontiers in Open Innovation* (pp. 1-37). Oxford: Oxford University Press.
5. Cooper, W. W., Seiford, L. M., & Tone, K. (2007). *Data Envelopment Analysis A Comprehensive Text with Models, Applications, References and DEA-Solver Software*. New York: Springer Science+Business.
6. Cvetkoska, V. (2011). Data Envelopment Analysis Approach and Its Application in Information and Communication Technologies . *International Conference on Information and Communication Technologies for Sustainable Agri-production and Environment (HAICTA 2011)* (pp. 421-430). Skiathos: HAICTA Proceedings.
7. Dworak, E., Grzelak, M. M., & Roszko-Wójtowicz, E. (2022). Comparison of National Innovation Systems in the European Union Countries. *risks*, 1-20.
8. Edquist, C. (1997). *Systems of Innovation Technologies, Institutions and Organizations*. LONDON AND NEW YORK : Pinter.
9. Feinson, S. ((n.d.)). *National Innovation Systems Overview and Country Cases*. Washington: Consortium for Science, Policy & Outcomes (CSPO).
10. Huguenin, J.-M. (2012). *Data Envelopment Analysis (DEA): A pedagogical guide for decision makers in the public sector*. Lausanne: Institut de hautes études en administration publique.
11. Johnson, B., Edquist, C., & Lundvall, B.-Å. (2003). Economic Development and the National System of Innovation Approach. *International Conference on Innovation Systems and Development Strategies for the Third Millennium* (pp. 1-18). Rio de Janeiro: Globelics.

REFERENCES

12. Li, X., Wu, T., Zhang, H.-J., & Yang, D.-Y. (2023). National innovation systems and the achievement of sustainable development goals: Effect of knowledge-based dynamic capability. *Journal of Innovation & Knowledge*, 1-12.
13. Lundvall, B.-Å. (2015). The origins of the national innovation system concept and its usefulness in the era of the globalizing economy. *the 13th Globelics Conference* (pp. 1-25). Havana: Globelics and Aalborg University.
14. Lundvall, B.-Å., Joseph, K., Chaminade, C., & Vang, J. (2009). *Handbook of Innovation Systems and Developing Countries Building Domestic Capabilities in a Global Setting*. Cheltenham, UK: Edward Elgar Publishing.
15. Lundvall, B.-k. (2010). *National Systems of Innovation Toward a Theory of Innovation and Interactive Learning*. London, New York: Anthem Press.
16. Ministre, S. d. (2021). *Plan d'action du Gouvernement pour la mise en œuvre du programme du Président de la République*. Algiers: Services du Premier Ministre.
17. OECD. (2005). *Governance of Innovation Systems*. Paris: OECD Publishing.
18. SCImago. ((n.d)). *SJR - SCImago Journal & Country Rank: Methodology*. Retrieved February 02, 2026, from SCImago Journal & Country Rank: <https://www.scimagojr.com/methodology.php>
19. Tone, K., & Tsutsui, M. ((n.d)). *Dynamic DEA: A slacks-based measure approach*. Tokyo: GRIPS Policy Information Center.
20. WIPO. (2024). *Global Innovation Index 2025 Innovation at a Crossroads*. Geneva: WIPO.
21. WIPO. (2025). *World Intellectual Property Indicators 2025*. Geneva : WIPO.
22. بلصير, خ. (2025). القرار 1275 كآلية لتجسيد المسؤولية الاجتماعية وتعزيز الدور التنموي للجامعة الجزائرية. *مجلة قيس للدراسات الإنسانية والاجتماعية*. 1193-1216 ,
23. وزير التعليم العالي والبحث العلمي. (2022). *قرار رقم 1275 مؤرخ في 27 سبتمبر 2022 يحدد كفايات إعداد مشروع مذكرة تخرج للحصول على شهادة جامعية-مؤسسة ناشئة من قبل طلبة مؤسسات التعليم العالي. الجزائر : وزارة التعليم العالي والبحث العلمي.*

APPENDICES

Appendix.1: Frequency of Innovation Input Indicators in Previous DEA-based Studies

INPUTS						
Studies	R&D Spending	R&D Labor	Economic Openness	Institutional Context	Fixed Assets	Innovation Performance
Davor Vlačić et al., 2025	X	X				
Abdel Latef Anouze et al., 2024	X	X	X		X	
Veronika Cabinova et al., 2024	X	X				
Meda Andrijauskienė et al., 2023	X	X	X	X		
Svetlana V. Ratner et al., 2022	X	X		X		
Ibrahim Alnafrh, 2021	X	X				
Irena Łacka and Łukasz Brzezicki, 2021	X	X		X	X	X
Naser Ali Azimi et al., 2021	X	X		X		
Eva Jurickova et al., 2019	X	X				
Eva Jurickova et al., 2017	X	X				
Frequency	10	10	2	4	2	1

Source: Compiled by the researcher based on previous DEA-based studies

Appendix.2: Frequency of Innovation Output Indicators in Previous DEA-based Studies

OUTPUTS							
Studies	PATENTS	Scientific Publications	High-tech exports	Trademark	Design Applications	IP Receipts	Economic Impacts
Davor Vlačić et al., 2025	X	X					
Abdel Latef Anouze et al., 2024	X	X	X				
Veronika Cabinova et al., 2024	X	X	X				
Meda Andrijauskienė et al., 2023	X			X	X		
Svetlana V. Ratner et al., 2022			X			X	

Ibrahim AlnafrAh, 2021	X	X	X	X			
Irena Łacka and Łukasz Brzezicki, 2021			X				X
Naser Ali Azimi et al., 2021	X	X					X
Eva Jurickova et al., 2019	X	X					
Eva Jurickova et al., 2017	X						X
Frequency	8	6	5	2	1	1	3

Source: Compiled by the researcher based on previous DEA-based studies

Note: For the purpose of structural clarity and conciseness, indicators belonging to the same functional category have been aggregated. This categorization ensures a streamlined presentation without compromising the analytical depth of each innovation dimension.

Appendix.3: Raw Data Matrix for Innovation Inputs and Outputs (2015–2024)

DMU	Time	In1	In2	Out1	Out2	Out3
DZA	2015	6107	123	79	2240	4
CHE	2015	46776	46175	22197	172323	6679
USA	2015	708794	538055	257092	773670	73984
IRN	2015	46168	11306	2694	28681	99
NOR	2015	21791	5698	3080	16376	762
MAR	2015	4871	311	187	7382	10
EGY	2015	17201	829	140	4524	22
ARE	2015	5065	550	106	14463	128
IRQ	2015	2231	346	199	1279	3
JOR	2015	2690	182	36	2575	7
SYC	2015	62	62	66	1688	22
MUS	2015	243	118	34	3170	26
ZAF	2015	21468	2049	1226	20809	225
NAM	2015	329	17	13	302	3
SEN	2015	792	258	204	4646	3
CMR	2015	1257	460	409	5411	1
DZA	2016	6817	117	64	106	2
CHE	2016	48493	47361	25960	151660	6862
USA	2016	716269	530398	277145	750024	77140
IRN	2016	53031	15086	3155	23652	163
NOR	2016	23916	5863	3555	15454	949
MAR	2016	6300	264	141	8094	20
EGY	2016	19659	1045	126	4325	20
ARE	2016	5814	778	145	15561	137
IRQ	2016	3233	489	265	594	3
JOR	2016	3101	150	52	3737	24

