International Journal of Business Innovation and Research

ISSN online: 1751-0260 - ISSN print: 1751-0252
https://www.inderscience.com/ijbir

Evaluating the efficiency of regional innovation systems: a case study of innovative countries in transition

Mohammad A.A.M.J. AlSaffar, Odeh R. Al-Jayyousi, Fairouz M. Aldhmour, Abdel Latef M. Anouze, Abeer Fareed Alkhwaldi

DOI: 10.1504/IJBIR.2025.10071118

Article History:

Received:	06 October 2024
Last revised:	21 December 2024
Accepted:	01 February 2025
Published online:	21 May 2025

Evaluating the efficiency of regional innovation systems: a case study of innovative countries in transition

Mohammad A.A.M.J. AlSaffar,
Odeh R. Al-Jayyousi and
Fairouz M. Aldhmour*

Business Administration Department,
College of Education, Administrative and Technical Sciences,
Arabian Gulf University,
Manama, Bahrain
Email: mohamedals@Agu.edu.bh
Email: odehaj@agu.edu.bh
Email: Fairouzm@agu.edu.bh
*Corresponding author

Abdel Latef M. Anouze

Department of Management and Marketing,
College of Business and Economics,
Qatar University,
Doha, Qatar
Email: a.anouz@qu.edu.qa

Abeer Fareed Alkhwaldi

Department of Management Information Systems,
College of Business,
Mutah University,
Karak 61710, Jordan
Email: Abeerkh@mutah.edu.jo

Abstract: This research aims to assess the regional innovation system (RIS) efficiency for regions in transition, i.e., the Gulf Cooperation Council (GCC) countries, Central Asia, Eastern Europe, and Africa. Dynamic network data envelopment analysis (DNDEA) model is used to measure efficiency of set of decision-making units (DMUs). The study assessed the RIS performance of the four regions with reference to the top ten innovative countries based on the GII 2021 report. The variables used to measure efficiency include R&D expenditure, researcher, FDI, patent origin, PCT patent applications, journals articles, citable documents H-index, high-tech exports, and ICT. Secondary data were collected from the Global Innovation Index (GII) Report over period 2014–2021. The research identified the most innovative regions and showed that Central Asia is ranked as the first innovative region. Africa was ranked as moderate in terms of RIS efficiency. In stage three, it is observed that the GCC,

Eastern Europe and Africa were less efficient compared to Central Asia. This research recommends investing in inputs devoted to innovation such as R&D expenditure and human capital to develop the innovation capacity of countries.

Keywords: regional innovation system; RIS; innovation efficiency; regions in transition; innovation performance; dynamic network data envelopment analysis; DNDEA.

Reference to this paper should be made as follows: AlSaffar, M.A.A.M.J., Al-Jayyousi, O.R., Aldhmour, F.M., Anouze, A.L.M. and Alkhwaldi, A.F. (2025) 'Evaluating the efficiency of regional innovation systems: a case study of innovative countries in transition', *Int. J. Business Innovation and Research*, Vol. 37, No. 5, pp.1–30.

Biographical notes: Mohammad A.A.M.J. AlSaffar holds a PhD in Innovation Management from the Arabian Gulf University (AGU). Also, He has an MSc in Innovation and Technology Management, Kingdom of Bahrain from the AGU. He is the Manager in public sector in Kuwait.

Odeh R. Al-Jayyousi is a distinguished academic and consultant in innovation policy and sustainable development. He holds a PhD in Urban Planning and Policy from the University of Illinois in Chicago. He has authored several books and over 70 peer-reviewed articles on topics such as sustainable development, renewable energy, and innovation. He has received multiple awards, including the Scientists for Social Initiatives Award (2014) and the Global CSR Award (2020). Additionally, he is a member of the UN GEO6 Scientific Advisory Panel.

Fairouz M. Aldhmour is a faculty member in the Department of Business Administration at the Arabian Gulf University (AGU) in Bahrain. She holds a PhD in Management Information Systems from the Leeds metropolitan University, UK. Her research interests encompass leadership and entrepreneurial behaviour, artificial intelligence, digital innovation, and diversity management. He has contributed to various academic conferences and has a strong publication record in her field.

Abdel Latef M. Anouze is an Associate Professor at Qatar University's College of Business and Economics. He holds a PhD in Operations and Information Management from Aston University, UK. His research focuses on evaluating efficiency and productivity in gulf commercial banks, employing methodologies like data envelopment analysis (DEA) and cognitive analytics. He has authored numerous publications in prestigious journals and has presented them at various international conferences. His work contributes significantly to understanding and optimizing organisational efficiency and effectiveness, particularly in the banking and public sectors.

Abeer Fareed Alkhwaldi is an Assistant Professor in the Department of Management Information Systems at Mutah University, Jordan. She earned her PhD in Management Information Systems from the University of Bradford, UK, in 2019. Her research interests encompass human-computer interaction (HCI), technology acceptance, e-government, digital transformation, blockchain, and FinTech. He has contributed to various international conferences and has publications in reputable journals.

1 Research background

Regional innovation system (RIS) is vital for fostering added value in national economies. RIS is underpinned by human capital and the capability to commercialise. RIS is characterised by the rapid diffusion of knowledge, skills, and best practices within a geographic area larger than a city, but smaller than a nation (Luongo et al., 2023). A RIS as a governance and business model is designed to foster economic development. However, to achieve a sound RIS several conditions and enablers should be provided including infrastructure, human capital, policy, and finance since RIS reflects the synergy at the regional level to implement, exploit, and generate knowledge. In addition, Janošec et al. (2024) found that the government support for R&D has an effective impact on evolution of the innovation environment. This research aims to assess RIS efficiency for regions in transition including the Gulf Cooperation Council (GCC), Central Asia, Eastern Europe, and Africa during the period 2014–2021.

Innovation can be defined based on stage, means, purpose, type and attributes (Baregheh et al., 2009). Innovation is conceptualised as the creation of a novel idea or a new product and processes (Wong and Merrilees, 2008). RIS reflects the synergy at the regional level to implement, exploit, and generate knowledge. Moreover, RIS, according to Asheim and Coenen (2005) and Isaksen et al. (2022), is defined as interactive knowledge generation subsystems. RIS represents the symbiotic relations between companies, firms, public or governmental to promote competitiveness and efficient performance (Al-Khalifa et al., 2021; Isaksen et al., 2022). Innovation is critical to improve economic performance through renewing product cycles, introducing new markets, and enhancing the cost efficiency of public and private entities (Andreoni and Tregenna, 2018).

The GCC countries are keen to enhance innovation ecosystems as part of vision 2030 (Nurunnabi, 2017). The GCC needs to make a transition from an oil-based economy to a service-based economy to enhance innovation efficiency as reflected in the metrics in the Global Innovation Index (GII) Report. It is critical for GCC to assess the efficiency of countries in transition to foster productivity and competitiveness through assessing the key attributes and enablers of RIS models. This paper aims to assess the RIS efficiency for selected countries in transition using DEA and recommend appropriate policies to foster RIS efficiency. The following section reviews the literature related to RIS. Methodology and data analysis are presented in Sections 3 and 4. Conclusions and implications are outlined in Section 5.

2 Literature reviewer

RIS is a social system that includes the systematic interaction of the various public and private sector organisations to improve knowledge and local innovation (Samara et al., 2024). It depicts the interactive knowledge flow (Asheim and Coenen, 2005). RIS describes the symbiotic relations between sectors (Cooke, 2021, 2003) since it provides the ecosystem for the different actors to accelerate economic development in countries in transition. Enabling the environment is key to achieving a sound RIS in any region, these include infrastructure, human capital, policy, and finance. Economies in many regions in transitions are based on natural resources but are making plans to diversify the economy through investments in ICT infrastructure, business environment, human capital,

education, and R&D to promote local economies and foster innovation (Alshahrani et al., 2023). Bolsunovskaya et al. (2023) suggested RIS digital platform, that includes module of simulation experiments, various approaches to data analysis and visualisation. To increase the National Innovation System and sustainable economic development, they must assess current opportunities, address obstacles, and explore the policies that can improve its innovation and IT capabilities (Sube et al., 2025). Since knowledge economy and services are underpinned by clusters and RISs, it is imperative to benchmark and assess the innovative performance of RIS.

Data envelopment analysis (DEA) is a sound tool for estimating the effectiveness of RIS using nonparametric mathematical programming (Anouze et al., 2024) which was applied in many contexts as shown in Table 1.

Table 1 Models per region based on systematic literature review

Model	*Author*	*Region*	*Model*
National innovation system	Anouze et al. (2024)	GCC	ICT-driven innovation
Regional innovation systems	Firsova and Chernyshova (2018)	China	Regional systems of innovation: technological system of innovation. Sectoral systems of innovation
Regional innovation system and interaction with actors	Cooke (2004)	European Union	Regional Innovation system: technology transfer activity: universities (knowledge generation sub-system). Businesses (knowledge utilisation sub-system).
Innovation system	Chen and Guan (2011)	China	Innovation system: (institutions and framework conditions); innovative resources; innovative output (downstream commercialisation).

Yam et al. (2011) developed conceptualisation for RIS to measure innovation performance. Besides, other studies measured RIS using number of patents and absorptive capacity (Pradana et al., 2020); R&D expenditure (Anouze et al., 2024; Aldhmour and Doyle, 2023). Many ecosystems were developed in the GCC including Dubai Biotechnology and Research Park (DuBiotech), King Abdulaziz City for Science and Technology, and Bahrain FinTech Bay. Table 2 showed the key enablers for RIS based on literature related to regions in transition.

