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THE BIDIRECTIONAL RELATIONSHIP BETWEEN HIGHER EDUCATION AND INNOVATION: EMPIRICAL EVIDENCE FROM MENA REGION

Abstract: *The purpose of this paper is to examine the bidirectional relationship between two sets of variables, higher education and training (eight indicators) and innovation (seven indicators), using the canonical correlation analysis (CCA). The study utilises data published by the World Economic Forum Reports for seven years (2012-2018) for a sample of 12 countries in the MENA area. CCA is used to analyse the relationship between the two sets of variables. It helps in the evaluation of the interchangeable relationships between the two sets of multiple variates. More in-depth analysis of the nature of such a relationship between the two sets of variables is provided through redundancy analysis to identify the percentage of the variance in each set that is interpreted by the other set, and the commonality analysis to determine the variance of canonical function that is due to unique or standard variables. Canonical analysis shows the causality between the two endogenous sets of variables. Also, the findings suggest that technology alone is not an antidote, while other factors might have a significant impact on innovation. Commonality analysis shows that the role of quality of management school in explaining the variation in canonical function of innovation in common with "quality of education system", "quality of math and science", "internet access", "training availability and "staff training produce"*

Keywords: *Higher Education and Training, Innovation, Canonical Correlation Analysis, Emerging Markets*

1. Introduction

Higher education plays an essential role in the economic development of countries worldwide. It is a fundamental and reliable axis to achieve prosperity and progress. Higher education institutions need help with many problems, including adherence to tradition, which is one of the obstacles to universities benefiting from innovation and technology. For example, innovation is likely to make a massive difference in our world as it can help to develop and overcome any new risks the world may face (Bates, 2009). According to Arima (2002), the needs of societies are continuously changing. Consequently, there is need to rethink university education's purpose education. Although higher education has evolved over the centuries to keep pace with changes in societies, it still needs to be improved for some curricula in addition to the development of new curricula where universities must adopt technology-based innovation in many educational materials to

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fill some gaps in higher education. Wildavsky et al. (2012, p. 1) pointed out that "higher education has to change. It needs more innovation". The integration of modern information technology-based innovation in educational processes helps to acquire knowledge easily. Therefore, educational institutions can meet the needs of the labour market with qualified graduates (Cai et al., 2019). In this regard, Gourova et al. (2014) concluded that higher education institutions play an exclusive role to their customers including public and private firms through the transfer of knowledge. Such knowledge is essential for countries tilling to achieve advanced economies and prosperity for their people. This requires the availability of well-educated and well-trained workers to perform complicated tasks using advanced technology-based innovation that is rapidly adapted to their changing environment and evolving labour market needs. Several studies have addressed the relationship between higher education and innovation from one direction (Goddard &Vallance, 2013; Etzkowitz, 2013; Buasuwan, 2018; Cai et al., 2019; Cai et al., 2020).

The current study investigates the bidirectional relationship between higher education and innovation, in addition, it provides a deep analysis of the nature of such relationships using unique analyses namely, the canonical correlation, redundancy, and commonality analyses. In this regard, we considered the main ideas for both social cognitive theory and constructivist theory by selecting eight indicators for higher education & training factors. The nature of these indicators is related to the external environment and personal aspects such as "quality of the education system", "quality of math and science education", "quality of management schools", "Internet access in schools", "local availability of specialized training services" and "extent of staff training". The above-mentioned indicators have been suggested by the World Economic Forum (WEF) to reflect the competitive characteristics of countries. Furthermore, the study calls to apply technology-based innovation to improve higher education as a new stream for the future. Such a stream can affect the ability to innovate because it reflects the extent to which professional researchers can benefit from technology in creating new ideas, ways, or new products and moreover, its effects on labour market efficiency (Billon et al., 2017; Yunis et al., 2018).

Our study has unique characteristics over previous studies. First, it provides evidence of the bidirectional relationship between higher education & training set and innovation set. Whereas, previous studies, (Thor, 2011, Cai and Liu, 2015; Cai et al., 2020) on higher education and innovation, have examined the relationship between the two sets of variables from one direction. Second, this study uses a sample of 12 Middle Eastern countries that suffer from the lack of studies in this area of research, therefore, it provides a valuable contribution to the field of higher education & innovation. Third, the study uses a set of distinct measures to estimate higher education & innovation by adopting eight variables for the higher education & training set and seven variables for the innovation set. These two sets of variables have been suggested by the WEF to reflect the competitive advantages of each country which makes a clear difference between the current study and previous studies. Moreover, the data related to these variables have been collected by international organizations with a distinguished global reputation such as International Monetary Fund (IMF); the World Bank; and various United Nations' specialized agencies which provide a high level of accuracy for such data. Fourth, the current study employs the canonical correlation analysis, as a unique statistical method to explore the bidirectional relationship between higher education & training set and innovation set in a sample of 12 the Middle East and North African countries (MEAN), and to determine the most common factors in each set and the percentage of the variance explained in each variable over the other. Moreover, it the redundancy, and commonality analyses to identify the percentage of variance and such variance is due to unique or common variables. Fifth, the results of our study may provide some avenues for regulators in MEAN countries to support both education and innovation in educational institutions, which has the greatest impact on the economic development of these countries and the achievement of a higher level of well-being for their people.