SYC	2016	49	113	71	609	48
MUS	2016	322	111	36	2352	17
ZAF	2016	23985	1949	1077	12492	207
NAM	2016	358	22	16	277	10
SEN	2016	805	394	119	4646	1
CMR	2016	1417	817	206	5411	3
DZA	2017	7521	163	85	3525	1
CHE	2017	50813	44574	26160	168412	6939
USA	2017	735452	534314	285846	793384	80401
IRN	2017	57103	15486	3726	28540	143
NOR	2017	25029	5814	3583	21261	890
MAR	2017	6855	267	92	10983	12
EGY	2017	19751	1134	148	4125	23
ARE	2017	6744	724	271	17768	208
IRQ	2017	4513	632	330	1485	2
JOR	2017	3625	87	45	3424	15
SYC	2017	61	64	66	1174	51
MUS	2017	385	49	35	3651	21
ZAF	2017	25827	2135	1430	15691	212
NAM	2017	438	14	14	396	10
SEN	2017	842	395	544	4641	2
CMR	2017	1670	531	530	4073	1
DZA	2018	8499	162	35	2865	4
CHE	2018	51241	46866	26109	167129	6860
USA	2018	744306	525013	289087	812808	81217
IRN	2018	59793	12078	3057	29660	107
NOR	2018	25794	6430	3706	22252	848
MAR	2018	7707	339	207	9038	12
EGY	2018	22349	1159	240	7098	20
ARE	2018	7493	744	319	18461	154
IRQ	2018	9374	663	400	2506	6
JOR	2018	4510	51	85	3374	10
SYC	2018	55	107	60	682	35
MUS	2018	366	195	37	4546	27
ZAF	2018	27392	1827	1443	23493	212
NAM	2018	497	24	4	316	16
SEN	2018	882	341	426	4864	2
CMR	2018	1742	707	629	5319	8
DZA	2019	8477	119	34	2562	6
CHE	2019	51501	46399	27349	188541	7203
USA	2019	733093	539792	309625	893641	81215
IRN	2019	67715	11703	2580	30600	99
NOR	2019	26464	6165	3537	23209	826
MAR	2019	8889	293	164	10907	13
EGY	2019	26122	1165	50	8086	18
ARE	2019	9409	794	389	18364	153
IRQ	2019	14587	745	450	887	2

JOR	2019	5493	48	37	4098	10
SYC	2019	55	37	55	1559	22
MUS	2019	573	70	34	4263	29
ZAF	2019	30120	1480	1555	24786	191
NAM	2019	471	21	8	482	8
SEN	2019	950	221	307	4915	3
CMR	2019	1935	528	582	5628	2
DZA	2020	8612	170	49	4389	3
CHE	2020	54609	44998	28152	175825	7523
USA	2020	742757	514646	306555	835794	85102
IRN	2020	74488	11550	3444	33650	99
NOR	2020	28207	5912	3912	21289	827
MAR	2020	10322	341	143	9940	20
EGY	2020	32558	1167	115	6517	24
ARE	2020	11147	843	295	20591	186
IRQ	2020	19518	645	385	757	4
JOR	2020	6752	72	42	3672	13
SYC	2020	99	53	49	3553	14
MUS	2020	512	116	79	4085	55
ZAF	2020	32442	1421	1023	17619	194
NAM	2020	629	21	9	329	5
SEN	2020	1113	239	358	4471	1
CMR	2020	2356	715	646	6801	3
DZA	2021	9976	280	104	6655	3
CHE	2021	59491	48530	26808	182491	7689
USA	2021	768099	530381	298682	898517	80872
IRN	2021	77975	10358	2788	38171	107
NOR	2021	30332	5773	4030	27305	862
MAR	2021	11625	402	203	13045	11
EGY	2021	38786	984	129	9523	22
ARE	2021	13512	659	376	17535	155
IRQ	2021	17929	639	483	910	3
JOR	2021	8014	50	34	3238	15
SYC	2021	105	50	25	2206	7
MUS	2021	566	173	53	4706	40
ZAF	2021	34610	1421	1314	15839	205
NAM	2021	741	21	9	326	10
SEN	2021	1100	606	119	6255	2
CMR	2021	2700	1076	514	6187	2
DZA	2022	11081	483	125	5705	7
CHE	2022	58784	51703	24851	168959	7673
USA	2022	736868	536799	278125	896304	73390
IRN	2022	78400	8397	2144	27357	88
NOR	2022	30521	5912	3784	24083	770
MAR	2022	12800	368	231	13454	17
EGY	2022	43809	851	148	11709	21
ARE	2022	16548	829	318	24427	246

IRQ	2022	20401	820	689	1304	3
JOR	2022	9580	65	31	3445	9
SYC	2022	104	47	17	1536	11
MUS	2022	600	403	41	3491	45
ZAF	2022	35639	1400	1175	23213	217
NAM	2022	743	20	9	323	7
SEN	2022	1222	583	359	2238	2
CMR	2022	2900	805	714	2799	3
DZA	2023	11129	1412	137	5878	4
CHE	2023	58012	53344	27690	167267	7178
USA	2023	734258	531963	302571	827097	79165
IRN	2023	74150	8654	1780	24200	113
NOR	2023	31328	5576	4029	20892	841
MAR	2023	14836	488	300	13440	14
EGY	2023	42722	812	91	14779	21
ARE	2023	20007	1810	475	31318	171
IRQ	2023	26595	746	344	1216	3
JOR	2023	11877	58	26	3445	13
SYC	2023	77	25	31	2183	26
MUS	2023	515	292	95	3699	32
ZAF	2023	35596	1432	1107	20850	208
NAM	2023	799	17	4	102	9
SEN	2023	1222	358	341	4555	2
CMR	2023	3019	736	920	5690	3
DZA	2024	13081	1122	106	2076	4
CHE	2024	58724	52579	27264	162770	7178
USA	2024	743884	511452	287929	837199	79165
IRN	2024	75501	8446	1576	22303	113
NOR	2024	31793	5610	3365	19930	841
MAR	2024	18273	426	205	14105	14
EGY	2024	43835	778	119	7854	21
ARE	2024	22930	1248	563	44350	171
IRQ	2024	28606	574	177	1848	3
JOR	2024	14427	92	24	4201	13
SYC	2024	100	62	49	1688	26
MUS	2024	585	442	77	6274	32
ZAF	2024	37121	1203	991	19139	208
NAM	2024	822	25	23	310	9
SEN	2024	1320	265	238	5227	2
CMR	2024	3375	1344	579	6790	3

Source: Compiled by the researcher based on MAXDEA guide

Note:

- Country codes are based on the ISO 3166-1 alpha-3 international standard;
- Red-shaded values denote missing data points calculated via arithmetic mean imputation.

