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THE ROLE OF HUMAN RESOURCES IN REALIZING TECHNOLOGICAL PROGRESS: CAN INNOVATION FOLLOWERS BE ABLE TO CATCH-UP WITH INNOVATION LEADERS? [1]

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Abstract

The income and technological inequalities between countries can be derived from differences in country-specific conditions of technological progress. Innovation requires appropriate human resources and institutional environment, as well as firms to innovate. Differences in human, financial and institutional conditions create technology disparities which lead to innovation- and imitation-based economies with different economic performance. Technological changes in the economy are made possible by the creation and application of new knowledge. Therefore, technological progress can be interpreted as a specific form of knowledge accumulation, in which the human resources of the countries play a key role. In the 21st century, the third and then the fourth industrial revolution induce significant changes in the labor market. This research aims to illustrate the inequalities of innovation's human conditions between innovation leader and follower countries using quantitative analytical techniques. Based on this, we can conclude that effective labor market adaptation manifested in efficient formal education system and staff training, can create opportunities for innovation followers to catch-up with innovation leaders.

Keywords: technological progress; human resources; innovation leaders and followers

1. INTRODUCTION

Nowadays, we have to face with the challenges of the new techno-economic paradigm shift called fourth industrial revolution. This phenomenon induces fundamental changes in economic processes to which we have to adapt. The labor market is one of the most affected areas, where the most dramatic changes are expected. Many workplaces are in danger due to the new technologies, but at the same time, new jobs are required where people create innovations. So, the role of human resources is emphasized in this era, because people are able to create new ideas, and thus new technologies, while they have to adapt to the changed circumstances. Human capital is the set of skills and capabilities that enable people to create new ideas and to apply new technologies. The individual's abilities are shaped and expanded through learning, so human

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capital can be developed through formal and informal learning, as well as interaction between individuals (knowledge transfers). Simplified, innovation is the embodiment of knowledge gained through education and professional experience.

Emphasizing the role of human capital in technological progress, Caselli & Coleman (2006) pointed out that the technological differences between countries are due to the qualification asymmetry, because innovation requires more skilled workforce, while the less skilled workforce is suitable for imitation. By distinguishing the efficiency of skilled and unskilled labor, the authors can model the world technology frontier. At the frontier, the high-skilled workforce dominates, while far away from the frontier the qualified workforce is replaced by the less qualified one. In higher-income countries, there are more skilled workers, and therefore, these countries choose technology that requires high-skilled labor, whose labor productivity is higher. In contrast, lower-income countries choose technology that is better suited to the unskilled labor force which is better available to them. Several empirical studies confirm that the higher-income countries are typically technologically more advanced, their innovation activity is more intensive and they create the majority of the innovations, in contrast with the lower-income countries, which are typically technological followers, and can adapt new technologies through the imitation of technological leaders (Barro & Sala-i-Martin, 1997; Acemoglu, Aghion & Zilibotti, 2006; Basu & Weil, 1998; Jerzmanowski, 2006).

Most countries are unable to create new technologies because they do not have the appropriate physical and human resources, as well as the institutional environment does not favor to innovation. However, technological progress can also be observed in these countries, by adapting the new technologies developed and applied effectively elsewhere. Human capital is also essential for the creation and adaptation of technology, so human conditions determine the technological development path of the countries. This research aims to illustrate the inequalities of innovation's human resources conditions between innovation leader and follower countries using quantitative analytical techniques. Based on this, we try to answer the question whether innovation followers are able to catch up with innovation leaders. The new wave of technological progress creates an opportunity of reducing the technology gap between countries.