We are motivated to focus on MEAN by using a sample of 12 countries namely, Bahrain, Cyprus, Egypt, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Turkey, United Arab Emirates and Yemen. for several reasons. First, these countries have a common heritage of history, culture, trade relations and economic conditions, which makes the study sample is coherent and consistent. Secondly, these countries suffer from a shortage in the number of studies related to higher education and innovation, unlike most developed countries. Third, MEAN countries are a model for both developing countries and emerging markets as well. Since these countries are characterized by being attractive to foreign investment, the results of this study may be of interest to many different parties inside and outside these countries. The structure of the current study is as follows. Section 2 presents a literature review and hypotheses development. Section 3 offers details on the research methodology. The section shows data analysis and results. Section 5 concludes the study.

2. Literature Review and Hypotheses Development

2.1. The Impact of Higher Education & Training on Innovation

The topic of the university's role in creating innovation within societies is receiving a great and increasing attention, as the education reform process requires the interaction and integration of universities in their society with industry and other actors to enhance innovation (Mowery & Sampat, 2005; Etzkowitz, 2013). The educational system is one of the most important elements of the innovation system in any country. The effectiveness of the educational system depends on a range of factors including human resources and linking the adequacy of the education system with the requirements of the economy, nationally in particular and globally in general. For example, in China, Cai and Liu (2015) examined the effect of universities' role in innovation systems by considering universities' engagement with society to promote innovation systems. Magno and Sembrano (2007) argued that innovation is the ideas or methods conceived by innovators, then turned these ideas into new practices in recent years. Therefore, innovation is a tool that can be used by higher education institutions to adopt the requirements of societies and students to bring new changes in educational practices through the adoption of modern technology. There are different forms of educational innovations including innovative models of education; new textbooks and programs; new or improved learning technologies (such as distance or online learning and Internet technology); updating the content of the curriculum; new teaching technologies; ideological innovation; scientific and methodological innovation; managerial innovation and others. (Zhu, 2015; Buasuwan, 2018).

Universities are facing pressure from many external parties including the government and the public to change their strategy and adopt new policies that can enhance innovation in university education (Cai, 2017). Thus, to understand the innovation process in universities, Musselin (2007, p. 317) reported that "one has to take 'two speeds' of change into account". Lundvall (2013, p. 33) pointed out that "as one that starts with combining elements of existing knowledge and ends with new knowledge as an important output". This process is linked with the knowledge that can be gained by educational organisations therefore innovative ideas need educational interaction and good implementation of these ideas needs a learning process carried out by scientific bodies with accumulative experience in the field of innovations (Cai, 2017). Finally, Armstrong and Taylor (2000) identified several effects of the universities in their societies related to economic development in both the short and long term such as improving the quality of labour by providing quality skilled graduates and skilled workers to labour markets; and skilled staff to provide expert advice to regulators and agencies; enhancing the cultural and economic developments. Based on the above discussion, the first hypothesis is suggested as follows:

H1: Higher education & training has a significant impact on innovation.

2.2. The Impact of Innovation on Higher Education & Training

According to Rogers (2003, p. 22), innovation is "the degree to which an individual or other unit of adoption is relatively earlier in adopting new ideas than other members of a system". Braak (2001, p.144) also described innovativeness as "a relatively stable, socially - constructed, innovation-dependent characteristic that indicates an individual's willingness to change his or her familiar practices". However, Goddard & Vallance (2013) argued that innovation in higher education is part of an intertwined and connected social system, and universities of course are part of this system, then innovation in higher education is seen as a response to changes in society and the economic system where universities play a vital through managing and transferring the knowledge economy. In this avenue, Billon et al. (2017) argued that innovations are the result of interactions between a range of socio-economic factors as well as research and development activities. Therefore, the economic and social development of societies affects the innovation process in higher education (Goddard & Vallance, 2013). Etzkowitz and Leydesdorff (1997) determined three main elements of the innovation system. Such elements are industry, university, and government. Innovations in higher education aim to have long-term effects. For example, universities are becoming increasingly intertwined with and supportive of industrial innovation (Etzkowitz, 2003) similar argument was provided by Wang (2014).

Furthermore, Makori et al. (2013) reported that technology-based innovation is one of the most influential factors in societies and institutions, including educational institutions, especially in the twenty-first century with the knowledge-based economy. The concept of technology-based innovation reflects programs and services related to the circulation of information over the Internet, simulations and others. The process of integrating technology-based innovation with the educational process aims to take advantage of different technologies in transferring educational experiences through social networks, distance education, blogs and e-learning. Integrating technology with education increases innovation opportunities (Baer and McCormick, 2012). Technology-based innovation is the main driver of economic growth, social development of people and good performance of business enterprises (Yunis et al., 2018). Such an argument is consistent with the European Commission (2010) which pointed out that the economic prosperity of the people of the European Union is fundamentally dependent on innovation and technology. Because they are sources of competitive advantage associated with local knowledge creation and knowledge diffusion that may increase competitiveness and economic growth at the regional level (European Commission, 2010). Innovations and technology services are commodities whose demand is positively affected by a combination of economic factors such as household income, gross domestic product (GDP) and unemployment (Vicente and López, 2011; Neokosmidis et al., 2015).