Evaluating RIS performance entails input-output analysis (Markard and Truffer, 2008) but it is a complex process since it depends on selected variables and maturity of information systems (Carlsson et al., 2002). The RIS is underpinned by institutions and organisations associated with a particular geographic area (Moulaert and Sekia, 2003), knowledge generation (Kuştepeli et al., 2013), university-industry collaboration (Fritsch and Slavtchev, 2011), technology (Markard and Truffer, 2008), spatial indicators and innovation capacity (Zabala-Iturriagagoitia et al., 2007).

Table 2 Key enablers of RIS based on literature

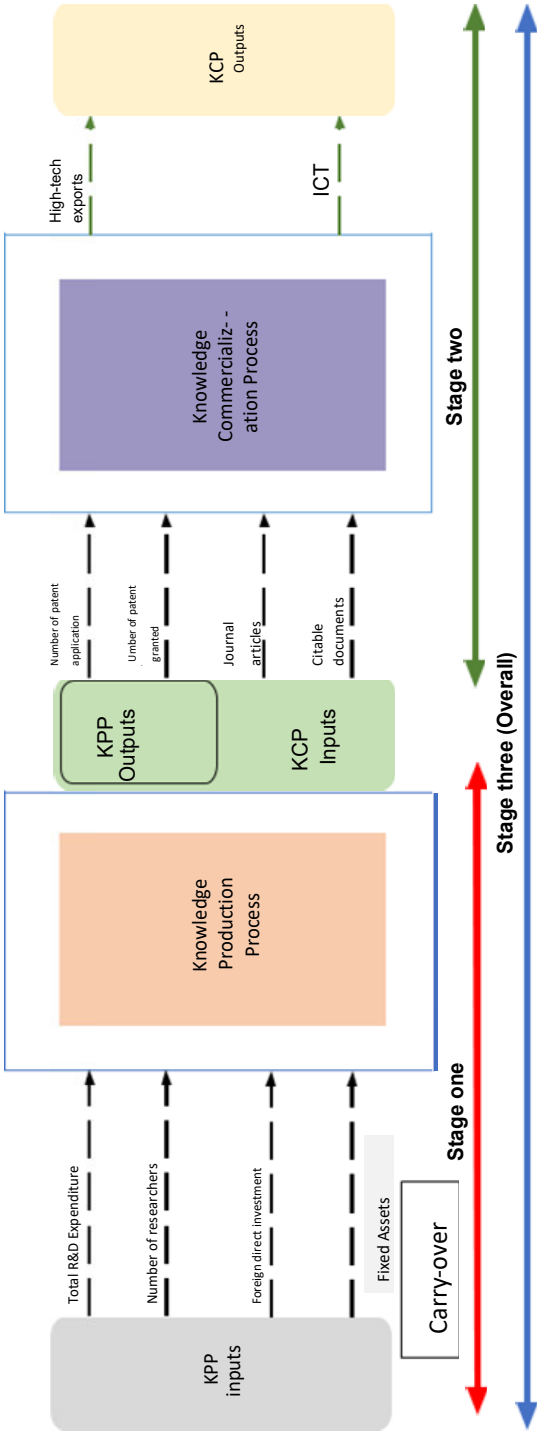
Key enablers	*Regions*
Availability of scientists and engineers	USA
Company spending on R&D university-industry	
Collaboration in R&D	
Public research organisations	European Union
Educational organisations	
Technology mediating organisation	
Policy institutions	
Regional development agencies	
Regional governance subsystem	
PCT patent applications	China
Scientific and technical articles	
Citable documents	
Human development index	
Multinational firms	Russia
International laws	
Regional trade agreements	
Intellectual property rights	
International financial	
Regulations	
Educational and training system	
R&D system	
Governance system	
Sectoral systems of innovation	

A systematic review for RIS and DEA literature was conducted to identify gaps in knowledge. This review attempted to gather objective DEA data on the selected studies. Peer reviewed articles in journals listed in Scopus were searched using the following keywords in the title: 'regional innovation system (systems)', or 'regional innovation (systems) system'. The period for the articles was defined as 2000 to 2021. Inclusion criteria include peer-reviewed articles with ten citations. Out of 446 articles only 151 were chosen after applying exclusion criteria. The articles were published in several journals including the *European Planning Studies*, 23 publications 15%, and *Regional Studies Journal*, 15 publications 10%. The three most cited articles were that of (Braczyk and Heidenreich 1998; Cooke et al., 1997). These articles applied theoretical and conceptual analysis and identified new approaches to achieving competitive advantage (Braczyk and Heidenreich, 1998).

Table 3 Most cited articles for RIS using DEA

#	*Authors*	*Title of the article*	*Journal*	*Citations*	*Methodology*	*Findings*
1	Braczyk et al. (1998)	Regional innovation systems: the role of governances in a globalised world	*Psychology Press*	4,161	Theoretical and conceptual analysis	New approaches to competitive advantage emerged from innovative capacities
2	Cooke et al. (1997)	Regional innovation systems: Institutional and organisational dimensions	*Research Policy*	3,607	Theoretical and conceptual analysis	RISs it was conceived from the perspective of a collectivist system based on a partial constitution regulation
3	Cooke (2001)	Regional innovation systems, clusters, and the knowledge economy	*Industrial and corporate change*	3,270	Theoretical and conceptual analysis	Promote formal learning and interactive innovation
4	Asheim and Isaken (2002)	Regional innovation systems: the integration of local 'sticky' and global 'ubiquitous' knowledge	*The Journal of Technology Transfer*	2,328	Empirical study quantitative research methodologies descriptive statistics	Innovation processes are considered regional phenomena in regional grouping
5	Asheim and Coenen (2005)	Knowledge bases and regional innovation systems: comparing Nordic clusters	*Research Policy*	2,003	Empirical study quantitative research methodologies descriptive statistics	The regional level often provides a basic approach that is embedded in networks of the actors

Figure 1 Research model (see online version for colours)



Source: Alnafrah (2021)

RISs were conceptualised in terms of a collective order based on micro constitutional regulation (Cooke et al., 1997) and promoting both systemic learning and interactive innovation. The review shows only three studies of the most cited articles were empirical studies using quantitative research methodologies with a statistical analysis of the results as shown in Table 3. These include the work of Asheim and Coenen (2005) and Asheim and Isaken (1997) which addressed location, agglomeration, and innovation. The review showed that 24 studies applied to the DEA for evaluating RIS. The only comparative study was that of Zhang and Wang (2019) in which they compared between developed and emerging economies.

3 Research methodology

Dynamic network data envelopment analysis (DNDEA) model was used in this research which is a non-parametric linear programming model measuring different decision-making units (DMUs) (Feng et al., 2021). The research model includes three stages as illustrated in Figure 1. The analysed DMUs were the countries in transition in GCC, Eastern Europe, Africa, and Central Asia. Variable return to scale (VRS) was adopted to measure the multiple oriented, decreasing or increasing inputs and outputs. Secondary data were collected from GII reports for the years (2014–2021) to perform the DEA to ensure consistency.

The research model includes independent, intermediate, and dependent variables. First, the independent variables include total R&D expenditure, the number of researchers and foreign direct investment but we have fixed assets as carry-over. The intermediate variables include number of patent applications, number of patents granted, journal articles and citable documents. The dependent variables include high technology exports and information and communications technology (ICT). Moreover, the model consists of three stages where stage one includes input and output of the knowledge production process (KPP). Stage two includes the input and output of the knowledge commercialisation process (KCP). Stage three (overall) includes both KPP&KCP processes. In the KPP process, the efficiency of the production process of both technical and scientific is measured. Whereas the KCP depicts the efficiency of processes converting technical and scientific knowledge into innovation, known as KCP, are measured (Alnafrah, 2021).

3.1 Innovation system indicators KPIs: DEA variables of inputs and outputs

The variables used to measure efficiency include R&D expenditure, number of researchers, foreign direct investment (FDI), patent origin, PCT patent applications, journals articles, citable documents H index, high-tech exports and ICT. Secondary data were collected from the GII Report for the years (2014–2021).

3.2 Sample size

The sample of the study includes 33 countries from four regions, i.e., the GCC, Eastern European, Central Asian, and African region. The benchmarking was taken based on the top ten innovation countries from the GII 2021 report. The rationale for choosing the sample is to identify the key attributes for innovation in regions in transition. The

countries that are included in the sample of this research is GCC (Bahrain, Kuwait, Oman, Saudi Arabia, Qatar, United Arab Emirates), Eastern Europe (Estonia, Latvia, Russia), Eastern Europe (Ukraine, Poland, Romania, Hungary, Czech Republic), Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan), Africa (Nigeria, Egypt, Algeria, Morocco, Kenya), and the top ten (Switzerland, Sweden, the USA, the UK, Korea, Netherlands, Finland, Singapore, Denmark, Germany). The following section outlines inputs and key results of DEA.