2. THE MAIN FEATURES OF TECHNO-ECONOMIC PARADIGM SHIFTS

The worldwide dynamic development of technology started more than 200 years ago, when the first industrial revolution began in Britain in the 18th century and from there spread to other parts of the world. This was a complex technological, economic and social change that distracted the economic thinking in a new direction. Based on the summarized empirical evidence of Williamson (2009:183), the standard of living in the countries of the world did not change prior to the Industrial Revolution and there were no large income differences among the countries either. Thus, economic growth and technological progress occur in close interaction. According to Mokyr (2004), the complementarity of radical innovations, i.e. macroinventions, and incremental innovations, i.e. microinventions, accounted for the enormous economic impact of Industrial Revolution, which launched not only technological progress, but also an increase in the income of the world's countries. The first inventions appeared in the British textile industry, mechanization in industry and agriculture also led to productivity gains, and finally, a qualitative change took place in all sectors of the economy. From the second half of the 19th century new revolutionary changes took place from the United States and Germany. There have been world-wide technological innovations in the steel industry, in chemistry and in electricity, while macroinventions appeared in new and more industries. A new era has begun with the invention of internal-combustion engines which has led to the recovery of transport and trade (Mokyr 2005). In the 1960s, the appearance of information and communication technologies in United States induced a new wave of technological progress mainly in the service sector, resulting fundamental structural change in the economy. Nowadays, we live in the era of the Fourth Industrial Revolution or Industry 4.0, in which the digitization, automatization and robotization process reorganizes the production systems. Big Data, internet of things (IoT), artificial intelligence, cyber-physical systems, 3D printing and robots are related to this revolution. We have to face new challenges, but at the same time new possibilities arise in the economy. Summarizing the potential impacts of industry 4.0, Kovács (2017) emphasized that this industrial revolution transforms our working and living conditions. Furthermore, the efficiency is improving, the new technologies can enhance the realization of sustainable and green economy and finally they generate overall productivity growth.

The scope of fourth industrial revolution is much wider than previous ones, technological changes are faster and they have more complex effects on the whole economy. This is illustrated by Schwab (2016:13) who pointed out that spindle (one of the main inventions of the first industrial revolution) took almost 120 years to spread outside of Europe while internet permeated across the world in less than a decade. Schwab (2016) identified the megatrends clustered by three groups (physical, digital, biological) which are the main drivers of the 4th Industrial Revolution. Based on this classification, there are four main physical manifestations of the technological megatrends, i.e. autonomous vehicles, 3D printing, advanced robotics and new materials. These new technologies can substitute the human resources in production process, because they are more efficient and make less mistakes than people. This will be the most important challenge in the labor market in the future. Unfortunately, many jobs may be disappeared due to the technological development. According to the estimation of Frey and Osborne (2013) about 47% of total US employment is at risk. The authors examined 702 jobs and they estimated that for example the work of telemarketers and library technicians with 99%, while accounting and credit analysts with 98% can be robotized within two decades. According to Chui et al. (2015), fewer than 5 percent of occupations can be entirely automated using current technology, however, about 60 percent of occupations could have 30 percent or more of their constituent activities automated. The World Economic Forum (2016) forecasted that 7.1 million jobs will be disappeared globally, while 2 million new ones will be created by the technological progress. This report estimated that more than a third of the knowledge and skills needed for current jobs to load changes within five years (will not be part of the knowledge currently in use longer needed, however, increases the demand for new skills specified). Szalavetz (2018:56) emphasized that the diffusion of new technologies also creates new workplaces. A significant employment growth is expected, for example, in manufacturers, service providers and installers of industrial robots, infrastructure providers of cyber-physical systems, including suppliers of security solutions for these systems. The number of people employed in business intelligence activities and cyber-physical production systems will increase. In sum, a significant rearrangement is expected in the labor market, which favors mainly the skilled workers with up-to-date knowledge.

Based on the above-mentioned findings, it can be stated that human resources and the labor market are particularly sensitive areas of technological changes. According to Andor (2018:47) it seems to be more difficult to reconcile the flexibility required by economic competition with the stability of employment and the quality of jobs and the exploitation of the possibilities of the technology with the need to maintain quality jobs and social cohesion. The society needs to be prepared to receive, process and evaluate the rapidly expanding amount of information and knowledge (Simai, 2018:94).