Furthermore, Zhu (2015) conducted survey research among six Chinese universities to examine the association between organisational culture and technology as well as, the implementation of innovation factors. The major finding of Zhu's study is that organisational culture has a significant impact on using technology in higher education, including online learning. Isleem (2003) investigated the use of technology-based innovation for educational purposes in "Ohio public schools" focusing on several factors such as the level of technology used by teachers, attitude, and the characteristics of teachers. The main finding of Isleem's study is that the greater the experience of the teacher with the computer, the greater his or her appetite for using the computer over teachers who lack the experience to deal with computers. Makori et al. (2013) examined the use of technology-based innovation in higher education, in two Kenyan universities, using different research methods such as a survey, interviews and document analysis. They revealed that where graduates lack the relevant technology knowledge and skills, there is an urgent need for technology-based innovation to be integrated with higher education to meet the demands of the job market. According to above discussion, the second hypothesis is established as follows:

H2: Innovation has a significant impact on higher education & training.

3. Research Methodology

3.1. The Impact of Innovation on Higher Education & Training

CCA can be used "when you wish to analyse the relationship between two sets of variables" (Pallant, 2013, p. 102). It helps in the evaluation of the interchangeable relationship between two sets of multiple variates. It is a method of giving meaning of cross-covariance matrices (Hair et al., 2010). The main objective of CCA is to identify the best linear combination between the two sets of data that maximizes the linear correlation between them. One is a linear combination of the variates of the first set, and the other is a linear combination of the variates in the second set. Such that, If there are two sets of variates with each set consisting of two or more variates "$X=(x_1,\dots,x_i)$" and "$Y=(y_1,\dots,y_j)$", i and j the numbers of variates in each set, the CCA can find the orthogonal linear transformation of X and Y that have the highest correlation coefficients with each other, if we have "$U=a'X$" and "$V=b'Y$". The highest number of canonical functions that can be found equals the minimum variates in any set $\min(i,j)$ (Stevens, 1996; Hair et al., 2010; Warner, 2008).

In the present study, CCA is used to identify the inter-relation between the two sets of variables. First set is "higher education & training" that includes eight variates namely, "secondary education enrolment rate gross % (SEER)"; "tertiary education enrolment rate gross % (TEER)"; "quality of the education system (QOES)"; "quality of math and science education (QMSE)"; "quality of management schools (QOMS)"; "internet access in schools (IAIS)"; "local availability of specialized training services (LAST)" and "extent of staff training (EOST)". The second set is "innovation" that includes seven variates namely, "capacity for innovation" (CFIN); "quality of scientific research institutions" (QSRI); "company spending on research and development (R&D)" (CSRD); "university-industry collaboration in R&D" (UCRD);"Gov't procurement of advanced technology products" (GPAT); "availability of scientists and engineers" (ASAE); and "patent applications" (PATA). Since the present study has two sets of variates where the first set has seven variates and the second with eight variates, therefore the number of canonical functions is equal to the number of variates in the smaller set (min(7,8)=7). All the analyses in the present study were done using the package CCA in R-software (http://cran.r-project.org/).

Table 1. Higher education & training (the first set)

The first set: Higher education & training ("X")			
No.	Variable	Notation	Description
1	"Secondary education enrolment rate gross percentage" (hard data)	SEER "X1"	"According to the World Bank's World Development Indicators, this corresponds to the ratio of total enrolment, regardless of age, to the population of the age set that officially corresponds to the secondary education level."
2	"Tertiary education enrolment rate gross percentage" (hard data)	TEER"X2"	"According to the World Bank's World Development Indicators, this corresponds to the ratio of total enrolment, regardless of age, to the population of the age set that officially corresponds to the tertiary education level"
3	"Quality of the education system"	QOES"X3"	"How well does the educational system in your country meet the needs of a competitive economy? [1 = not well at all; 7 = very well]"
4	"Quality of math and science education"	QMSE"X4"	"How would you assess the quality of math and science education in your country's schools? [1 = poor; 7 = excellent – among the best in the world]"
5	"Quality of management schools"	QOMS"X5"	"How would you assess the quality of management or business schools in your country? [1 = poor; 7 = excellent – among the best in the world]"
6	"Internet access in schools"	IAIS"X6"	"How would you rate the level of access to the Internet in schools in your country? [1 = very limited; 7 = extensive]"
7	"Local availability of specialized training services"	LAST"X7"	"In your country, to what extent are high-quality, specialized training services available? [1 = not available; 7 = widely available]"
8	"Extent of staff training"	MOST"X8"	"To what extent do companies in your country invest in training and employee development? [1 = hardly at all; 7 = to a great extent]"

Source: "Global Competitiveness Report (from 2012 to 2018). "World Economic Forum"; available at: https://www.weforum.org"

3.2. Data Collection and Sample Size

Our sample includes 12 countries from MEAN area namely, Bahrain, Cyprus, Egypt, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Turkey, United Arab Emirates and Yemen. Data needed for variables of the study (set 1: "higher education and training" and set 2: "innovation") were collected from WEF Reports covering the period from 2012 to 2018. These variables are pillars of the Global Competitiveness Index (GCI) that was established by WEF.