Table 4 Definitions of innovation system indicators KPIs

Variables	*Definitions*	*Source*
R&D expenditure	"This indicator measures gross domestic expenditure on R&D as a percentage of the last period gross domestic product (GDP)".	Andrade (2020)
Citable documents H-index	"The H-index expresses the journal's number of articles (H) that have received at least H citations. It quantifies both journal scientific productivity and scientific impact, and is also applicable to scientists, journals, and so on. The H-index is tabulated from the number of citations received in subsequent years by articles published each year, divided by the number of articles published that year".	
Researchers	"Researchers per million population, full-time equivalent".	
Patent applications by origin	"Number of resident patent applications filed at a given national or regional patent office (per billion PPP$ GDP)".	
PCT applications by origin	"Number of Patent Cooperation Treaty applications filed by residents (per billion PPP$ GDP)".	
Journal article	"Number of scientific and technical journal articles (per billion PPP$ GDP)".	
Foreign direct investment (FDI)	"Foreign direct investment is the average of the most recent three years of net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short- term capital as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors and is divided by GDP".	Andrade, (2014, 2020)
High-tech exports	"High-technology exports minus re-exports (% of total trade)".	
ICT services exports	"Telecommunications, computer, and information services (% of total trade) according to the Extended Balance of Payments Services Classification EBOPS 2010, coded SI: Telecommunications, computer, and information services".	
Fixed asset	The capital stock of each country is calculated by investing in the fixed assets of each country at the end of each year. Unit: billion dollars.	Feng et al. (2021)

4 Data analysis

The GCC region

Table 5 Data description of the GCC region (2014–2021)

		R&D expenditure	*Researcher*	*FDI*	*Patent origin*	*PCT*	*Citable documents H-index*	*ICT*	*Journals articles*	*Fixed assets*	*HighTech export*
2014	Average	0.1	175.3	1.3	0.1	0.2	74.3	0.1	0.1	1.4	5.4
	Stand	0.2	152.1	1.1	0.1	0.1	30.6	0.1	0.1	1.8	2.0
	Max	0.5	478.1	2.7	0.4	0.3	124.0	0.2	0.4	4.0	9.3
	Min	0.0	47.4	0.0	0.0	0.1	39.0	0.0	0.0	0	4
2015	Average	0.2	226.9	1.7	0.1	0.1	85.5	0.2	0.1	2.0	3.7
	Stand	0.2	176.6	1.1	0.1	0.1	35.4	0.2	0.1	0.0	1.7
	Max	0.5	586.9	3.0	0.3	0.2	144.0	0.5	0.3	2.0	6.9
	Min	0.0	135.1	0.0	0.0	0.0	43.0	0.0	0.0	2.0	2.4
2016	Average	0.3	206.3	1.4	0.1	0.1	96.2	0.4	0.2	1.4	4.1
	Stand	0.3	191.4	1.1	0.2	0.0	40.1	0.3	0.2	1.7	2.0
	Max	0.7	597.1	2.8	0.6	0.1	164.0	1.0	0.5	3.8	7.5
	Min	0.0	127.3	0.3	0.0	0.0	48.0	0.0	0.0	0.1	2.2
2017	Average	0.5	609.2	0.8	0.1	0.1	7.6	0.7	0.3	1.8	4.6
	Stand	0.3	701.9	1.0	0.2	0.1	4.5	0.6	0.2	1.9	2.2
	Max	0.9	2,003.4	2.7	0.5	0.2	15.5	1.7	0.5	4.9	8.0
	Min	0.1	128.4	0.0	0.0	0.0	2.4	0.0	0.1	0.1	2.6
2018	Average	0.5	682.3	0.9	0.2	0.1	8.3	1.2	0.3	1.9	3.3
	Stand	0.4	860.1	0.9	0.2	0.1	5.2	0.9	0.3	1.9	1.8
	Max	1.0	2,406.6	2.6	0.7	0.2	17.6	2.6	0.6	4.9	6.2
	Min	0.1	129.3	0.3	0.1	0.0	2.3	0.1	0.0	0.1	1.4
2019	Average	0.5	767.8	1.1	0.2	0.1	8.7	1.7	0.2	1.7	3.4
	Stand	0.4	812.2	0.8	0.3	0.1	5.6	1.2	0.2	1.5	1.6
	Max	1.0	2,406.6	2.6	0.7	0.4	18.7	3.6	0.6	3.9	6.2
	Min	0.1	244.0	0.2	0.0	0.0	2.4	0.2	0.0	0.2	1.8
2020	Average	0.5	766.0	73.7	0.2	0.1	10.4	2.1	0.1	2.0	4.2
	Stand	0.5	800.0	11.5	0.3	0.1	5.9	1.5	0.1	1.3	2.0
	Max	1.3	2,378.9	88.7	0.9	0.3	21.0	4.6	0.3	3.8	7.8
	Min	0.1	236.0	54.0	0.0	0.0	3.9	0.3	0.0	0.3	2.2
2021	Average	0.5	772.4	78.5	0.1	0.2	11.1	2.6	1.9	2.4	9.6
	Stand	0.5	794.6	15.8	0.1	0.2	6.3	2.0	3.7	2.6	4.0
	Max	1.3	2,378.9	100.9	0.2	0.6	22.7	5.9	9.4	7.4	15.9
	Min	0.1	281.2	54.0	0.1	0.0	4.4	0.4	0.1	0.3	4.7

Source: Andrade (2014, 2020)

The Eastern European Region

Table 6 Evaluating the efficiency of regional innovation systems in the Eastern European Region (2014-2021)

		R&D expenditure	*Researcher*	*FDI*	*Patent origin*	*PCT*	*Citable documents H-index*	*ICT*	*Journals articles*	*Fixed assets*	*HighTech export*
2014	Average	1.2	3,193.4	4.0	5.1	0.6	201.5	1.6	26.5	2.2	7.8
	Stand	0.6	1,549.7	2.5	3.3	0.4	89.6	0.5	13.8	1.0	6.0
	Max	2.2	5,906.5	7.4	11.5	1.2	325.0	2.3	53.1	3.8	17.1
	Min	0.5	1,168.7	0.6	0.7	0.1	85.0	0.7	10.7	1.0	1.5
2015	Average	1.1	2,236.1	2.1	4.3	0.5	22.8	1.9	23.4	3.3	7.8
	Stand	0.6	966.1	1.4	2.5	0.2	97.4	0.8	13.4	1.6	5.5
	Max	2.0	3,423.6	3.7	8.2	0.8	355.0	3.3	48.5	6.0	16.3
	Min	0.4	862.0	0.0	0.7	0.1	94.0	0.8	8.2	1.8	1.7
2016	Average	1.1	2,306.2	3.4	3.9	0.5	245.4	2.2	22.8	4.4	8.5
	Stand	0.5	955.3	2.8	1.9	0.3	107.1	0.9	12.0	2.2	5.1
	Max	2.0	3,418.5	9.0	6.8	1.0	390.0	3.7	44.1	7.8	16.3
	Min	0.4	921.5	0.6	2.2	0.1	104.0	0.9	9.3	1.9	2.1
2017	Average	1.1	2,296.8	2.3	4.1	0.4	22.4	2.6	23.1	5.5	8.8
	Stand	0.5	1,011.9	0.6	2.2	0.2	107.7	1.2	13.0	2.6	4.9
	Max	2.0	3,611.9	3.2	7.9	0.7	36.6	4.4	47.6	9.2	16.7
	Min	0.5	894.8	1.4	1.6	0.1	7.8	1.2	8.8	2.3	3.1
2018	Average	1.0	2,269.6	4.6	3.7	0.5	22.6	3.0	16.3		
	Stand	0.5	1,007.1	6.2	2.0	0.3	10.7	1.3	8.1		
	Max	1.7	3,518.8	19.8	7.0	1.1	36.7	4.8	30.8		
	Min	0.4	912.4	1.4	1.9	0.0	8.1	1.3	7.2		
2019	Average	1.0	2,479.0	4.1	3.4	0.5	22.9	3.1	15.2		
	Stand	0.5	1,076.9	3.9	1.7	0.3	10.9	1.4	7.6		
	Max	1.8	3,689.9	13.6	6.2	1.1	37.4	4.9	28.7		
	Min	0.4	890.2	1.6	1.9	0.1	8.4	1.3	6.9		
2020	Average	1.1	2,566.2	46.6	3.1	0.5	24.4	3.3	16.4		
	Stand	0.5	1,173.3	17.1	1.8	0.2	10.5	1.6	8.0		
	Max	1.9	3,862.7	76.0	6.0	0.8	38.2	5.4	30.7		
	Min	0.5	882.4	25.9	1.6	0.1	9.3	1.8	7.3		
2021	Average	1.1	2,688.7	42.0	2.7	0.4	24.6	3.8	23.2		
	Stand	0.5	1,291.9	12.6	1.5	0.3	10.3	1.8	12.1		
	Max	1.9	4,057.3	59.0	5.7	1.1	37.7	6.3	43.5		
	Min	0.5	896.0	24.7	1.5	0.1	9.5	1.3	9.1		

Source: Andrade (2014, 2020)

The African Region

Table 7 Data description African region (2014–2021)

		R&D expenditure	*Researcher*	*FDI*	*Patent origin*	*PCT*	*Citable documents H-index*	*ICT*	*Journals articles*
2014	Average	0.5	627.2	1.7	1.2	0.1	105.8	0.6	0.3
	Stand	0.4	484.7	1.4	0.4	0.1	24.6	0.4	0.5
	Max	1.0	1,146.1	3.6	1.6	0.2	132.0	1.2	1.1
	Min	0.1	119.7	0.0	0.4	0.0	78.0	0.2	0.0
2015	Average	0.5	352.3	1.7	0.7	0.1	119.6	1.1	0.2
	Stand	0.4	325.8	1.0	0.5	0.1	27.4	0.7	0.2
	Max	1.0	864.5	3.2	1.3	0.2	149.0	1.9	0.6
	Min	0.1	38.6	0.8	0.1	0.0	89.0	0.3	0.0
2016	Average	0.5	452.8	1.6	0.7	0.1	131.8	1.6	0.3
	Stand	0.4	330.4	1.0	0.5	0.1	31.3	1.1	0.2
	Max	0.8	856.9	3.3	1.4	0.1	165.0	2.8	0.6
	Min	0.0	38.6	0.7	0.1	0.0	97.0	0.4	0.0
2017	Average	0.5	487.4	1.5	0.6	0.0	10.9	2.1	0.5
	Stand	0.4	388.1	1.1	0.4	0.0	3.2	1.4	0.6
	Max	0.8	1,032.5	3.2	1.0	0.1	14.5	3.6	1.5
	Min	0.0	38.6	0.4	0.1	0.0	7.2	0.4	0.0
2018	Average	0.5	493.1	1.5	0.6	0.0	11.4	2.6	0.5
	Stand	0.4	402.1	1.0	0.4	0.1	3.2	1.7	0.7
	Max	0.8	1,069.0	2.9	0.9	0.2	15.2	4.4	1.6
	Min	0.0	38.6	0.5	0.1	0.0	7.7	0.4	0.0
2019	Average	0.5	705.9	1.5	0.5	0.0	11.6	3.1	0.4
	Stand	0.3	307.9	1.0	0.3	0.1	3.2	2.1	0.6
	Max	0.8	1,069.0	2.6	0.8	0.2	15.5	5.2	1.5
	Min	0.0	225.0	0.5	0.1	0.0	8.0	0.4	0.0
2020	Average	0.5	710.8	34.7	0.6	0.0	13.1	3.6	0.5
	Stand	0.3	310.3	28.8	0.5	0.0	3.2	2.3	0.7
	Max	0.8	1,073.5	84.9	1.4	0.1	17.4	6.0	1.7
	Min	0.0	221.4	10.9	0.1	0.0	9.7	0.9	0.0
2021	Average	0.5	710.8	35.1	0.6	0.0	13.5	4.1	0.6
	Stand	0.3	310.3	30.2	0.5	0.1	3.2	2.6	0.8
	Max	0.8	1,073.5	87.8	1.3	0.2	17.7	6.8	2.1
	Min	0.0	221.4	10.5	0.1	0.0	10.2	1.4	0.0