3. RESEARCH QUESTIONS, DATA AND METHODOLOGY

This research aims to illustrate the differences in human resources' conditions between innovation leader and follower countries. 35 European countries were involved in the analysis and they were classified into innovation performance groups based on Summary Innovation Index (SII). The European Innovation Scorecard provides data related to innovation performance of these countries. It assesses relative strengths and weaknesses of national innovation systems and helps countries to identify areas they need to develop. Until 2016, SII approached innovation from three sides, as innovation drivers or enablers, firm activities and outputs. There were 8 dimensions and 25 variables to describe the countries' innovation performance (Hollanders – Es-Sadki – Kanerva, 2016). In 2017 a refined analytical framework was presented, now the database contains more indicators (27) than the previous one, and these variables are classified into four main groups – framework conditions, investment, innovation activities and impacts – instead of the former three one (Hollanders-Es-Sadki, 2017). Based on SII, countries are classified into four innovation performance groups: innovation leaders, strong innovators, moderate innovators and modest innovators. According to EIS (2017) European countries[2] can be grouped as follows (the order fits for innovation performance):

- *Innovation leaders*: Switzerland, Sweden, Denmark, Finland, Netherlands, United Kingdom, Germany
- *Strong Innovators*: Iceland, Austria, Luxembourg, Belgium, Norway, Ireland, Israel, France, Slovenia
- *Moderate Innovators*: Czech Republic, Portugal, Estonia, Lithuania, Spain, Malta, Italy, Cyprus, Slovakia, Greece, Hungary, Serbia, Turkey, Latvia, Poland, Croatia
- *Modest Innovators*: Bulgaria, Romania, Ukraine

RESEARCH QUESTION 1

Are there any significant differences between innovation performance groups in the field of human resources?

Measuring country-specific human characteristics, variables from Global Competitiveness Index (GCI) created by World Economic Forum are used. Eight variables are selected which linked to human resources' conditions of technological progress. The *quality of primary education* is measured by a seven-point grading scale based on the opinion how responders assess this. The *quality of educational system*, the *quality of math and science education*, and the *quality of management schools* can be measured in the same way. These quality indicators are compiled on the basis of the World Economic Forum executives' answers, which are obtained in the form of questionnaire data collection. The quantitative side of human characteristics can be measured by *the enrollment rates* related to *the primary, secondary and tertiary education*. Based on the

[2] EIS (2017) includes the data of 36 countries, but Macedonia is excluded from the analysis, because it has no available data in Global Competitiveness Index in the field of human resources.

principle of lifelong-learning, employees have to learn at workplace too, so the *extent of staff training* variable is also included in this analysis.

Using non-parametric and parametric statistical methods, the human resources' conditions can be compared in innovation performance groups. The first step of the analysis is the normality test (Kolmogorov-Smirnov Test) in order to know that the distribution of variables is normal or not. This depends on how the means of the subfields can be compared. Parametric and non-parametric hypothesis testing also can be used to know is there a difference in human conditions between groups.

RESEARCH QUESTION 2
Whether countries belong to the same group based on their human resource characteristics as their aggregate innovation performance?

For this purpose, a multivariate statistical method based on group formation, i.e. discriminant analysis can be used to analyze the relationship between a nonmetric, nominal measurement level, a group-forming dependent variable, and independent metric variables. This method is also suitable for identifying variables that can significantly differentiate groups (Sajtos & Mitev, 2007). In the discriminant analysis, the stepwise method is used based on Wilks' Lambda and Mahalanobis method of distance, if we are also interested in the essential variables separating the groups (Obádovics 2004, 72). Applying this statistical method, one or more discriminant functions may be created using the indicators included in the analysis. These functions highlight the variables that have the most significant influence on belonging to the innovation performance groups.

4. EMPIRICAL RESULTS

As a first step of the analysis, I examined the normal distribution of variables (results in details in *Appendix 1*). Fortunately, the criteria of normality is met, so all eight indicators are appropriate for Independent-Samples T test. This statistical method was used to know whether there is a significant difference in the variables between the innovation performance groups. The method requires only two samples, so I tested the difference of means by group pairs. Firstly, I compared innovation leaders with strong innovators, then strong innovators with moderate ones and finally moderate innovators with modest ones. Results can be seen in *Table 1*, while descriptive statistics are found in *Appendix 2*.