Appendix.4: 2015- DEA-SBM model outputs

DMU	DZA	CHE	USA	IRN	NOR	MAR	EGY	ARE	IRQ	JOR	SYC	MUS	ZAF	NAM	SEN	CMR
Score	0.280019	1	1	0.145158	1	1	0.234899	1	0.121379	0.276534	1	1	1	1	1	1
Rank	12	1	1	15	1	1	14	1	16	13	1	1	1	1	1	1
Benchmark(lambda)	NOR(0.003135)	CHE(1)	USA(1)	CHE(0.235	NOR(1)	MAR(1)	CHE(0.006	ARE(1)	NOR(0.02	ARE(0.245	SYC(1)	MUS(1)	ZAF(1)	NAM(1)	SEN(1)	CMR(1)
Slack Movement(In1)	-5532.637809	0	0	-31269.7	0	0	-11880.9	0	0	-1397.75	0	0	0	0	0	0
Slack Movement(In2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slack Movement(Out1)	0	0	0	2619.908	0	0	101.088	0	0	39.83607	0	0	0	0	0	0
Slack Movement(Out2)	628.41396	0	0	22997.17	0	0	10904.32	0	3147.011	2254.393	0	0	0	0	0	0
Slack Movement(Out3)	29.73211	0	0	1573.385	0	0	146.0598	0	57.76607	41.06557	0	0	0	0	0	0
Projection(In1)	574.362191	46776	708794	14898.28	21791	4871	5320.066	5065	2231	1292.246	62	243	21468	329	792	1257
Projection(In2)	123	46175	538055	11306	5698	311	829	550	346	182	62	118	2049	17	258	460
Projection(Out1)	79	22197	257092	5313.908	3080	187	241.088	106	199	75.83607	66	34	1226	13	204	409
Projection(Out2)	2868.41396	172323	773670	51678.17	16376	7382	15428.32	14463	4426.011	4829.393	1688	3170	20809	302	4646	5411
Projection(Out3)	33.73211	6679	73984	1672.385	762	10	168.0598	128	60.76607	48.06557	22	26	225	3	3	1
Dual Price(In1)	0	-1.22E-05	-1.31E-06	0	-1.62E-05	0	0	0	-3.81E-05	0	-5.27E-03	-1.29E-02	-1.01E-05	0	-5.83E-03	0
Dual Price(In2)	-2.39E-02	0	0	-5.84E-04	-2.02E-03	-2.98E-02	-3.58E-03	-2.93E-03	-3.34E-02	-1.45E-02	0	0	-6.38E-04	-1.11E-01	-4.26E-02	-1.43E-01
Dual Price(Out1)	2.36E-02	1.50E-05	1.30E-06	1.24E-04	2.50E-03	2.82E-02	2.38E-03	3.14E-03	3.41E-02	9.26E-03	5.05E-03	9.80E-03	7.83E-04	2.56E-02	4.56E-02	1.86E-01
Dual Price(Out2)	1.49E-04	1.93E-06	4.31E-07	1.16E-05	2.04E-05	7.74E-04	7.37E-05	9.79E-05	2.61E-04	1.29E-04	1.97E-04	1.75E-03	1.60E-05	1.10E-03	2.84E-03	8.58E-05
Dual Price(Out3)	8.33E-02	4.99E-05	4.51E-06	3.37E-03	5.26E-03	3.33E-02	1.52E-02	2.60E-03	1.11E-01	4.76E-02	1.52E-02	1.28E-02	1.48E-03	1.11E-01	1.11E-01	3.33E-01
RTS Constant	-2.155839	-0.43124	-0.07187	-0.29122	-0.1889	-2.0554	-1.28663	-0.46947	-3.06483	-0.97879	-0.67306	-3.08078	-0.10219	0.888846	-7.25506	-10.8544

Appendix.5: 2016- DEA-SBM model outputs

DMU	DZA	CHE	USA	IRN	NOR	MAR	EGY	ARE	IRQ	JOR	SYC	MUS	ZAF	NAM	SEN	CMR
Score	0.075868	1	1	0.161962	1	1	0.194631	1	0.073048	0.827565	1	1	0.87397	1	1	0.068669
Rank	14	1	1	13	1	1	12	1	15	11	1	1	10	1	1	16
Benchmark(lambda)	MAR(0.39	CHE(1)	USA(1)	CHE(0.222	NOR(1)	MAR(1)	NOR(0.15	ARE(1)	NOR(0.05	MAR(0.43	SYC(1)	MUS(1)	CHE(0.009	NAM(1)	SEN(1)	CHE(0.013
Slack Movement(In1)	-4126.4	0	0	-23652.7	0	0	-15444.1	0	-1314.34	-258.161	0	0	-13847.9	0	0	0
Slack Movement(In2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slack Movement(Out1)	1.070248	0	0	5379.549	0	0	477.1581	0	0	32.18443	0	0	0	0	0	197.9623
Slack Movement(Out2)	3239.657	0	0	22074.01	0	0	0	0	2346.672	0	0	0	0	0	0	0
Slack Movement(Out3)	11.92562	0	0	2100.174	0	0	172.5358	0	102.3543	0.147901	0	0	89.55035	0	0	119.1803
Projection(In1)	2690.603	48493	716269	29378.28	23916	6300	4214.893	5814	1918.663	2842.839	49	322	10137.14	358	805	1417
Projection(In2)	117	47361	530398	15086	5863	264	1045	778	489	150	113	111	1949	22	394	817
Projection(Out1)	65.07025	25960	277145	8534.549	3555	141	603.1581	145	265	84.18443	71	36	1077	16	119	403.9623
Projection(Out2)	3345.657	151660	750024	45726.01	15454	8094	4325	15561	2940.672	3737	609	2352	12492	277	4646	5411
Projection(Out3)	13.92562	6862	77140	2263.174	949	20	192.5358	137	105.3543	24.1479	48	17	296.5503	10	1	122.1803
Dual Price(In1)	0	-2.05E-05	-1.31E-06	0	0	0	0	0	0	0	-5.19E-03	-1.27E-03	0	0	-4.87E-02	-7.89E-03
Dual Price(In2)	-1.11E-01	0	0	-3.95E-04	-3.90E-04	-5.80E-03	-4.43E-03	-1.93E-03	-2.94E-02	-1.04E-02	0	-8.91E-03	-2.03E-03	-5.32E-02	-6.49E-02	-1.91E-02
Dual Price(Out1)	5.21E-03	1.28E-05	1.20E-06	1.06E-04	4.99E-04	4.68E-03	2.65E-03	2.30E-03	1.74E-02	6.41E-03	4.69E-03	9.26E-03	2.65E-03	2.08E-02	2.80E-03	1.62E-03
Dual Price(Out2)	3.14E-03	2.20E-06	4.44E-07	1.41E-05	2.16E-05	1.36E-04	8.49E-05	1.04E-04	5.61E-04	2.02E-04	5.47E-04	7.23E-04	1.13E-04	1.20E-03	2.05E-02	3.22E-03
Dual Price(Out3)	1.67E-01	4.86E-05	4.32E-06	2.04E-03	3.51E-04	1.67E-02	1.67E-02	2.43E-03	1.11E-01	1.39E-02	6.94E-03	1.96E-02	1.61E-03	8.68E-02	3.33E-01	1.11E-01
RTS Constant	-0.17566	-0.00358	-0.06497	-0.22003	-0.15251	-0.55975	-0.53852	-0.77916	-3.58814	-0.06837	-0.74557	-0.96979	-0.78675	-0.36363	-31.064	-4.86277