Source: Andrade (2014, 2020)

The Central Asian Region

Table 8 Data description Central Asia region (2014–2021)

		R&D expenditure	*Researcher*	*FDI*	*Patent origin*	*PCT*	*Citable documents H-index*	*ICT*	*Journals articles*	*Fixed assets*	*HighTech export*
2014	Average	0.1	601.2	5.4	4.4	0.1	39.8	0.3	2.4	0.7	3.7
	Stand	0.1	382.0	4.8	3.7	0.1	15.1	0.2	1.7	0.9	1.9
	Max	0.2	1,079.3	11.2	8.4	0.3	53.0	0.4	4.5	2.1	6.4
	Min	0.0	200.3	0.2	0.2	0.0	23.0	0.0	0.3	0.2	2.1
2015	Average	0.1	647.1	4.5	3.2	0.0	44.0	0.4	2.1	0.9	2.5
	Stand	0.1	93.8	4.2	2.7	0.1	17.3	0.3	1.6	1.1	1.3
	Max	0.2	763.5	10.5	6.1	0.1	59.0	0.6	4.1	2.6	4.4
	Min	0.0	533.9	1.3	0.1	0.0	24.0	0.0	0.1	0.2	1.6
2016	Average	0.1	550.6	2.3	2.9	0.1	33.0	0.5	2.0	1.1	2.4
	Stand	0.1	367.1	1.6	3.5	0.1	26.6	0.4	2.2	1.8	2.0
	Max	0.2	734.1	3.5	7.1	0.1	64.0	0.8	4.8	3.8	4.7
	Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2017	Average	0.1	550.6	4.4	2.4	0.0	1.3	0.6	2.7	0.4	2.5
	Stand	0.1	367.1	4.3	3.0	0.0	1.7	0.5	2.6	0.3	2.3
	Max	0.2	734.1	10.3	6.4	0.1	3.6	1.0	5.9	0.7	5.6
	Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2018	Average	0.1	515.7	5.1	1.7	0.0	1.2	0.7	2.6	1.0	1.9
	Stand	0.1	343.8	4.0	2.0	0.0	1.7	0.5	2.1	1.4	1.4
	Max	0.1	687.6	9.6	4.2	0.1	3.5	1.2	5.0	3.0	3.5
	Min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2019	Average	0.1	687.6	6.0	2.8	0.0	1.6	0.8	3.0	0.5	2.2
	Stand	0.1	0.0	2.4	3.0	0.0	1.8	0.6	0.6	0.4	0.9
	Max	0.1	687.6	8.3	6.0	0.0	3.5	1.3	3.6	1.0	3.2
	Min	0.0	687.6	3.5	0.1	0.0	0.0	0.0	2.3	0.2	1.6
2020	Average	0.1	571.6	15.9	2.4	0.1	3.5	0.9	1.3	0.3	2.6
	Stand	0.0	77.9	12.4	2.5	0.1	1.7	0.6	1.3	0.3	1.5
	Max	0.1	666.9	27.3	6.0	0.1	5.1	1.4	3.2	0.7	4.7
	Min	0.1	476.2	0.0	0.1	0.0	1.2	0.0	0.1	0.0	1.2
2021	Average	0.1	571.6	23.0	1.7	0.1	3.6	1.0	1.4	0.4	4.3
	Stand	0.0	77.9	7.8	1.0	0.1	1.8	0.6	1.7	0.3	2.3
	Max	0.1	666.9	30.0	2.8	0.1	5.3	1.5	3.9	0.8	7.4
	Min	0.1	476.2	11.8	0.4	0.0	1.1	0.1	0.1	0.2	2.1

Source: Andrade (2014, 2020)

Top ten innovative countries based GII 2021 report

Table 9 Data description top ten innovative countries based GII 2021 report

		R&D expenditure	*Researcher*	*FDI*	*Patent origin*	PCT	*Citable documents H-index*	ICT	*Journals articles*	*Fixed assets*	*HighTech export*
2014	Average	2.9	7,579.9	2.9	16.3	6.7	602.7	5.7	12.2	2.1	45.0
	Stand	0.8	1,788.4	6.3	27.2	3.6	327.2	1.3	6.6	1.9	16.7
	Max	4.4	10,678.8	20.	92.7	12.	1380.0	7.6	26.0	6.0	67.2
	Min	1.7	4,979.6	0.0	3.3	2.1	268.0	3.6	5.3	0.2	20.5
2015	Average	2.9	5,523.4	3.1	15.8	5.6	666.5	8.6	12.7	2.5	41.4
	Stand	0.8	1,375.4	6.5	28.0	2.6	357.2	2.1	7.3	1.8	15.1
	Max	4.2	7,271.3	21.4	94.3	8.8	1518.0	11.5	26.8	6.0	63.4
	Min	1.7	3,978.7	0.0	2.6	2.1	308.0	5.3	4.5	0.3	20.6
2016	Average	2.8	5,630.6	4.0	21.0	5.4	727.8	11.5	12.5	2.6	41.3
	Stand	0.8	1,375.3	6.6	25.4	2.6	384.6	2.8	7.1	2.0	15.3
	Max	4.3	7,198.2	21.8	92.0	8.9	1648.0	15.7	26.8	6.7	64.5
	Min	1.7	4,018.6	0.2	2.9	1.9	349.0	7.0	5.0	0.4	19.9
2017	Average	2.8	5,723.1	5.9	20.4	5.3	64.8	14.3	13.2	3.9	41.8
	Stand	0.7	1,378.5	8.4	25.0	2.5	24.2	3.6	7.9	3.1	16.1
	Max	4.2	7,483.6	22.2	90.3	8.8	100.0	20.0	29.1	9.9	66.8
	Min	1.7	4,232.0	0.0	3.1	1.8	33.9	8.7	5.0	0.6	19.8
2018	Average	2.8	5,877.2	6.0	19.4	5.2	65.1	17.1	13.0	3.6	25.8
	Stand	0.7	1,244.9	7.7	23.3	2.5	23.8	4.2	7.8	2.7	9.2
	Max	4.2	7,514.7	22.8	84.5	8.7	100.0	24.2	28.6	8.8	38.5
	Min	1.7	4,313.4	0.6	3.3	1.7	35.6	10.4	4.7	0.6	11.5
2019	Average	2.9	6,007.7	8.0	18.4	5.1	65.6	19.9	11.5	3.4	24.0
	Stand	0.8	1,365.2	9.5	21.5	2.5	23.6	4.9	8.4	2.2	8.4
	Max	4.6	7,923.2	27.7	78.2	8.3	100.0	28.4	27.4	8.1	35.6
	Min	1.7	4,256.3	0.8	3.0	1.7	36.5	12.1	4.4	0.7	10.5
2020	Average	2.9	12,252.9	134.4	17.4	4.9	65.8	22.8	11.6	3.3	25.3
	Stand	0.8	19,234.9	35.2	19.9	2.5	23.2	5.7	8.7	2.1	9.2
	Max	4.5	66,861.1	186.0	72.7	8.2	100.0	33.0	28.4	7.6	38.2
	Min	1.7	4,412.4	77.7	2.8	1.8	37.8	13.8	4.2	0.7	10.7
2021	Average	2.9	6,366.8	134.0	16.9	5.1	65.9	25.7	11.4	3.8	41.3
	Stand	0.8	1,399.0	36.1	20.6	2.5	23.0	6.5	7.4	3.0	15.0
	Max	4.6	8,407.8	191.8	74.5	8.7	100.0	37.5	25.3	11.3	62.2
	Min	1.8	4,408.2	80.2	3.0	2.0	38.4	15.5	4.3	0.9	18.9

Source: Andrade (2014, 2020)

The RIS efficiency results

Table 10 The efficiency score of each region based on DNDEA output-oriented VRS model (division 1)