3.3. Measurement of the variables of the study

The measurement of two sets of variables used in this study is based on the data collected from "Global Competitiveness Reports" related to seven years (from 2012 until 2018) that established by WEF through GCI. Details on these sets and their variables are shown in Tables 1 & 2.

Table 2. Innovation (the second set)

The second set: Innovation ("Y")			
No.	Variable	Notation	Description
1	"Capacity for innovation"	CFIN"Y1"	"In your country, companies obtain technology (1 = exclusively from licensing or imitating foreign companies, 7 = by conducting formal research and pioneering their own new products and processes)"
2	"Quality of scientific research institutions"	QSRI"Y2"	"Scientific research institutions in your country (e.g., university laboratories, government laboratories) are (1 = nonexistent, 7 = the best in their fields internationally)"
3	"Company spending on R&D"	CSRD"Y3"	"Companies in your country (1 = do not spend money on research and development, 7 = spend heavily on research and development relative to international peers)"
4	"University-industry collaboration in R&D"	UCRD"Y4"	"In the area of R&D, collaboration between the business community and local universities is (1 = minimal or nonexistent, 7 = intensive and ongoing)"
	"Government procurement of advanced technology products"	GPAT"Y5"	"In your country, government procurement decisions result in technological innovation (1 = strongly disagree, 7 = strongly agree)"
6	"Availability of scientists and engineers"	ASAE"Y6"	"Scientists and engineers in your country are (1 = nonexistent or rare, 7 = widely available)"
7	"Patent applications" (hard data)	PATA"Y7"	"Number of utility patents (i.e., patents for invention) granted between Beginning of year, January 1, to end of year, December 31, per million population"

Source: "Global Competitiveness Report (from 2012 to 2018). "World Economic Forum"; available at: https://www.weforum.org"

4. Data Analysis and Results

4.1. Descriptive Analysis

Descriptive statistics are given in Table 3 below. The average, median, standard deviation (SD) and skewness and kurtosis for all variables in both sets ("Education" and "innovation") are provided. The highest mean score is for SEER (89.514) and TEER (35.624) while the mean score for other variables is almost the same and with low score. Also, most variables' distribution is nearly symmetric where the value of skewness near zero except for SEER (-1.212) and PATA (1.458).

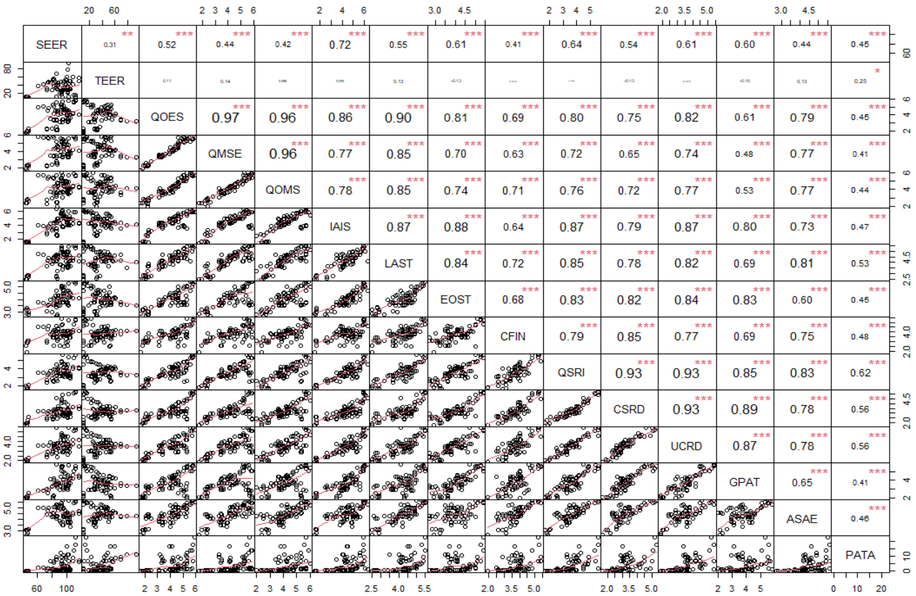
Table 3. Descriptive statistics for the two sets of the study