Appendix.6: 2017- DEA-SBM model outputs

DMU	DZA	CHE	USA	IRN	NOR	MAR	EGY	ARE	IRQ	JOR	SYC	MUS	ZAF	NAM	SEN	CMR
Score	0.039099	1	1	0.135674	1	1	0.150789	1	0.034037	0.598181	1	1	1	1	1	0.051531
Rank	15	1	1	13	1	1	12	1	16	11	1	1	1	1	1	14
Benchmark(lambda)	ARE(0.15)	CHE(1)	USA(1)	CHE(0.336	NOR(1)	MAR(1)	CHE(0.009	ARE(1)	CHE(0.002	ARE(0.048	SYC(1)	MUS(1)	ZAF(1)	NAM(1)	SEN(1)	NOR(0.04
Slack Movement(In1)	-6457.55	0	0	-35523.3	0	0	-12595	0	-3052.37	0	0	0	0	0	0	-5.97811
Slack Movement(In2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slack Movement(Out1)	11.75	0	0	5260.471	0	0	365.0636	0	0	12.71555	0	0	0	0	0	0
Slack Movement(Out2)	138.1	0	0	39941.95	0	0	15051.53	0	11080.65	0	0	0	0	0	0	228.1164
Slack Movement(Out3)	73.55	0	0	2330.975	0	0	247.9352	0	155.3553	25.98957	0	0	0	0	0	55.16113
Projection(In1)	1063.45	50813	735452	21579.73	25029	6855	7156.048	6744	4513	572.6285	61	385	25827	438	842	1664.022
Projection(In2)	163	44574	534314	15486	5814	267	1134	724	632	87	64	49	2135	14	395	531
Projection(Out1)	96.75	26160	285846	8986.471	3583	92	513.0636	271	330	57.71555	66	35	1430	14	544	530
Projection(Out2)	3663.1	168412	793384	68481.95	21261	10983	19176.53	17768	12565.65	3424	1174	3651	15691	396	4641	4301.116
Projection(Out3)	74.55	6939	80401	2473.975	890	12	270.9352	208	157.3553	40.98957	51	21	212	10	2	56.16113
Dual Price(In1)	0	0	-1.27E-06	0	0	0	0	0	-3.12E-04	0	-4.42E-03	-1.48E-02	0	0	-1.39E-01	0
Dual Price(In2)	-8.29E-02	-2.17E-05	0	-4.51E-04	-2.06E-02	-2.40E-02	-3.83E-03	-1.07E-03	-6.00E-02	-1.45E-02	0	0	-2.66E-03	-1.03E-01	0	-1.20E-01
Dual Price(Out1)	3.92E-03	1.27E-05	1.17E-06	8.95E-05	2.00E-02	3.62E-03	2.25E-03	1.23E-03	5.75E-02	7.41E-03	5.05E-03	9.52E-03	3.43E-03	2.38E-02	8.93E-02	1.17E-01
Dual Price(Out2)	9.46E-05	1.98E-06	4.20E-07	1.17E-05	1.57E-05	7.20E-04	8.08E-05	2.71E-05	2.24E-04	2.74E-04	2.84E-04	2.27E-03	1.13E-04	8.42E-04	2.13E-02	8.18E-05
Dual Price(Out3)	3.33E-01	4.80E-05	4.15E-06	2.33E-03	5.71E-02	2.78E-02	1.45E-02	1.60E-03	1.67E-01	2.22E-02	6.54E-03	1.78E-02	1.57E-03	3.33E-02	1.67E-01	3.33E-01
RTS Constant	-12.065	-0.0329	-0.06546	-0.39027	-2.93111	-2.1627	-2.28629	-0.37742	-8.70054	-1.01736	-0.73042	-3.29571	-1.34693	0.442626	-30.9099	-17.1074

Appendix.7: 2018- DEA-SBM model outputs

DMU	DZA	CHE	USA	IRN	NOR	MAR	EGY	ARE	IRQ	JOR	SYC	MUS	ZAF	NAM	SEN	CMR
Score	0.209405	1	1	0.141741	0.786035	0.407275	0.188924	1	0.117697	1	1	1	1	1	1	0.319104
Rank	13	1	1	15	10	11	14	1	16	1	1	1	1	1	1	12
Benchmark(lambda)	ARE(0.099	CHE(1)	USA(1)	USA(0.021	CHE(0.107	ARE(0.331	USA(0.000	ARE(1)	ARE(0.516	JOR(1)	SYC(1)	MUS(1)	ZAF(1)	NAM(1)	SEN(1)	USA(0.000
Slack Movement(In1)	-7023.84	0	0	-36371.1	0	-1459.93	-14272.8	0	-52.5015	0	0	0	0	0	0	0
Slack Movement(In2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slack Movement(Out1)	54.63662	0	0	3504.781	147.0184	0	307.5825	0	0	0	0	0	0	0	0	0
Slack Movement(Out2)	0	0	0	5973.728	15591.11	0.548553	11991.79	0	11541.73	0	0	0	0	0	0	364.46
Slack Movement(Out3)	39.06091	0	0	1799.474	64.69644	52.39157	198.1677	0	107.3016	0	0	0	0	0	0	50.66239
Projection(In1)	1475.161	51241	744306	23421.92	25794	6247.072	8076.245	7493	9321.499	4510	55	366	27392	497	882	1742
Projection(In2)	162	46866	525013	12078	6430	339	1159	744	663	51	107	195	1827	24	341	707
Projection(Out1)	89.63662	26109	289087	6561.781	3853.018	207	547.5825	319	400	85	60	37	1443	4	426	629
Projection(Out2)	2865	167129	812808	35633.73	37843.11	9038.549	19089.79	18461	14047.73	3374	682	4546	23493	316	4864	5683.46
Projection(Out3)	43.06091	6860	81217	1906.474	912.6964	64.39157	218.1677	154	113.3016	10	35	27	212	16	2	58.66239
Dual Price(In1)	0	-1.19E-05	-1.26E-06	0	-1.62E-06	0	0	-1.90E-05	0	-7.85E-05	-5.69E-03	-8.79E-03	0	-9.10E-03	-4.55E-03	-1.05E-04
Dual Price(In2)	-2.44E-02	0	0	-5.59E-04	-1.54E-04	-8.95E-03	-3.41E-03	-9.50E-04	-1.97E-02	-1.20E-02	0	0	-4.19E-04	-1.14E-01	-4.37E-02	-1.29E-02
Dual Price(Out1)	9.52E-03	1.28E-05	1.15E-06	1.09E-04	8.99E-05	7.02E-03	1.39E-03	1.04E-03	1.55E-02	9.75E-03	5.56E-03	9.01E-03	2.59E-04	8.33E-02	3.16E-02	1.19E-02
Dual Price(Out2)	1.78E-04	1.99E-06	4.10E-07	1.12E-05	1.50E-05	3.69E-05	4.70E-05	2.14E-05	1.33E-04	9.88E-05	4.89E-04	7.87E-04	1.42E-05	1.05E-03	1.89E-03	6.27E-05
Dual Price(Out3)	8.33E-02	4.86E-05	4.10E-06	3.12E-03	3.93E-04	2.78E-02	1.67E-02	2.16E-03	5.56E-02	3.33E-02	9.52E-03	1.23E-02	1.57E-03	2.08E-02	1.67E-01	4.17E-02
RTS Constant	-0.99825	-0.38943	-0.06224	-0.30628	-0.2389	-0.54276	-1.33728	-0.21301	-1.31786	-0.52726	-0.68724	-1.02569	-0.27478	6.260469	-4.09621	-0.9516