		2014	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*Average*
GCC	Average	0.785	0.363	0.557	0.519	0.572	0.401	0.524	0.594	0.539
	Stand dev.	0.374	0.308	0.252	0.344	0.403	0.360	0.443	0.467	0.238
	Max	1.000	0.965	1.000	1.000	1.000	1.000	1.000	1.000	0.864
	Min	0.085	0.085	0.304	0.041	0.049	0.026	0.029	0.020	0.277
Eastern Europe	Average	0.252	0.571	0.323	0.377	0.460	0.388	0.445	0.632	0.370
	Stand dev.	0.140	0.390	0.282	0.304	0.289	0.314	0.290	0.346	0.201
	Max	0.456	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.767
	Min	0.067	0.142	0.149	0.147	0.164	0.163	0.206	0.250	0.168
Central Asia	Average	0.780	0.911	0.636	0.746	0.923	0.613	0.661	0.434	0.750
	Stand dev.	0.264	0.164	0.254	0.296	0.092	0.429	0.333	0.410	0.160
	Max	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.898
	Min	0.470	0.666	0.416	0.439	0.815	0.088	0.236	0.019	0.569
Africa	Average	0.416	0.602	0.353	0.512	0.409	0.307	0.327	0.323	0.376
	Stand dev.	0.335	0.523	0.349	0.444	0.381	0.357	0.383	0.375	0.362
	Max	0.372	0.591	0.389	0.487	0.403	0.374	0.378	0.384	0.386
	Min	0.330	0.612	0.446	0.509	0.465	0.435	0.442	0.449	0.421
Top ten	Average	0.533	0.828	0.758	0.803	0.704	0.813	0.714	0.881	0.677
	Stand dev.	0.325	0.308	0.306	0.310	0.289	0.276	0.279	0.255	0.279
	Max	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Min	0.165	0.309	0.190	0.228	0.191	0.339	0.297	0.399	0.211

Table 11 The efficiency score of each region based on DNDEA output oriented VRS model (division 2)

		2014	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*Average*
GCC	Average	0.480	0.516	0.379	0.565	0.454	0.420	0.275	0.777	0.483
	Stand dev.	0.412	0.319	0.424	0.478	0.363	0.307	0.226	0.290	0.238
	Max	1.000	0.932	1.000	1.000	1.000	0.888	0.608	1.000	0.786
	Min	0.064	0.093	0.044	0.062	0.070	0.092	0.066	0.254	0.208
Eastern Europe	Average	0.650	0.798	0.730	0.876	0.806	0.849	0.735	0.859	0.788
	Stand dev.	0.226	0.185	0.238	0.150	0.238	0.202	0.270	0.245	0.181
	Max	0.945	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.993
	Min	0.246	0.471	0.414	0.623	0.306	0.431	0.277	0.312	0.487
Central Asia	Average	0.569	0.382	0.786	0.667	0.893	0.558	0.529	0.453	0.605
	Stand dev.	0.407	0.415	0.429	0.388	0.214	0.327	0.394	0.403	0.249
	Max	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.946
	Min	0.207	0.101	0.142	0.276	0.572	0.222	0.080	0.029	0.349

Table 11 The efficiency score of each region based on DNDEA output oriented VRS model (division 2) (continued)

		2014	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*Average*
Africa	Average	0.270	0.368	0.340	0.458	0.239	0.314	0.264	0.295	0.319
	Stand dev.	0.314	0.381	0.396	0.535	0.250	0.288	0.304	0.342	0.351
	Max	0.354	0.419	0.400	0.617	0.293	0.339	0.351	0.373	0.393
	Min	0.377	0.446	0.462	0.722	0.306	0.363	0.392	0.410	0.435
Top ten	Average	0.817	0.975	0.836	0.938	0.893	0.927	0.802	0.948	0.892
	Stand dev.	0.263	0.053	0.226	0.148	0.197	0.112	0.229	0.070	0.119
	Max	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.997
	Min	0.277	0.880	0.395	0.576	0.488	0.704	0.377	0.852	0.688

Table 12 The efficiency score of each region based on DNDEA output oriented VRS model (division 2)

		2014	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*Average*
GCC	Average	0.577	0.344	0.680	0.469	0.755	0.370	0.484	0.792	0.559
	Stand dev.	0.431	0.150	0.376	0.420	0.405	0.364	0.415	0.343	0.265
	Max	1.000	0.488	1.000	1.000	1.000	1.000	1.000	1.000	0.825
	Min	0.142	0.146	0.196	0.106	0.043	0.036	0.060	0.193	0.163
Eastern Europe	Average	0.774	0.770	0.834	0.817	0.896	0.820	0.782	0.881	0.822
	Stand dev.	0.287	0.283	0.251	0.236	0.231	0.235	0.287	0.255	0.237
	Max	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Min	0.233	0.236	0.285	0.334	0.347	0.326	0.252	0.286	0.287
Central Asia	Average	0.577	0.385	0.626	0.849	1.000	0.630	0.471	0.983	0.690
	Stand dev.	0.488	0.421	0.434	0.303	-	0.284	0.273	0.034	0.138
	Max	1.000	1.000	1.000	1.000	1.000	1.000	0.809	1.000	0.872
	Min	0.148	0.068	0.194	0.395	1.000	0.316	0.142	0.932	0.535
Africa	Average	0.296	0.478	0.442	0.689	0.687	0.512	0.391	0.712	0.454
	Stand dev.	0.340	0.374	0.380	0.627	0.624	0.561	0.452	0.837	0.449
	Max	0.385	0.432	0.426	0.731	0.737	0.662	0.520	0.804	0.517
	Min	0.414	0.468	0.470	0.677	0.685	0.619	0.547	0.765	0.529
Top ten	Average	0.913	0.904	0.896	0.910	0.905	0.798	0.645	0.870	0.840
	Stand dev.	0.215	0.201	0.210	0.201	0.206	0.213	0.251	0.219	0.194
	Max	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Min	0.426	0.468	0.432	0.433	0.416	0.395	0.306	0.449	0.395

Malmquist projection

Table 13 VRS output-oriented projection

2021			*GCC*	*Eastern Europe*	*Central Asia*	*Africa*	*Top ten*
			Average	*Average*	*Average*	*Average*	*Average*
Div1	Patent origin	Data	0.233	3.100	2.375	0.620	17.350
		Projection	1.899	8.259	3.443	5.122	29.285
	(%)	Difference(%)	-	2.333	0.628	18.396	1.656
	PCT patent	Data	0.083	0.450	0.050	0.020	4.940
		Projection	0.212	1.590	0.058	0.154	5.502
	(%)	Difference(%)	-	3.305	-	-	0.254
Div2	High-tech exports	Data	0.133	8.688	1.325	0.480	11.600
		Projection	3.966	11.783	2.475	5.606	13.310
	(%)	Difference(%)	-	1.070	10.509	-	0.346
	ICT service exports	Data	1.950	3.325	0.275	1.720	3.300
		Projection	3.012	4.061	0.775	3.540	4.201
	(%)	Difference(%)	1.374	0.475	-	5.372	0.343
	Journal articles(%)	Data	4.233	16.363	2.600	6.020	25.320
		Projection	6.321	21.811	4.858	8.527	36.326
		Difference(%)	0.543	0.530	1.417	0.558	0.689
Div3	High-tech exports	Data	0.133	8.688	1.325	0.480	11.600
		Projection	2.259	11.076	1.715	3.009	16.006
	(%)	Difference(%)	-	0.886	3.899	-	0.730
	ICT service exports	Data	1.950	3.325	0.275	1.720	3.300
		Projection	3.516	4.313	0.697	3.342	5.484
	(%)	Difference(%)	1.432	0.568	-	2.439	0.985
	Journal articles	Data	4.233	16.363	2.600	6.020	25.320
		Projection	7.160	18.819	3.848	8.585	34.019
	(%)	Difference(%)	0.669	0.306	0.849	0.487	0.509

Malmquist index VRS output-oriented division 1

Table 14 Malmquist index VRS output-oriented division 1

		2015->2017	*2017->2019*	*2019->2021*	*Geometric mean*
GCC	Average	1.824	0.676	0.502	0.704
	Stand dev.	2.183	0.639	0.309	0.448
	Max	6.144	1.812	1.000	1.509
	Min	0.323	0.106	0.126	0.262
Eastern Europe	Average	4.398	2.396	0.468	1.441
	Stand dev.	6.764	0.688	0.166	0.533
	Max	21.041	3.116	0.852	2.669
	Min	1.017	0.876	0.358	0.930

Table 14 Malmquist index VRS output-oriented division 1 (continued)

		2015->2017	*2017->2019*	*2019->2021*	*Geometric mean*
Central Asia	Average	1.389	1.232	0.750	1.030
	Stand dev.	0.398	0.737	0.251	0.251
	Max	1.820	2.201	1.116	1.346
	Min	0.911	0.437	0.552	0.796
Africa	Average	1.705	1.285	0.528	0.985
	Stand dev.	1.858	1.244	0.583	1.041
	Max	2.075	1.157	0.577	1.064
	Min	2.260	1.195	0.571	1.101
Top ten	Average	1.849	1.118	0.731	1.112
	Stand dev.	0.641	0.235	0.184	0.093
	Max	2.824	1.403	1.018	1.271
	Min	1.057	0.762	0.518	1.013

Malmquist index VRS output-oriented division 2

Table 15 Malmquist index VRS output-oriented division 2

		2015->2017	*2017->2019*	*2019->2021*	*Geometric mean*
GCC	Average	1.537	2.012	0.994	1.262
	Stand dev.	1.288	1.451	0.351	0.457
	Max	3.338	4.678	1.341	1.943
	Min	0.280	0.971	0.483	0.792
Eastern Europe	Average	1.481	1.270	1.392	1.356
	Stand dev.	0.553	0.198	0.124	0.128
	Max	2.809	1.583	1.567	1.603
	Min	1.072	0.936	1.191	1.198
Central Asia	Average	1.639	6.879	0.686	1.663
	Stand dev.	0.683	9.460	0.493	1.347
	Max	2.203	20.850	1.164	3.594
	Min	0.686	1.000	0.092	0.573
Africa	Average	2.207	1.092	1.397	1.381
	Stand dev.	2.426	0.948	1.430	1.387
	Max	2.075	1.069	1.373	1.394
	Min	2.223	1.102	1.475	1.470
Top ten	Average	1.506	1.103	1.314	1.245
	Stand dev.	1.282	0.108	0.183	0.249
	Max	4.711	1.339	1.510	1.817
	Min	0.721	0.962	1.009	