Variables	**Mean**	**Median**	**SD**	**Skewness**
SEER	89.514	92.30	16.813	-1.212
TEER	35.624	33.15	17.477	0.580
QOES	4.027	4.20	1.138	-0.413
QMSE	4.171	4.20	1.142	-0.275
QMOS	4.250	4.30	1.002	-0.207
IAIS	4.358	4.40	1.205	-0.702
LAST	4.230	4.30	0.774	-0.471
EOST	4.048	4.00	0.687	0.109
CFIN	3.817	3.80	0.720	0.124
QSRI	3.617	3.60	0.920	0.109
CSRD	3.258	3.10	0.797	0.771
UCRD	3.560	3.60	0.838	0.182
GPAT	3.754	3.70	0.989	0.315
ASAE	4.432	4.40	0.688	-0.376
PATA	4.168	1.70	4.977	1.458

4.2 The Correlation Analysis

Figure 1 shows a visualisation of correlation matrix between the two sets, 'higher education & training' and 'innovation'. In the bottom part, it shows the pair scatter plot with a fitted line, while it shows the (absolute) value of the correlation adding the result of correlation test as stars in the top part. There are strong and significant correlations between the two sets except for one, TEER, which has a weak and insignificance correlation with other variables. The highest correlation is 0.97 (QOES and QMSE), followed by 0.96 (QOES and QMSE and QMSE and QMOS). This high correlation between the two sets supports making further CCA analysis to find out the interaction between "higher education & training" and "innovation".

Correlation between the two sets supports making further CCA analysis to find out any interaction between "higher education & training" and "innovation".



Note: ***significant at 0.001, **significance at 0.01, *significance at 0.05
Correlation matrix between "higher education & training" and "Innovation"

Figure 1. A visualization of correlation matrix between the two sets Measuring statistical significance of the CCA

4.3 Measuring statistical significance of the CCA

Table 4 shows the canonical correlation (CanR) between the two sets and the p-value (Pr>F) to test if the canonical correlations in the current row and all that follow are zero (Dattalo, 2014). The results of p-values confirm that there are significant four canonical correlations where the p-value is less than 0.05, therefore, the null hypothesis is rejected.

Moreover, the first column, which shows the strength of the relationships, indicates that the strength of the relationship between first pair of canonicals (X_1,Y_1) is 0.93, the second pair of canonicals (X_2,Y_2) is 0.86, the third pair canonicals (X_3,Y_3) is 0.71 and it is 0.50 for the last significant pair of canonicals, (X_4,Y_4).

Table 4. Assessment of the overall model fit

CanR	LR test stat	approx F	num DF	den DF	(Pr>F)
0.93	0.01	8.82	56	376.89	0.00
0.86	0.08	5.71	42	331.78	0.00
0.71	0.31	3.28	30	286.00	0.00
0.50	0.61	1.93	20	239.75	0.01
0.37	0.81	1.35	12	193.43	0.19
0.25	0.93	0.88	06	148.00	0.51
0.06	1	-	02	-	-

Findings on Table 4 show that there are four significant canonical correlation (p-value < 0.01). Therefore, H 1 and H 2 can be accepted. These results suggest that both sets impact each other and a bidirectional relationship exists. Therefore, the development or change in any set must be seen through the other set. Further analyses have been conducted in the next section to provide more explanations on the nature of the relationship between the two sets and to identify the main players in each set.

4.4 Standardized and Loading Values

To determine the importance of individual variables within each set, we computed the canonical correlation functions as shown in Table V. Then, standardized and loading values were estimated in Tables 6 and 7 as presented below.

Table 5 illustrates the estimates of CanR, square of canonical correlation (CanRSQ), eigen, percent and cumulative of CCA. It is found that the first canonical correlation is about 0.93 that representing 85.9% (canRSQ) of the amount of variance in the first canonical function for the first set accounted for through the first canonical function. In the second set, the estimates of canonical correlation are about 0.86. There is 74.6% of the amount of variance in the second canonical function for the first set accounted for through the second canonical function in the second set and so on. The eigen value represents the shared variance between two canonical functions. There are 57.61% of shared variance for the first canonical functions while it is 27.77% for the second function the shared variance and so on. In total, the first four canonical functions have shared variance of 97.85% (Cumulative).

Table 5. The estimate of the canonical correlation functions

No. of functions	CanR	CanRSQ	Eigen	Percent	Cumulative
1	0.927	0.859	6.083	57.61	57.62
2	0.863	0.746	2.931	27.77	85.38
3	0.706	0.498	0.992	09.39	94.78
4	0.495	0.245	0.325	03.08	97.86
5	0.365	0.133	0.154	01.45	99.31
6	0.253	0.064	0.068	00.65	99.96
7	0.062	0.004	0.004	00.04	100.00

The standardized canonical coefficients, which can be used to reflect the relative importance of the original variates in each canonical function (Chew and Dillon, 2014), are presented in Table 6 below. Regardless the sign of the first canonical function (Xcan1), it can be considered the most important variables in the first set, IAIS (-0.525), followed by QMSE (0.522), then QOES (-0.457), LAST (-0.383), QOMS (-0.186), SEER (-0.146), TEER (0.142) and EOST (0.122).