Appendix.8: 2019- DEA-SBM model outputs

DMU	DZA	CHE	USA	IRN	NOR	MAR	EGY	ARE	IRQ	JOR	SYC	MUS	ZAF	NAM	SEN	CMR
Score	0.285289	1	1	0.12953	0.74385	1	0.084386	1	0.034069	1	1	1	1	1	1	1
Rank	13	1	1	14	12	1	15	1	16	1	1	1	1	1	1	1
Benchmark(lambda)	SYC(0.943	CHE(1)	USA(1)	CHE(0.239	CHE(0.108	MAR(1)	SYC(0.218	ARE(1)	ARE(0.732	JOR(1)	SYC(1)	MUS(1)	ZAF(1)	NAM(1)	SEN(1)	CMR(1)
Slack Movement(In1)	-6713.52	0	0	-48237.3	0	0	-2565.05	0	-4511.46	0	0	0	0	0	0	0
Slack Movement(In2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slack Movement(Out1)	106.2391	0	0	4258	485.3477	0	1177.557	0	0	0	0	0	0	0	0	0
Slack Movement(Out2)	316.8988	0	0	28471.4	17524.23	0	11629.66	0	15811.51	0	0	0	0	0	0	0
Slack Movement(Out3)	25.6036	0	0	1740.404	116.2923	0	136.1081	0	134.4609	0	0	0	0	0	0	0
Projection(In1)	1763.475	51501	733093	19477.67	26464	8889	23556.95	9409	10075.54	5493	55	573	30120	471	950	1935
Projection(In2)	119	46399	539792	11703	6165	293	1165	794	745	48	37	70	1480	21	221	528
Projection(Out1)	140.2391	27349	309625	6838	4022.348	164	1227.557	389	450	37	55	34	1555	8	307	582
Projection(Out2)	2878.899	188541	893641	59071.4	40733.23	10907	19715.66	18364	16698.51	4098	1559	4263	24786	482	4915	5628
Projection(Out3)	31.6036	7203	81215	1839.404	942.2923	13	154.1081	153	136.4609	10	22	29	191	8	3	2
Dual Price(In1)	0	-1.19E-05	-1.28E-06	0	-4.96E-06	0	0	0	0	0	-6.11E-03	-2.30E-02	-1.61E-05	0	-8.26E-04	-1.78E-03
Dual Price(In2)	-1.88E-02	0	0	-6.38E-04	-1.67E-04	-1.68E-02	-9.76E-03	-2.21E-03	-4.52E-02	-2.94E-02	0	0	-6.08E-04	-2.05E-01	-3.66E-02	-8.17E-02
Dual Price(Out1)	9.80E-03	1.22E-05	1.08E-06	1.29E-04	9.42E-05	2.03E-03	6.67E-03	8.57E-04	1.91E-02	1.81E-02	6.06E-03	9.80E-03	5.13E-04	4.17E-02	3.06E-02	9.80E-02
Dual Price(Out2)	1.30E-04	1.77E-06	3.73E-07	1.09E-05	1.44E-05	5.86E-04	4.12E-05	1.82E-05	3.76E-04	4.14E-04	2.14E-04	4.45E-03	1.34E-05	6.92E-04	5.55E-04	5.92E-05
Dual Price(Out3)	5.56E-02	4.63E-05	4.10E-06	3.37E-03	4.04E-04	2.56E-02	1.85E-02	1.06E-02	1.67E-01	3.33E-02	1.52E-02	1.15E-02	1.75E-03	4.17E-02	1.11E-01	1.67E-01
RTS Constant	-1.26897	-0.38705	-0.06355	-0.25926	-0.18276	-2.13391	-0.47713	-0.53159	-3.91868	-1.28733	-0.66409	-6.45908	-0.07905	3.313505	-3.59491	-11.1366

Appendix.9: 2020- DEA-SBM model outputs

DMU	DZA	CHE	USA	IRN	NOR	MAR	EGY	ARE	IRQ	JOR	SYC	MUS	ZAF	NAM	SEN	CMR
Score	0.121327	1	1	0.126972	1	1	0.169777	1	0.062863	0.67851	1	1	1	1	1	1
Rank	15	1	1	14	1	1	13	1	16	12	1	1	1	1	1	1
Benchmark(lambda)	ARE(0.074	CHE(1)	USA(1)	CHE(0.242	NOR(1)	MAR(1)	CHE(0.007	ARE(1)	ARE(0.247	SYC(0.698	SYC(1)	MUS(1)	ZAF(1)	NAM(1)	SEN(1)	CMR(1)
Slack Movement(In1)	-7310.06	0	0	-52802	0	0	-21092.1	0	-7832.26	-6528.44	0	0	0	0	0	0
Slack Movement(In2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slack Movement(Out1)	46.04402	0	0	3605.952	0	0	384.4087	0	0	16.04762	0	0	0	0	0	0
Slack Movement(Out2)	922.0303	0	0	24583.18	0	0	15213.07	0	11032.38	41.44444	0	0	0	0	0	0
Slack Movement(Out3)	61.7304	0	0	1866.125	0	0	215.8373	0	120.5969	13.36508	0	0	0	0	0	0
Projection(In1)	1301.945	54609	742757	21685.96	28207	10322	11465.91	11147	11685.74	223.5556	99	512	32442	629	1113	2356
Projection(In2)	170	44998	514646	11550	5912	341	1167	843	645	72	53	116	1421	21	239	715
Projection(Out1)	95.04402	28152	306555	7049.952	3912	143	499.4087	295	385	58.04762	49	79	1023	9	358	646
Projection(Out2)	5311.03	175825	835794	58233.18	21289	9940	21730.07	20591	11789.38	3713.444	3553	4085	17619	329	4471	6801
Projection(Out3)	64.7304	7523	85102	1965.125	827	20	239.8373	186	124.5969	26.36508	14	55	194	5	1	3
Dual Price(In1)	0	-1.16E-05	-1.26E-06	0	0	0	0	-2.33E-06	0	0	0	-2.31E-05	-3.15E-06	0	-2.56E-04	-1.30E-02
Dual Price(In2)	-2.38E-02	0	0	-6.55E-04	-2.67E-03	-1.08E-01	-4.32E-03	-1.28E-03	-3.31E-02	-2.12E-02	-2.33E-02	-4.79E-03	-8.89E-04	-1.67E-01	-1.41E-01	#####
Dual Price(Out1)	6.80E-03	1.18E-05	1.09E-06	9.68E-05	4.10E-03	5.36E-02	2.90E-03	1.13E-03	2.71E-02	7.94E-03	1.48E-02	4.22E-03	8.57E-04	3.70E-02	1.24E-01	1.56E+00
Dual Price(Out2)	7.59E-05	1.90E-06	3.99E-07	9.91E-06	1.57E-05	4.06E-03	5.11E-05	1.91E-05	4.40E-04	9.08E-05	9.38E-05	8.16E-05	1.89E-05	1.01E-03	2.10E-03	5.76E-02
Dual Price(Out3)	1.11E-01	4.43E-05	3.92E-06	3.37E-03	4.03E-04	1.67E-02	1.39E-02	3.03E-03	8.33E-02	2.56E-02	2.38E-02	1.12E-02	1.72E-03	6.67E-02	3.33E-01	1.11E-01
RTS Constant	-4.20181	-0.36634	-0.06118	-0.30632	-0.8992	-11.5716	-0.85293	-0.18412	-4.68943	0.054948	-0.15409	-0.71613	-0.17694	2.509589	-20.2529	-517.26