Malmquist index VRS output-oriented division 3

Table 16 Malmquist index VRS output-oriented division 3

		2015->2017	*2017->2019*	*2019->2021*	*Geometric mean*
GCC	Average	0.718	0.685	0.781	0.679
	Stand dev.	0.315	0.449	0.445	0.296
	Max	1.111	1.298	1.397	1.093
	Min	0.383	0.219	0.157	0.244
Eastern Europe	Average	1.069	1.019	0.846	0.960
	Stand dev.	0.229	0.126	0.202	0.099
	Max	1.557	1.228	1.041	1.053
	Min	0.841	0.798	0.457	0.804
Central Asia	Average	1.332	1.816	0.486	0.978
	Stand dev.	0.877	1.206	0.202	0.348
	Max	2.598	3.494	0.676	1.358
	Min	0.572	0.881	0.282	0.649
Africa	Average	3.183	1.533	0.830	1.137
	Stand dev.	1.514	1.658	0.924	1.053
	Max	1.726	1.913	0.725	1.124
	Min	1.881	1.889	0.803	1.177
Top ten	Average	0.971	0.859	0.732	0.843
	Stand dev.	0.070	0.178	0.185	0.121
	Max	1.010	1.069	1.014	1.009
	Min	0.841	0.574	0.530	0.671

Frontier-shift VRS output-oriented division 1

Table 17 Frontier-shift VRS output-oriented division 1

		2015->2017	*2017->2019*	*2019->2021*	*Geometric mean*
GCC	Average	1.518	0.710	0.595	0.845
	Stand dev.	0.778	0.366	0.320	0.409
	Max	2.835	1.213	1.000	1.509
	Min	0.598	0.295	0.310	0.414
Eastern Europe	Average	2.144	1.670	0.483	1.146
	Stand dev.	0.482	0.687	0.172	0.146
	Max	2.731	2.530	0.731	1.367
	Min	1.408	0.883	0.268	0.945
Central Asia	Average	1.844	0.793	1.253	1.120
	Stand dev.	0.937	0.382	0.603	0.265
	Max	3.083	1.122	2.048	1.401
	Min	0.807	0.258	0.634	0.796

Table 17 Frontier-shift VRS output-oriented division 1 (continued)

		2015->2017	*2017->2019*	*2019->2021*	*Geometric mean*
Africa	Average	2.622	1.068	1.113	1.288
	Stand dev.	2.736	1.076	0.740	1.176
	Max	3.126	1.107	0.808	1.279
	Min	2.479	1.120	0.770	1.159
Top ten	Average	1.280	1.201	0.711	0.984
	Stand dev.	0.553	0.182	0.199	0.109
	Max	2.448	1.446	0.988	1.140
	Min	0.608	0.923	0.334	0.775

Frontier-shift VRS output-oriented division 2

Table 18 Frontier-shift VRS output-oriented division 2

		2015->2017	*2017->2019*	*2019->2021*	*Geometric mean*
GCC	Average	2.294	1.052	1.736	1.502
	Stand dev.	1.530	0.162	1.078	0.534
	Max	4.005	1.374	3.844	2.416
	Min	0.768	0.916	1.000	1.000
Eastern Europe	Average	1.267	1.164	1.559	1.304
	Stand dev.	0.317	0.221	0.135	0.110
	Max	1.767	1.583	1.793	1.541
	Min	0.925	0.892	1.445	1.176
Central Asia	Average	1.258	6.022	1.112	1.675
	Stand dev.	0.721	9.886	0.137	1.291
	Max	2.203	20.850	1.295	3.594
	Min	0.486	1.000	1.002	0.822
Africa	Average	1.723	1.516	1.732	1.377
	Stand dev.	1.868	1.704	1.398	1.402
	Max	1.996	1.302	1.503	1.365
	Min	1.651	1.492	1.533	1.397
Top ten	Average	1.142	1.019	1.499	1.235
	Stand dev.	0.329	0.111	0.250	0.139
	Max	1.926	1.126	1.915	1.515
	Min	1.007	0.812	1.133	

VRS output-oriented division 3

Table 19 Frontier-shift VRS output-oriented division 3

		2015->2017	*2017->2019*	*2019->2021*	*Geometric mean*
GCC	Average	0.621	0.670	1.066	0.723
	Stand dev.	0.488	0.328	0.280	0.311
	Max	1.492	1.058	1.616	1.143
	Min	0.158	0.241	0.809	0.417
Eastern Europe	Average	0.955	0.932	0.996	0.956
	Stand dev.	0.121	0.098	0.194	0.102
	Max	1.090	1.030	1.305	1.055
	Min	0.742	0.798	0.629	0.799
Central Asia	Average	1.050	0.787	1.675	0.940
	Stand dev.	0.603	0.187	1.898	0.187
	Max	1.835	1.000	4.518	1.203
	Min	0.385	0.589	0.573	0.793
Africa	Average	0.924	0.786	1.497	0.941
	Stand dev.	0.879	0.807	0.981	0.835
	Max	0.982	0.768	0.977	0.858
	Min	0.964	0.837	0.999	0.884
Top ten	Average	0.984	0.846	1.044	0.952
	Stand dev.	0.146	0.143	0.164	0.096
	Max	1.213	1.015	1.273	1.025
	Min	0.679	0.596	0.722	0.750

Catch-up VRS output-oriented division 1

Table 20 Catch-up VRS output-oriented division 1

		2015->2017	*2017->2019*	*2019->2021*	*Geometric mean*
GCC	Average	1.271	1.027	0.831	0.836
	Stand dev.	1.541	0.686	0.304	0.285
	Max	4.382	1.981	1.236	1.119
	Min	0.304	0.106	0.408	0.360
Eastern Europe	Average	2.661	1.566	1.029	1.276
	Stand dev.	4.973	0.611	0.309	0.517
	Max	14.942	2.660	1.541	2.463
	Min	0.538	0.962	0.507	0.850
Central Asia	Average	0.887	1.571	0.702	0.943
	Stand dev.	0.459	0.407	0.312	0.220
	Max	1.537	1.963	1.000	1.086
	Min	0.537	1.000	0.269	0.618

Table 20 Catch-up VRS output-oriented division 1 (continued)

		2015->2017	*2017->2019*	*2019->2021*	*Geometric mean*
Africa	Average	1.039	1.229	0.830	0.915
	Stand dev.	1.155	1.184	0.979	1.021
	Max	1.190	1.056	0.870	0.946
	Min	1.392	1.082	0.922	1.041
Top ten	Average	1.888	0.942	1.075	1.143
	Stand dev.	0.725	0.188	0.332	0.116
	Max	2.982	1.179	1.619	1.307
	Min	1.000	0.552	0.635	1.000

Catch-up VRS output-oriented division 2

Table 21 Catch-up VRS output-oriented division 2

		2015->2017	*2017->2019*	*2019->2021*	*Geometric mean*
GCC	Average	0.658	1.981	0.665	0.854
	Stand dev.	0.278	1.485	0.303	0.192
	Max	1.000	4.678	1.113	1.112
	Min	0.280	0.707	0.349	0.666
Eastern Europe	Average	1.172	1.117	0.900	1.040
	Stand dev.	0.269	0.232	0.117	0.051
	Max	1.683	1.493	1.000	1.124
	Min	0.836	0.738	0.664	0.982
Central Asia	Average	1.779	1.756	0.653	0.984
	Stand dev.	1.646	1.511	0.512	0.352
	Max	4.228	4.022	1.161	1.474
	Min	0.686	1.000	0.080	0.698
Africa	Average	1.706	1.738	1.088	1.132
	Stand dev.	1.824	1.458	1.234	1.142
	Max	1.507	1.731	1.085	1.200
	Min	1.737	1.559	1.175	1.272
Top ten	Average	0.956	1.100	0.891	1.013
	Stand dev.	0.839	0.241	0.143	0.215
	Max	3.257	1.648	1.000	1.534
	Min	0.665	0.854	0.648	0.865

Catch-up VRS output-oriented division 3

Table 22 Catch-up VRS Output-oriented Division 3

		2015->2017	*2017->2019*	*2019->2021*	*Geometric mean*
GCC	Average	2.001	1.103	0.757	0.998
	Stand dev.	2.467	0.553	0.456	0.488
	Max	7.022	1.746	1.397	1.915
	Min	0.669	0.219	0.165	0.548
Eastern Europe	Average	1.138	1.105	0.855	1.006
	Stand dev.	0.300	0.186	0.171	0.058
	Max	1.771	1.462	1.000	1.134
	Min	0.801	0.912	0.603	0.948
Central Asia	Average	2.317	2.590	0.471	1.063
	Stand dev.	2.980	2.000	0.273	0.445
	Max	6.749	5.151	0.809	1.713
	Min	0.312	1.000	0.142	0.762
Africa	Average	3.023	2.253	0.877	1.228
	Stand dev.	1.621	2.439	1.035	1.263
	Max	1.696	2.850	0.857	1.321
	Min	1.858	2.458	0.951	1.349
Top ten	Average	0.992	1.023	0.713	0.885
	Stand dev.	0.209	0.206	0.195	0.076
	Max	1.429	1.442	1.000	1.000
	Min	0.693	0.780	0.469	0.777

Table 23 Projection link

2021			*GCC*	*Eastern Europe*	*Central Asia*	*Africa*	*Top ten*
			Average	*Average*	*Average*	*Average*	*Average*
Div1	Citable documents H-index	Data	10.383	24.388	3.450	13.080	57.600
		Projection	9.594	20.558	3.450	11.501	48.620
	(%)	Difference(%)	(0.040)	(0.103)	-	(0.118)	(0.123)

Table 24 shows projection carry-over which is the fixed assets variable in the last period carry-over in 2021 in stage one and two. In the GCC region, the average was 2.117 in division one. So, there is no need to increase the variable in division one. In stage two, the average was 2.117 and the projection was 3.069. Hence, it must increase by 60.4%. However, in the Eastern European region the variable should increase 3.6%. While in the Central Asian region there is no need to increase the variable. In the African region in stage one, the average was 3.580 and the projection was 4.114. This variable must be increased by 45.8% to improve performance. In stage two the average was observed as 3.580 and the projection was 4.788. Hence, the variable must increase by 72.8% to improve it.