Table 6. Standardized Coefficients for Higher Education & Training (First Set)

Variables	Xcan1	Xcan2	Xcan3	Xcan4
SEER	-0.146	0.143	0.282	-0.081
TEER	0.142	-0.160	-0.326	-0.995
QOES	-0.457	-0.132	0.814	0.021
QMSE	0.522	-0.800	-2.139	1.117
QOMS	-0.186	-0.066	2.621	-0.707
IAIS	-0.525	0.139	-1.609	1.106
LAST	-0.383	-0.582	-0.117	-0.330
EOST	0.122	1.212	0.360	-1.148

Regardless the sign of the first canonical function (Ycan1), it can be considered the most important variable in the second set, QSRI (-0.753), followed by CSRD (0.437), then UCRD (-0.432), GPAT (-0.218), ASAE (0.066), PATA (0.066) and CFIN (-0.017) as shown in Table 7.

Table 7. Standardized coefficients for innovation (second set)

Variables	Ycan1	Ycan2	Ycan3	Ycan4
CFIN	-0.017	-0.139	0.514	-1.259
QSRI	-0.753	0.194	-0.804	0.764
CSRD	0.437	0.482	2.642	1.772
UCRD	-0.432	-0.710	-0.075	-0.434
GPAT	-0.218	1.222	-1.390	-0.737
ASAE	-0.088	-1.098	-0.666	0.297
PATA	0.066	-0.022	-0.280	-1.074

In Table 8, the canonical loadings have been increasingly used to interpret CCA (Härdle and Simar, 2007). They measure the linear correlations between observed variate the h or k sets and the set's canonical function. The square of loading coefficients reflects the variance of the original variate shares with the canonical function. The loading coefficients identify the important contribution of any variate to each canonical function (Huang et al., 2009).

The highest the coefficient, the more important it has in obtaining the canonical function. From Table IIX, regardless the sign of loading coefficients, it can be concluded the most important variables in the first set are IAIS (-0.978), followed by LAST (-0.923), then EOST (-0.912), QOES (-0.884), QOMS (-0.813), QMSE (-0.793), SEER (-0.706) and TEER (-0.003). Results of Table IIX suggest that the most important factors in higher education & training set are the availability of both the Internet and specialized training centers and the quality of the education system.

Table 8. Loading coefficients of higher education & training (first set)

Variables	Xcan1	Xcan2	Xcan3	Xcan4
SEER	-0.706	0.158	-0.239	-0.264
TEER	-0.003	-0.472	-0.380	-0.743
QOES	-0.884	-0.341	0.161	0.013
QMSE	-0.793	-0.494	0.163	0.059
QOMS	-0.813	-0.411	0.343	-0.009
IAIS	-0.978	0.010	-0.131	0.006
LAST	-0.923	-0.239	0.044	-0.145
EOST	-0.912	0.242	0.158	-0.098

Regardless the sign of loading coefficients in the second set, it can be concluded from Table 8 that the most important variables in the second set are QSRI (-0.979), followed by UCRD (-0.962), CSRD (-0.910), GPAT (-0.886), ASAE (-0.829), CFIN (-0.761) and PATA (-0.538). Results of Table 9 suggest that the most important factors in innovation set are the availability of both specialized scientific research centres and the company's spending on research and development of products, as well as the reliance of scientific research on joint cooperation between the university and industry.

Table 9. Loading coefficients of innovation (second set)

Variables	Ycan1	Ycan2	Ycan3	Ycan4
CFIN	-0.761	-0.110	0.458	-0.285
QSRI	-0.979	-0.012	0.095	-0.035
CSRD	-0.910	0.099	0.342	-0.012
UCRD	-0.962	0.006	0.152	-0.038
GPAT	-0.886	0.381	0.017	-0.009
ASAE	-0.829	-0.433	0.029	0.052
PATA	-0.538	-0.101	0.030	-0.605

Figure 2 shows the biplot for the two canonical functions and their variables in terms of loading values. The furthest away these loading values or arrows from origin (0,0), the more impact the variable has on its canonical function. Also, Figure II shows that the impact of the two sets is in the same direction. For the education set ("X"), IAIS has the highest impact followed by EOST while, there is no impact for TEER variable. For the second set, the QSRI has the highest impact followed by UCRD, while PATA has the least impact. One of the most important implications of Figure II is all variables of higher education & training set have a high correlation with first canonical function except for TEER variable. In addition, all variables in innovation set have a high correlation with first canonical function. Such finding supports the impact of each set on the other.