Appendix.10: 2021- DEA-SBM model outputs

DMU	DZA	CHE	USA	IRN	NOR	MAR	EGY	ARE	IRQ	JOR	SYC	MUS	ZAF	NAM	SEN	CMR
Score	0.117314	1	1	0.157026	1	1	0.189919	1	0.054321	1	1	1	1	1	0.051973	0.0314
Rank	13	1	1	12	1	1	11	1	14	1	1	1	1	1	15	16
Benchmark(lambda)	ARE(0.405	CHE(1)	USA(1)	CHE(0.202	NOR(1)	MAR(1)	ARE(0.573	ARE(1)	ARE(0.445	JOR(1)	SYC(1)	MUS(1)	ZAF(1)	NAM(1)	CHE(0.008	CHE(0.017
Slack Movement(In1)	-4050.53	0	0	-55147.3	0	0	-16275.5	0	-1301.79	0	0	0	0	0	0	0
Slack Movement(In2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slack Movement(Out1)	53.98589	0	0	2943.308	0	0	647.0656	0	0	0	0	0	0	0	173.5985	43.13965
Slack Movement(Out2)	657.0987	0	0	12785.24	0	0	7288.64	0	11615.89	0	0	0	0	0	48.62405	2762.805
Slack Movement(Out3)	65.86364	0	0	1574.441	0	0	154.3255	0	118.3885	0	0	0	0	0	106.5106	184.0245
Projection(In1)	5925.466	59491	768099	22827.67	30332	11625	22510.49	13512	16627.21	8014	105	566	34610	741	1100	2700
Projection(In2)	280	48530	530381	10358	5773	402	984	659	639	50	50	173	1421	21	606	1076
Projection(Out1)	157.9859	26808	298682	5731.308	4030	203	776.0656	376	483	34	25	53	1314	9	292.5985	557.1396
Projection(Out2)	7312.099	182491	898517	50956.24	27305	13045	16811.64	17535	12525.89	3238	2206	4706	15839	326	6303.624	8949.805
Projection(Out3)	68.86364	7689	80872	1681.441	862	11	176.3255	155	121.3885	15	7	40	205	10	108.5106	186.0245
Dual Price(In1)	0	-1.11E-05	-1.23E-06	0	-2.70E-07	-2.64E-04	0	-2.99E-05	0	-3.97E-05	-2.33E-04	-7.65E-03	0	-2.09E-04	-5.74E-04	-5.65E-04
Dual Price(In2)	-2.84E-02	0	0	-5.86E-04	-1.94E-04	-4.71E-02	-4.10E-03	-8.74E-04	-5.74E-02	-1.27E-02	-1.83E-02	0	-5.49E-04	-8.79E-02	-2.74E-02	-2.62E-02
Dual Price(Out1)	3.21E-03	1.24E-05	1.12E-06	1.20E-04	1.65E-04	1.64E-03	2.58E-03	8.87E-04	4.13E-02	9.80E-03	1.33E-02	6.29E-03	3.97E-04	3.70E-02	2.80E-03	6.49E-04
Dual Price(Out2)	5.01E-05	1.83E-06	3.71E-07	8.73E-06	1.22E-05	1.77E-03	3.50E-05	2.16E-05	3.66E-04	1.03E-04	1.66E-04	1.23E-03	2.10E-05	1.02E-03	5.33E-05	5.39E-05
Dual Price(Out3)	1.11E-01	4.34E-05	4.12E-06	3.12E-03	3.87E-04	3.03E-02	1.52E-02	2.15E-03	1.11E-01	2.22E-02	4.76E-02	8.33E-03	1.63E-03	3.33E-02	1.67E-01	1.67E-01
RTS Constant	-0.55889	-0.34003	-0.05621	-0.29452	-0.2047	-1.77899	-1.23386	-0.0668	-1.39037	-0.0485	-0.09321	-2.12561	-0.40874	1.000172	-1.99914	-2.09664