Table 24 Projection carry-over

		2021	GCC	Eastern Europe	Central Asia	Africa	Top ten
		(Last period carry-over)	Average	Average	Average	Average	Average
Div1	Fixed assets	Data	2.117	8.575	0.850	3.580	21.460
		Projection	2.117	8.801	0.851	4.114	21.936
	(%)	Difference (%)	-	0.036	-	0.458	0.027
Div2	Fixed assets	Data	2.117	8.575	0.850	3.580	21.460
		Projection	3.069	9.525	0.915	4.788	22.796
	(%)	Difference (%)	0.604	0.114	-	0.728	0.083

To identify if there exists a difference in performance of RIS (efficiency score) before and during COVID-19, a Mann-Whitney U test was computed as shown in Table 25. Analysis shows relative variations between the two-time intervals.

Table 25 The impact of COVID 19 on the efficiency of RIS Output oriented DEA model: Mann-Whitney test

RIS stage		Sample size	Mean rank	Mann Whitney U	Z-value
Stage one	Before	30	20.72	143.5	–0.203
	During	10	19.85	134.00	
Stage two	Before	30	21.03		–0.500
	During	10	18.90	145.00	
Stage three	Before	30	20.33		–0.156
	During	10	21.00		

5 Conclusions

The key conclusions with respect to innovation policy and ecosystem of innovation may be summarised as follows:

5.1 The ecosystem and enablers of RIS

This research shows that ecosystem is key in shaping the trajectory on innovative regions. The analysis shows that the key enablers of RIS include ICT infrastructure, investment in human capital and R&D and legal and institutional setup. There is a shift in the perception and metrics of innovation systems due to global competition and the transition from an internal knowledge base of companies to the global distributed knowledge base, global value chains and foreign direct investment. In a distributed knowledge base, innovation and knowledge density are taken as embodied knowledge as reflected in machinery and equipment, or as intermediate inputs (components and materials) in production processes. Besides, knowledge flows within the knowledge base distributed between industries are likely to occur with very different degrees of R&D intensity through linkages between synthetic and analytical knowledge bases as in the food and

biotechnology industry since value chains are located within the region, involving synergy between SMEs.

5.2 RIS efficiency in selected of countries in transition

This research reveals an innovation paradox where regions with limited inputs were able to achieve better innovation outputs than regions with high innovations inputs. RIS efficiency ranking using data from the 2014–2021 identify regions with high investment in high-tech related activities as 'leading' regions. The RIS indicators, in terms of efficiency and productivity, demonstrate that RIS are widely under-exploited in Africa and Central Asia due to lack of enabling environment and culture of innovation. Results reveal that regions with fewer resources devoted to innovation achieve outstanding levels of efficiency and regions with sound innovation systems do not show high efficiency levels. Regions like GCC and Eastern Europe devoted large amounts of resources to R&D and innovation are the regions which enjoy sound ecosystem of RIS. On the other hand, regions like Eastern Africa which have limited resources achieve better results in terms of efficiency. Research showed that the higher a region's technological level, the greater the need is for coordination of the innovation system as argued by Georghiou (2001).

This study found that regions with limited synergy across sectors RIS efficiency were low compared with other regions with similar investments in innovation inputs based on GII including R&D and FDI.

It is observed that some regions are ranked as limited or moderate in stage one innovation efficiency in the input-oriented model, but they become high or limited in stage two. This means that some regions invest in R&D, but the outcome is limited. On the other hand, some regions can transform R&D into products and services (high stage efficiency in stage two). This implies that some regions can leapfrog and catch up in innovative performance due to shifts in policies and investment priorities.

5.3 Policies to foster RIS innovation of countries in transition

National innovative capacity focuses on investment and policy choices by the government and the private sector to foster innovation performance. Key policies include IP protection and openness to international trade and human capital investment in science and engineering which are critical for enhancing efficiency of innovation. Moreover, inputs devoted to innovation such as R&D expenditure and human capital contribute to enhance efficiency of RIS. However, regions won't catch the wave of financial potential outcomes unless the ecosystem of innovation is adequate. A nation like Estonia has seen quick improvement with quick economic development (Iammarino et al., 2017).

In stage one, the productivity has risen for the African region from 0.928 to 1.173 in stage two. However, overall, productivity was observed as declining to 0.641. African nations contribute an extremely low number of articles, even though Kenya shows up in the positioning in the 48th position (Merigo et al., 2016). This study shows that in the Input-oriented model, the best average was the Central Asian region since its average was 0.872 which was observed as a moderate indicator, but it was ranked the highest region among all in the input-oriented model.

6 Policy implications and recommendations

The analysis of RIS indicators reveals that a set of factors contribute to the RIS ecosystem. The research shows the value of ensuring an interactive learning process to enable regions to make a transition from being innovative adopters to producers. The input in RIS efficiency, like R&D expenditures and human capital, are key to improving innovation indicators. Hence, countries should invest in capacity building and upgrading skills to create knowledge.

Research shows that funding is likely to be allocated to regional economies with competitive regional clusters. The argument is that global funding and FDI favor nations and regions where high performance locational and production assets exist. The key conclusion was that as economic co-ordination becomes globalised the key dynamics within firms in industrial clusters become regionalised. In evolutionary economics, firms are differentiated entities since they harness knowledge as key input for their production. The future of the region's companies depends more and more on their capacity to establish global links to form competitive advantage by adopting incremental innovation to foster knowledge diffusion and learning.

RIS efficiency analysis reveals that the innovation system is an open system that is the result of social interaction and consists of elements that interact in production, dissemination, and growth of new knowledge. Hence, sustaining a learning culture requires adequate institutions to ensure having 'learning institutions' and avoid 'lock-in'. This research shows variations in RIS efficiency and productivity due to the differences in the balance between FDI and large or small firms within the region. Regions in transition in this research are characterised by a concentration of pools of skilled labour and relative expenditure on R&D.

The analysis showed the importance of education in the innovation process. However, the question of how labour markets and human capital function within the RIS requires deeper investigation. One area of future research would be examining the role that human capital plays in shaping the absorptive capacity and performance of innovation. Practically, the possibility of attracting human capital to a particular location depends on market and policy conditions.

Specifically, for the GCC region, an investment was made to establish many universities to support innovation since universities are vital in facilitating knowledge transfer and fostering the innovative capacity of a region. The research recommends that regions in transition should enhance the innovative national capacity to produce and commercialise technologies. National innovative capacity focuses on a series of investment and policy choices by the government and the private sector that influence the incentives for research development and marketing activities in a country, which influence productivity. It was found that public policy is critical in determining the national innovative capacity. Therefore, policies for IP protection and openness to international trade and human capital investment in science and engineering are critical for enhancing innovation efficiency. Moreover, inputs devoted to innovation such as R&D expenditure and human capital contribute significantly to developing the innovation capacity of a country or a region.

7 Contribution to innovation policy

This research contributes to innovation policy reform for regions in transitions. It sheds light on how regions can catch up or leapfrog by proper investment in R&D and innovation inputs. Also, it shows the impact of globalisation on RIS efficiency. It showed that due to increased competition from the globalising economy there was a need to reform industrial policies in high-income countries like GCC, Central Asia, and Eastern Europe to be competitive. This research also contributes to practical application to enhance conditions of innovation for SMEs. This is in line with Asheim et al. (2003) who argued for the need for a more oriented system and pro-active innovation-led regional policy for SMEs. Hence, it is recommended that cooperation should be organised among the three actors of the triple helix, i.e., industry, university, and government to support creative environments and linkages of SMEs with R&D entities and a developing innovation oriented public sector. This research informs innovation policy in regions in transition like GCC which adopts diversification policy to make a shift to knowledge economy by adopting an entrepreneurial regional innovation system (ERIS) through different types of RIS like interactive network RIS and the globalised RIS.

This study revealed an innovation policy paradox which showed that regions with lower inputs have better innovation efficiency in outputs than regions with higher inputs. This implies that there is a need for deeper analysis of other contextual factors and dynamics that are not captured in GII.

8 Limitations of the study

The main limitations include the limited sections of regions in transitions and limited time frame. Also, GII is based on secondary data and future research may adopt mixed approaches to gain insights on the complex factors that contribute to RIS efficiency. Besides, the recommended policies are contextual and cannot be replicated. RIS efficiency analysis reveals that the innovation system is an open system that requires adequate institutions to ensure having 'learning institutions' and avoid 'lock-in'.

9 Future research

Future research may explore other regions in the developed nations like OECD and BRICS and assess efficiency with respect to SDGs like emerging technologies, food security, sustainability and climate change. Besides, future research may address the efficiency of small units of analysis including smart cities or industrial or financial zones.

Acknowledgements

This research is funded by Arabian Gulf University.

References

Aldhmour, F. and Doyle, E. (2023) 'Knowledge sharing of postgraduates online: the intention-behavior gap', *Information Sciences Letters*, Vol. 12, No. 2, pp.717–733, https://doi.org/10.18576/isl/120215.

Al-Khalifa, M., Al-Jayyousi, O., Mamlook, R. and Aldhmour, F. (2021) 'Assessing the ecosystem of innovation in GCC: policy implications and strategic directions', in Visvizi, A., Lytras, M.D. and Aljohani, N.R. (Eds.): *Research and Innovation Forum 2020. RIIFORUM 2020. Springer Proceedings in Complexity*, Springer, Cham, https://doi.org/10.1007/978-3-030-62066-0_29.