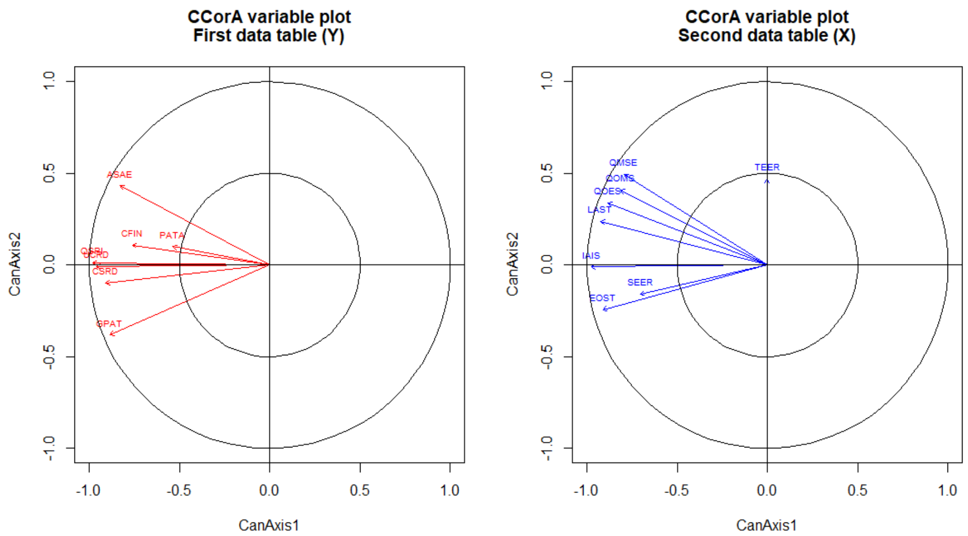


Figure 2. Biplot of the two canonical functions and their variables

4.5 Cross-loading

To identify the importance of one canonical correlation on another, first, we computed cross-loading in each set (higher education and innovation) in Tables 10 and 11. Second, we measured loading coefficients of each set with the other set canonical function in Tables 10 and 11 as follows. In Table X, regarding the sign of loading coefficients, it can be considered the most important variables in the first set that have correlated with second set (first canonical function) are IAIS (-0.906), followed by LAST (-0.855), then EOST (-0.845), QOES (-0.820), QOMS (-0.753), QMSE (-0.735), SEER (-0.654) and TEER (-0.003).

Table 10. Cross Loading coefficients of the first set with second set canonical function

Variables	Ycan1	Ycan2	Ycan3	Ycan4
SEER	-0.654	0.137	-0.169	-0.131
TEER	-0.003	-0.407	-0.268	-0.368
QOES	-0.820	-0.294	0.113	0.006
QMSE	-0.735	-0.427	0.115	0.029
QOMS	-0.753	-0.355	0.242	-0.005
IAIS	-0.906	0.009	-0.092	0.003
LAST	-0.855	-0.207	0.031	-0.072
EOST	-0.845	0.209	0.111	-0.048

Table 11. Cross Loading coefficients for the second set with first set canonical function

Variables	Xcan1	Xcan2	Xcan3	Xcan4
CFIN	-0.705	-0.095	0.323	-0.141
QSRI	-0.908	-0.010	0.067	-0.017
CSRD	-0.843	0.085	0.242	-0.006
UCRD	-0.892	0.005	0.108	-0.019
GPAT	-0.821	0.329	0.012	-0.004
ASAE	-0.768	-0.374	0.021	0.026
PATA	-0.498	-0.087	0.021	-0.300

Regardless the sign of loading coefficients, Table 11 leads to consider that the most important variables in the second set that correlated with first set (first canonical function) are QSRI (-0.908), followed by UCRD (-0.892), then CSRD (-0.843), GPAT (-0.821), ASAE (-0.768), CFIN (-0.705) and PATA (-0.498).

4.6 Redundancy Analysis

According to Dattalo (2014) and Jendoubi and Stimmer (2018), when using the CCA, the redundancy index is used to do the same function of the R-square in regression analysis. This index is the percentage of variance in the original variates of one set that is interpreted by the canonical function of the other set. High redundancy index proposes a high ability to forecast. If there is a clear definition for independent and dependent sets, the researcher may use the redundancy index for independent canonical function in forecasting the variance in the set of original variates in the dependent set.

Table 12. Redundancy index of the two sets (education & innovation)

	Xcan1	**Xcan2**	**Xcan3**	**Xcan4**	**Xcan5**	**Xcan6**	**Xcan7**	**Total**
Redundancy index	0.559	0.083	0.025	0.020	0.004	0.002	0	0.695
	Ycan1	Ycan2	Ycan3	Ycan4	Ycan5	Ycan6	Ycan7	
Redundancy index	0.619	0.039	0.026	0.016	0.003	0.002	0	0.706

Table 12 illustrates the redundancy index for the two sets. It can be concluded that the canonical variates for the first set (higher education and training) can explain 69.5% of variance in the original variables for the second set (innovation), especially, the Xcan1 contributes 55.9%. Moreover, the canonical variates for the second set (innovation) explains 70.6% of variance in the original variables for the first set (higher education and training), especially, Ycan1 contributes 61.9%.

4.7 Commonality Analysis

Commonality analysis clarifies the canonical impacts made by using the signals in each canonical set to split the variance of canonical functions produced from the other canonical set. These canonical variates can be divided to unique and common impacts. “A canonical commonality unique effect is computed as a squared correlation between the canonical variate for a given canonical set and a variable of interest in the other canonical set. A canonical commonality common effect is computed as a squared correlation between the canonical variate for a given canonical set and the set of variables of interest from the other canonical set after subtracting all unique effects and the variance explained by any other sets of variables” (Nimon et al., 2010).