Appendix.11: 2022- DEA-SBM model outputs

DMU	DZA	CHE	USA	IRN	NOR	MAR	EGY	ARE	IRQ	JOR	SYC	MUS	ZAF	NAM	SEN	CMR
Score	0.12244	1	1	0.1589	1	1	0.185425	1	0.060546	1	1	1	1	1	0.092292	1
Rank	14	1	1	13	1	1	12	1	16	1	1	1	1	1	15	1
Benchmark(lambda)	ARE(0.572	CHE(1)	USA(1)	CHE(0.148	NOR(1)	MAR(1)	CHE(0.000	ARE(1)	ZAF(0.524	JOR(1)	SYC(1)	MUS(1)	ZAF(1)	NAM(1)	USA(0.000	CMR(1)
Slack Movement(In1)	-1292.62	0	0	-55569	0	0	-27242.7	0	-1148.91	0	0	0	0	0	0	0
Slack Movement(In2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slack Movement(Out1)	60.84425	0	0	1823.521	0	0	180.6091	0	0	0	0	0	0	0	0	0
Slack Movement(Out2)	8412.996	0	0	18570.53	0	0	12780.5	0	11263.2	0	0	0	0	0	199.3815	0
Slack Movement(Out3)	136.7824	0	0	1262.838	0	0	228.2117	0	113.7343	0	0	0	0	0	58.83292	0
Projection(In1)	9788.383	58784	736868	22831.01	30521	12800	16566.26	16548	19252.09	9580	104	600	35639	743	1222	2900
Projection(In2)	483	51703	536799	8397	5912	368	851	829	820	65	47	403	1400	20	583	805
Projection(Out1)	185.8443	24851	278125	3967.521	3784	231	328.6091	318	689	31	17	41	1175	9	359	714
Projection(Out2)	14118	168959	896304	45927.53	24083	13454	24489.5	24427	12567.2	3445	1536	3491	23213	323	2437.382	2799
Projection(Out3)	143.7824	7673	73390	1350.838	770	17	249.2117	246	116.7343	9	11	45	217	7	60.83292	3
Dual Price(In1)	0	-1.70E-05	-1.29E-06	0	-2.74E-05	-3.71E-05	0	0	0	0	-3.74E-05	-1.36E-02	-1.88E-05	0	-2.16E-03	-1.46E-03
Dual Price(In2)	-1.68E-02	0	0	-6.63E-04	-6.74E-04	-1.87E-02	-3.48E-03	-1.45E-03	-3.53E-01	-2.12E-02	-2.59E-02	0	-8.08E-04	-9.18E-02	-5.82E-02	-3.89E-02
Dual Price(Out1)	2.67E-03	1.34E-05	1.20E-06	1.55E-04	8.38E-04	1.44E-02	2.25E-03	1.05E-03	3.93E-01	1.08E-02	1.96E-02	8.13E-03	1.03E-03	3.70E-02	7.36E-02	4.92E-02
Dual Price(Out2)	5.84E-05	1.97E-06	3.72E-07	1.22E-05	1.38E-05	2.76E-04	2.85E-05	2.44E-05	2.56E-04	2.06E-04	3.20E-04	3.22E-03	1.44E-05	1.03E-03	1.49E-04	1.19E-04
Dual Price(Out3)	4.76E-02	4.34E-05	4.54E-06	3.79E-03	1.74E-03	1.96E-02	1.59E-02	1.36E-03	1.11E-01	3.70E-02	3.24E-02	7.41E-03	1.54E-03	4.76E-02	1.67E-01	1.11E-01
RTS Constant	-0.03966	-0.00197	-0.05183	-0.72962	-0.02008	-0.00017	-2.42792	-0.05938	2.66907	0.001101	0.03834	-3.75423	-0.07515	0.836414	-0.35281	-0.26292

Appendix.12: 2023- DEA-SBM model outputs

DMU	DZA	CHE	USA	IRN	NOR	MAR	EGY	ARE	IRQ	JOR	SYC	MUS	ZAF	NAM	SEN	CMR
Score	0.045389	1	1	0.1899	1	1	0.24582	1	0.058698	1	1	1	1	1	1	1
Rank	16	1	1	14	1	1	13	1	15	1	1	1	1	1	1	1
Benchmark(lambda)	NOR(0.24	CHE(1)	USA(1)	USA(0.005	NOR(1)	MAR(1)	MAR(0.42	ARE(1)	SYC(0.487	JOR(1)	SYC(1)	MUS(1)	ZAF(1)	NAM(1)	SEN(1)	CMR(1)
Slack Movement(In1)	-3243.47	0	0	-38711.7	0	0	-21483.8	0	-8316.72	0	0	0	0	0	0	0
Slack Movement(In2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slack Movement(Out1)	892.9598	0	0	3994.697	0	0	506.0123	0	238.3831	0	0	0	0	0	0	0
Slack Movement(Out2)	979.7222	0	0	1406.21	0	0	0	0	10532.68	0	0	0	0	0	0	0
Slack Movement(Out3)	225.6399	0	0	1185.992	0	0	76.51289	0	116.2637	0	0	0	0	0	0	0
Projection(In1)	7885.528	58012	734258	35438.32	31328	14836	21238.17	20007	18278.28	11877	77	515	35596	799	1222	3019
Projection(In2)	1412	53344	531963	8654	5576	488	812	1810	746	58	25	292	1432	17	358	736
Projection(Out1)	1029.96	27690	302571	5774.697	4029	300	597.0123	475	582.3831	26	31	95	1107	4	341	920
Projection(Out2)	6857.722	167267	827097	25606.21	20892	13440	14779	31318	11748.68	3445	2183	3699	20850	102	4555	5690
Projection(Out3)	229.6399	7178	79165	1298.992	841	14	97.51289	171	119.2637	13	26	32	208	9	2	3
Dual Price(In1)	0	0	0	0	-1.16E-05	-4.02E-05	0	0	0	0	0	-1.37E-02	-7.32E-06	0	-1.80E-02	-1.19E-03
Dual Price(In2)	-1.42E-02	-1.79E-05	-1.82E-06	-5.66E-04	-2.43E-04	-7.92E-03	-8.62E-03	-8.46E-04	-1.88E-02	-3.96E-02	-1.38E-02	0	-4.65E-04	-1.21E+00	-6.94E-02	-3.43E-02
Dual Price(Out1)	2.43E-03	1.20E-05	1.10E-06	1.87E-04	1.90E-04	1.11E-03	3.66E-03	7.02E-04	9.69E-04	1.28E-02	1.08E-02	3.51E-03	3.01E-04	8.33E-02	3.79E-02	3.40E-02
Dual Price(Out2)	5.67E-05	1.99E-06	4.03E-07	1.38E-05	1.60E-05	3.77E-04	2.84E-04	7.98E-05	2.74E-04	1.35E-03	1.53E-04	3.77E-03	1.60E-05	3.27E-03	1.52E-02	5.86E-05
Dual Price(Out3)	8.33E-02	4.64E-05	4.21E-06	2.95E-03	7.99E-04	2.38E-02	1.59E-02	1.95E-03	1.11E-01	2.56E-02	1.28E-02	1.04E-02	1.60E-03	3.70E-02	1.67E-01	1.11E-01
RTS Constant	-2.01142	-0.04362	-0.03097	-0.36579	-0.05455	-1.27609	-0.93078	-1.63468	-3.04858	-3.02359	-0.65542	-7.55272	-0.07372	19.5706	-35.5179	-3.122