Alnafrah, I. (2021) 'Efficiency evaluation of BRICS's national innovation systems based on bias-corrected network data envelopment analysis', *J. Innov. Entrep*., Vol. 10, No. 26, https://doi.org/10.1186/s13731-021-00159-3.

Alshahrani, I., Al-Jayyousi, O., Aldhmour, F. and Alderaan, T. (2023) 'Towards understanding the influence of innovative work behavior on healthcare organizations' performance: the mediating role of transformational leaders', *Arab Gulf Journal of Scientific Research*, ahead-of-print, https://doi.org/10.1108/AGJSR-09-2022-0167.

Andrade, N. (2014) *Global innovation index: Innovation Trends and Report 2022, Global Innovation Index | Innovation Trends and Report 2022* [online] https://www.globalinnovationindex.org/gii-2022-report (accessed 14 May 2023).

Andrade, N. (2020) *Global Innovation Index: Innovation Trends and Report 2022, Global Innovation Index | Innovation Trends and Report* [online] https://www.globalinnovationindex.org/gii-2022-report (accessed 18 August 2024).

Andreoni, A. and Tregenna, F. (2018) 'Stuck in the middle: premature deindustrialization and industrial policy', *SSRN Electronic Journal*, DOI: 10.2139/ssrn.3269739.

Anouze, A., Al Khalifa, M. and Al-Jayyousi, O. (2024) 'Revaluating national innovation systems: an index based on dynamic-network data envelopment analysis', *Socio-economic planning sciences*, Vol. 95, https://doi.org/10.1016/j.seps.2024.102003.

Asheim, B. and Isaksen, A (1997) 'Location, agglomeration and innovation: towards regional innovation systems in Norway?', *European Planning Studies*, Vol. 5, No. 3, pp.299–330, DOI: 10.1080/09654319708720402.

Asheim, B.T. and Coenen, L. (2005) 'Knowledge bases and regional innovation systems: comparing Nordic clusters', *Research Policy*, Vol. 34, No. 8, pp.1173–1190, https://doi.org/10.1016/j.respol.2005.03.013

Asheim, B.T., Isaksen, A., Nauwelaers, C. and Tödtling, F. (2003) *Regional Innovation Policy for Small-Medium Enterprises*, Edward Elgar Publishing, Cheltenham, UK.

Baregheh, A., Rowley, J. and Sambrook, S. (2009) 'Towards a multidisciplinary definition of innovation', *Management Decision*, Vol. 47, No. 8, https://doi.org/10.1108/00251740910984578.

Bolsunovskaya, M., Kudryavtseva, T., Rudskaya, I., Gintciak, A., Zhidkov, D., Fedyaevskaya, D. and Burlutskaya, Z. (2023) 'Digital platform for modeling the development of regional innovation systems of Russian Federation', *International Journal of Technology*, Vol. 14, No. 8, pp.1779–1789, https://doi.org/10.14716/ijtech.v14i8.6843.

Braczyk, H. and Heidenreich, M. (1998) 'Regional governance structures in a globalized world, in Braczyk, H., Cooke, P. and Heidenreich, M. (Eds.): *Regional Innovation Systems*, pp.414–440, UCL Press, London.

Carlsson, B., Jacobsson, S., Holmén, M. and Rickne, A. (2002) 'Innovation systems: analytical and methodological issues', *Research Policy*, Vol. 31, No. 2, pp.233–245.

Chen, K. and Guan, J. (2011) 'Mapping the functionality of China's regional innovation systems: a structural approach', *China Economic Review*, Vol. 22, No. 1, pp.11–27, DOI: 10.1016/j.chieco.2010.08.002.

Cooke, P. (2003) *Strategies for Regional Innovation Systems: Learning Transfer and Applications*, United Nations Industrial Development Organization, Vienna.

Cooke, P. (2004) 'The role of research in regional innovation systems: new models meeting knowledge economy demands', *International Journal of Technology Management*, Vol. 28, Nos. 3–6, pp.507–533, DOI: 10.1504/IJTM.2004.005307.

Cooke, P. (2021) 'Systems of innovation and the learning region', *Handbook of Regional Science*, pp.835–852.

Cooke, P., Uranga, M.G. and Etxebarria, G. (1997) 'Regional innovation systems: institutional and organisational dimensions', *Research Policy*, Vol. 26, Nos. 4–5, pp.475–491, DOI: 10.1016/ s0048-7333(97)00025-5

Feng, Y., Zhang, H., Chiu, Y. and Chang, T. (2021) 'Innovation efficiency and the impact of institutional quality: a cross-country analysis using the two-stage meta-frontier dynamic network DEA model', *Scientometrics*, Vol. 126, No. 4, pp.3091–3129, DOI: 10.1007/s11192-020-03829-3.

Firsova, A. and Chernyshova, G. (2018) 'An analysis of efficiency of regional innovation systems taking into account the financing structure', in *Proceedings of the International Scientific Conference' Competitive, Sustainable and Secure Development of the Regional Economy: Response to Global Challenges' (CSSDRE 2018), Part of Series: Advances in Economics, Business and Management Research (AEBMR)*, Vol. 39, pp.417–422.

Fritsch, M. and Slavtchev, V. (2011) 'Determinants of the efficiency of regional innovation systems', *Regional Studies*, Vol. 45, No. 7, pp.905–918, https://doi.org/10.1080/ 00343400802251494.

Georghiou, L. (2001) 'Evolving frameworks for European collaboration in research and technology', *Research Policy*, Vol. 30, No. 6, pp.891–903, DOI: 10.1016/s0048-7333(00)00163-3.

Iammarino, S., Rodríguez-Pose, A. and Storper, M. (2017) *Why Regional Development Matters for Europe's Economic Future*, European Commission Directorate General for Regional and Urban Policy Working Paper, No. 7.

Isaksen, A., Trippl, M. and Mayer, H. (2022) 'Regional innovation systems in an era of grand societal challenges: reorientation versus transformation', *European Planning Studies*, Vol. 30, No. 11, pp.2125–2138, https://doi.org/10.1080/09654313.2022.2084226.

Janošec, A., Chmelíková, G., Blažková, I. and Somerlíková, K. (2024) 'Regional innovation systems as a remedy for structurally affected regions – empirical evidence from the Czech Republic', *Urban Sci*., Vol. 8, No. 88, https://doi.org/10.3390/ urbansci8030088.

Kuştepeli, Y., Gülcan, Y. and Akgüngör, S. (2013) 'The innovativeness of the Turkish textile industry within similar knowledge bases across different regional innovation systems', *European Urban and Regional Studies*, Vol. 20, No. 2, pp.227–242, https://doi.org/ 10.1177/0969776412448088.

Luongo, S., Sepe, F. and Del Gaudio, G. (2023) 'Regional innovation systems in tourism: the role of collaboration and competition', *Journal of Open Innovation: Technology, Market, and Complexity*, Vol. 9, No. 4, https://doi.org/10.1016/j.joitmc.2023.100148.

Markard, J. and Truffer, B. (2008) 'Technological innovation systems and the multi-level perspective: Towards an integrated framework', *Research Policy*, Vol. 37, No. 4, pp.596–615, DOI: 10.1016/j.respol.2008.01.004.

Merigo, J.M., Cancino, C.A., Coronado, F. and Urbano, D. (2016) 'Academic research in innovation: a country analysis', *Scientometrics*, Vol. 108, No. 2, pp.559–593, https://doi.org/10.1007/s11192-016-1984-4.

Moulaert, F. and Sekia, F. (2003) 'Territorial innovation models: a critical survey', Vol. 37, No. 3, pp.289–302, DOI: 10.1080/0034340032000065442.

Nurunnabi, M. (2017) 'Transformation from an oil-based economy to a knowledge-based economy in Saudi Arabia: the direction of Saudi vision 2030', *Journal of the Knowledge Economy*, Vol. 8, No. 2, DOI: 10.1007/s13132-017-0479-8.

Pradana, M., Pérez-Luño, A. and Fuentes-Blasco, M. (2020) 'Innovation as the key to gain performance from absorptive capacity and human capital', *Technology Analysis & Strategic Management*, Vol. 32, No. 7, pp.822–834, DOI: 10.1080/09537325.2020.1714578.

Samara, E., Kilintzis, P., Katsoras, E., Martinidis, G. and Kosti, P. (2024) 'A system dynamics approach for the development of a regional innovation system', *Journal of Innovation and Entrepreneurship*, Vol. 13, No. 1, pp.1–22, DOI: 10.1186/s13731-024-00385-5.

Sube, K., Belay, T., Hando, F. and Bayinesagn, A. (2025) 'Regional innovation system (RIS) as a means for development: policies, opportunities and challenges in Ethiopia', Vol. 14, No. 34, https://doi.org/10.12688/f1000research.159772.1.

Wong, H.Y. and Merrilees, B. (2008) 'The performance benefits of being brand- orientated', *Journal of Product & Brand Management*, Vol. 17, No. 6, pp.372–383, https://doi.org/10.1108/10610420810904112.

Yam, R., Lo, W., Tang, E. and Lau, A. (2011) 'Analysis of sources of innovation, technological innovation capabilities, and performance: an empirical study of Hong Kong manufacturing industries', Vol. 40, No. 3, pp.391–402, DOI: 10.1016/j.respol.2010.10.013.

Zabala-Iturriagagoitia, J., Jiménez-Sáez, F., Castro-Martínez, E. and Gutiérrez-Gracia, A. (2007) 'What indicators do (or do not) tell us about regional innovation systems', *Scientometrics*, Vol. 70, No. 1, pp.85–106, DOI: 10.1007/s11192-007-0106-8.

Zhang, C. and Wang, X. (2019) 'The influence of ICT-driven innovation: a comparative study on national innovation efficiency between developed and emerging countries', *Behaviour & Information Technology*, Vol. 38, No. 9, pp.876–886.