Table 13 below provides the splitting of higher education & training canonical first function by the variables in the innovation and the splitting of innovation canonical first function by the variables in the higher education & training indicators. The values point out “how much variance can be explained as unique or common by the variables” and the “% total” points out “the percentage of variance that can be illustrated out of the observed canonical impact”. It exposes that the higher education & training variables are explained by variance common to CFIN, QSRI, CSRD, UCRD, GPAT and ASAE (27.63%) of canonical impact, followed by CFIN, QSRI, CSRD, UCRD, GPAT, ASAE and PATA (21.92%). However, the unique support of these variables is very low. For example, the highest support is attributed to QSRI (0.0339), followed by UCRD (0.0152). Furthermore, it indicates that the innovation variate is explained by variance common to SEER, QOES, QMSE, QOES, QMSE, QOMS, IAIS, LAST, EOST (35.74%) of canonical impact, followed by QOES, QMSE, QOES, QMSE, QOMS, IAIS, LAST, EOST (24.39%) while, the unique support of these variables is very low. For example, the highest support is attributed to IAIS (0.0247), followed by LAST (0.0165).

Table 13. Commonality Analysis of education & innovation sets

Splitting of X canonical function				**Splitting of Y canonical function**			
	Unique	Common	% Total		Unique	Common	% Total
CFIN (y1)	0.0001	0.4973	0.4974	SEER (x1)	0.0061	0.4215	0.4276
QSRI (y2)	0.0339	0.7898	0.8237	TEER (x2)	0.0100	-0.100	0.0000
CSRD (y3)	0.0097	0.7008	0.7105	QOES (x3)	0.0032	0.8885	0.6717
UCRD (y4)	0.0152	0.77999	0.7951	QMSE (x4)	0.0055	0.5344	0.5399
GPAT (y5)	0.0067	0.6676	0.6743	QOMS (x5)	0.0018	0.5658	0.5676
ASAE (y6)	0.0118	0.5883	0.5901	IAIS (x6)	0.0247	0.7966	0.8213
PATA (y7)	0.0020	0.2462	0.2482	LAST (x7)	0.0165	0.7151	0.7316
				EOST (x8)	0.0014	0.7128	0.7142
Highest three commons		coefficients	% Total	Highest three commons		coefficients	% Total
y1, y2, y3, y4, y5 & y6		0.2373	27.63	x1, x3, x4, x5, x6, x7 & x8		0.3069	35.74
y1, y2, y3, y4, y5, y6 & y7		0.1882	21.92	x3, x4, x5, x6, x7 & x8		0.2095	24.39
y2, y3, y4 & y5		0.1024	11.93	x1, x3, x6, x7 & x8		0.0835	9.72

One of the interesting results is obtained by commonality analysis is the explained variance in innovation set is related to common variables instead of one unique variable while, the explained variance in higher education & training set is linked to common variables not a unique variable.

5. Conclusion

The study examines the bidirectional relationship between two sets of variables namely, higher education & training with eight indicators and innovation with seven indicators using the canonical correlation analysis through a sample of 12 MEAN countries. The main result of our study indicates that the canonical variates for the first set (higher education & training) explains 69.5% of variance in the original variables in the second set (innovation). The canonical variates for the second set (innovation) interprets 70.6% of variance in the original variables in the first set (higher education and training). The most important variables in the first set that correlates with second set in the first canonical function are "internet access in schools", followed by "local availability of specialized training services", then "extent of staff training, "quality of the education system, "quality of management schools, "quality of math and science education, "secondary education enrolment rate gross percentage and "Tertiary education enrolment rate gross percentage. The most important variables in the second set that correlates with first set in the first canonical function are "quality of scientific research institutions", followed by "University-industry collaboration in R&D", then "company spending on research and development", "government procurement of advanced technology products", "availability of scientists and engineers", "capacity for innovation" and "patent applications". All variables in higher education & training set have a high correlation with first canonical function except for "tertiary education enrolment rate gross percentage" variable. Further, all variables in innovation set have a high correlation with first canonical function. Our results have confirmed on the bidirectional relationship between higher education &training and innovation. Consequently, H 1 and H 2 are accepted.

Based on the redundancy analysis, the first canonical variate (Xcan1) for the first set (higher education & training) explains 55.5% of variance in the original variables for the second set (innovation), while all canonical variates explain 69.5%. Also, the canonical variate (Ycan1) for the second set (innovation) explains 61.9% of variance in the original variables for the first set (higher education and training), and in total, all canonicals explain 70.6%. Findings of the commonality analysis shows that the role of quality of management school in explaining the variation in canonical function of innovation (about 36%) in common with "quality of education system", "quality of math and science", "internet access", "training availability and staff training produce".

The current study, like other studies, have some limitations such as it considers only 12 MEAN countries. Therefore, it is recommended to extend it in a future study through the inclusion of other MENA countries which are ignored in the current study. In addition, the measurement of the variables is based on GCI that is established by WEF. Different measures and other variables can be used in future studies

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