Appendix.13: 2024- DEA-SBM model outputs

DMU	DZA	CHE	USA	IRN	NOR	MAR	EGY	ARE	IRQ	JOR	SYC	MUS	ZAF	NAM	SEN	CMR
Score	0.050106	1	1	0.17862	0.918693	0.417008	0.219539	1	0.068641	1	1	1	1	1	1	0.039806
Rank	15	1	1	13	10	11	12	1	14	1	1	1	1	1	1	16
Benchmark(lambda)	USA(0.000)	CHE(1)	USA(1)	USA(0.014)	USA(0.009)	ARE(0.279)	SYC(0.372)	ARE(1)	SYC(0.551)	JOR(1)	SYC(1)	MUS(1)	ZAF(1)	NAM(1)	SEN(1)	CHE(0.002)
Slack Movement(In1)	0	0	0	-42399.7	0	-10734.4	-20503.6	0	-11893.6	0	0	0	0	0	0	0
Slack Movement(In2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slack Movement(Out1)	456.4356	0	0	3041.183	0	14.58699	521.1236	0	294.7029	0	0	0	0	0	0	174.9488
Slack Movement(Out2)	23417.12	0	0	33232.58	4646.014	0	4784.847	0	7670.773	0	0	0	0	0	0	0
Slack Movement(Out3)	165.1503	0	0	1172.454	27.24055	57.72137	119.2086	0	104.6687	0	0	0	0	0	0	216.1878
Projection(In1)	13081	58724	743884	33101.28	31793	7538.648	23331.41	22930	16712.4	14427	100	585	37121	822	1320	3375
Projection(In2)	1122	52579	511452	8446	5610	426	778	1248	574	92	62	442	1203	25	265	1344
Projection(Out1)	562.4356	27264	287929	4617.183	3365	219.587	640.1236	563	471.7029	24	49	77	991	23	238	753.9488
Projection(Out2)	25493.12	162770	837199	55535.58	24576.01	14105	12638.85	44350	9518.773	4201	1688	6274	19139	310	5227	6790
Projection(Out3)	169.1503	7178	79165	1285.454	868.2406	71.72137	140.2086	171	107.6687	13	26	32	208	9	2	219.1878
Dual Price(In1)	-1.35E-04	0	-1.27E-06	0	-1.58E-05	0	0	0	0	0	0	-4.47E-03	-1.94E-05	0	-7.62E-03	-1.79E-03
Dual Price(In2)	-1.47E-02	-1.74E-05	0	-5.99E-04	-8.45E-04	-6.27E-03	-5.49E-03	-6.57E-04	-2.20E-02	-3.31E-02	-1.16E-02	0	-1.14E-03	-6.72E-02	-4.87E-02	-1.66E-02
Dual Price(Out1)	3.14E-03	1.22E-05	1.16E-06	2.12E-04	1.38E-03	1.63E-03	2.80E-03	5.92E-04	1.88E-03	1.39E-02	6.80E-03	4.33E-03	1.33E-03	1.45E-02	4.08E-02	5.76E-04
Dual Price(Out2)	1.61E-04	2.05E-06	3.98E-07	1.49E-05	1.67E-05	7.37E-05	4.24E-05	1.41E-05	1.80E-04	6.66E-04	1.97E-04	4.33E-04	1.74E-05	1.08E-03	4.38E-03	1.03E-03
Dual Price(Out3)	8.33E-02	4.64E-05	4.21E-06	2.95E-03	3.96E-04	2.38E-02	1.59E-02	1.95E-03	1.11E-01	2.56E-02	1.28E-02	1.04E-02	2.48E-03	3.70E-02	1.67E-01	1.11E-01
RTS Constant	-1.66489	-0.0839	-0.05174	-0.5387	-0.17305	-0.43457	-0.28099	-0.4712	-1.91936	-0.41846	-0.27962	-0.76623	-0.08699	0.68119	-9.93575	-3.45556

Appendix.14: Comparative Efficiency Scores: Algeria vs. Global Frontier and Peer Group (2015–2024)

Year	DZA	Peers	Frontier
2015	0.280019	0.641997	1
2016	0.075868	0.577761	1
2017	0.039099	0.552246	1
2018	0.209405	0.551197	1
2019	0.285289	0.665759	1
2020	0.121327	0.670902	1
2021	0.117314	0.498293	1
2022	0.12244	0.610796	1
2023	0.045389	0.721602	1
2024	0.050106	0.538034	1

Source: Compiled by the researcher based on DEA-SBM model outputs

Note:

- The Inefficient Peer Group represent countries that remained below the efficiency frontier throughout the ten-year period, includes: Iran, Norway, Morocco, Egypt, Iraq, Jordan, South Africa, Senegal, and Cameroon;
- The Efficient Frontier is composed of countries that maintained absolute efficiency (Score = 1.0) during the entire period, namely: Switzerland, the United States, the United Arab Emirates, Seychelles, Mauritius, and Namibia.

Appendix.15: Comparative Efficiency Scores of National Innovation Systems (2015 vs. 2024)

DMU	2015	2024
CHE	1	1
USA	1	1
ARE	1	1
SYC	1	1
MUS	1	1
ZAF	1	1
NAM	1	1
SEN	1	1
JOR	0.276534	1
NOR	1	0.918693
MAR	1	0.417008
EGY	0.234899	0.219539
IRN	0.145158	0.17862
IRQ	0.121379	0.068641
DZA	0.280019	0.050106
CMR	1	0.039806

Source: Compiled by the researcher based on DEA-SBM model outputs

Appendix.16: Annual Slack Values for Innovation Inputs and Outputs in Algeria (2015–2024)

Year	Absolute Slack Value	In1 Slack	In2 Slack	Out1 Slack	Out2 Slack	Out3 Slack
2015	5532.638	-5532.64	0	0	628.41396	29.73211
2016	4126.397	-4126.4	0	1.070248	3239.657	11.92562
2017	6457.55	-6457.55	0	11.75	138.1	73.55
2018	7023.839	-7023.84	0	54.636619	0	39.06091
2019	6713.525	-6713.52	0	106.23909	316.89882	25.6036
2020	7310.055	-7310.06	0	46.044017	922.03026	61.7304
2021	4050.534	-4050.53	0	53.985893	657.09875	65.86364
2022	1292.617	-1292.62	0	60.844252	8412.9963	136.7824
2023	3243.472	-3243.47	0	892.95983	979.72221	225.6399
2024	0	0	0	456.4356	23417.115	165.1503

Source: Compiled by the researcher based on DEA-SBM model outputs

Note: To facilitate visual comparison of structural imbalances, absolute values were utilized for input1 slack (representing excess).

Appendix.17: Returns to Scale Analysis: Individual Country Classifications and Aggregate Distribution (2024)

DMU	RTS	RTS	(%)	Count
DZA	-1.66489	DRS (Decreasing)	93.75%	15
CHE	-0.0839	IRS (Increasing)	6.25%	1
USA	-0.05174	CRS (Constant)	0%	0
IRN	-0.5387	Total	100%	16
NOR	-0.17305			
MAR	-0.43457			
EGY	-0.28099			
ARE	-0.4712			
IRQ	-1.91936			
JOR	-0.41846			
SYC	-0.27962			
MUS	-0.76623			
ZAF	-0.08699			
NAM	0.68119			
SEN	-9.93575			
CMR	-3.45556			

Source: Compiled by the researcher based on DEA-SBM model outputs

Appendix.18: Comparative Matrix of Innovation Inputs and Outputs: Algeria vs. UAE (Benchmark) – Raw and Normalized Data (2024)

DMU	In1	In2	Out1	Out2	Out3
DZA	13081	1122	106	2076	4
ARE	22930	1248	563	44350	171
DMU	In1	In2	Out1	Out2	Out3
DZA	0.570475	0.899038	0.188277	0.046809	0.023392
ARE	1	1	1	1	1

Source: Compiled by the researcher

Appendix.19: Comparative Efficiency Scores and Innovation Recovery Paths (2020–2024)

Year	DZA	ARE
2020	0.121327	1
2021	0.117314	1
2022	0.12244	1
2023	0.045389	1
2024	0.050106	1

Source: Compiled by the researcher based on DEA-SBM model outputs

Appendix.20: Efficiency Benchmarks and Reference Peers for Algeria (2024)

DMU	Benchmark(lambda)
DZA	USA(0.000816);ARE(0.542017);SYC(0.457167)