Table 1
Results of the Independent-Samples T tests

Variables	***Between innovation leader and strong innovators***				***Between strong innovators and moderate innovators***				***Between moderate innovators and modest innovators***			
	Levene's Test for Equality of Variances		t-test for Equality of Means		Levene's Test for Equality of Variances		t-test for Equality of Means		Levene's Test for Equality of Variances		t-test for Equality of Means	
	F	Sig.	t	Sig. (2-tailed)	F	Sig.	t	Sig. (2-tailed)	F	Sig.	t	Sig. (2-tailed)
Quality of primary education	5,556	,034	1,218*	,255*	1,476	,237	2,867	**,009**	0,903	,355	0,680	,506
Primary education enrollment rate	4,223	,059	2,055*	,068*	,002	,967	,918	,368	3,602	,076	2,677	**,017**
Secondary education enrollment rate	,004	,951	1,003	,333	2,243	,148	1,695	**,104**	1,454	,244	1,609	,126
Tertiary education enrollment rate	,284	,602	,056	,956	,133	,719	,164	,871	,006	,937	-,103	,919
Quality of the educational system	,071	,793	2,136	**,051**	,000	,989	4,395	**,000**	,179	,678	0,723	,480
Quality of math and science education	3,196	,095	1,559	,141	1,028	,321	2,953	**,007**	0,164	,691	-0,371	,715
Quality of management schools	,240	,632	2,276	**,039**	,360	,554	3,643	**,001**	,964	,340	2,344	**,031**
Extent of staff training	,611	,448	1,839	**,087**	1,137	,297	5,579	**,000**	2,418	,138	1,853	**,081**

* Note: these values are calculated if equal variances not assumed

Source: Own calculations based on *WEF-GCI* (2017-2018)

The Independent-Samples T test requires the equality of variances, so at first the Levene's test is run. If Sig > 0.05, we can accept that the variances of samples are equal. The results shows that the variance homogeneity is not assumed in the case, when we test the difference between innovation leaders and strong innovators related to the quality of primary education and primary education enrollment rate. Even if we look at the significance level of t test, we can conclude that there is no significant difference between most innovative groups in the case of primary education (values are calculated if equal variances are not assumed). The other cases the equal variances are assumed, so we can analyze the results in details.

First of all, the disparity between innovation leaders and strong innovators is highlighted. There is a significant difference in the case of the quality of educational system, the quality of management schools and the extent of staff training. Switzerland, one of the innovation leader countries, has the highest value of all three variables, which means that people feel high quality of formal educational system and corporate trainings too. The efficient education system complemented by staff training creates good opportunities to realize technological progress. Another point of view, there is no significant difference between the most innovative groups in the case of secondary and tertiary enrollment rate, and the quality of math and science education. It is quite surprising, because we assumed earlier that there would be a disparity in tertiary education enrollment rate which is aimed at acquiring higher-level knowledge required by innovation.

Secondly, analyzing the difference between strong and moderate innovators, it can be stated that the means are not equal in the case of the quality of primary education, the secondary education enrollment rate, the quality of educational system, the quality of math and science education, the quality of management schools and the extent of staff training. So, we can conclude that here is the biggest difference between innovation performance groups, the moderate innovators are lagged behind the most innovative groups almost all areas. It is surprising, that tertiary education enrollment rate is not as important as we would have assumed earlier. Similarly to the previous comparison, the primary education enrollment rate also does not differ significantly between these groups. The third comparison was made between moderate and modest innovators. It can be seen that are only three variables show significant difference, i.e. the primary education enrollment rate, the quality of management schools and the extent of staff training. In this case, there is a difference in primary education between countries but there is no significant advantage of moderate innovators in the field of secondary and tertiary education.

Summarizing the results of Independent-Samples T test, we can conclude that the most important variables in which country groups differ are the quality of management schools and the extent of staff training. It means that human resources associated with the corporate sector are the most relevant if we try to identify the areas where innovation followers have to improve. In addition, this result highlighted that the time spent in education as well as the level of education and training, linked to the idea of lifelong-learning, trainings at the workplace and continuous competence development become more and more important. Some organizations have begun to build mentoring systems in order to ensure the knowledge transfer between the older, more experienced workers and younger ones (Kozák 2016).

Finally, I applied discriminant analysis to know whether countries belongs to the same group based on their human characteristics as their aggregate innovation performance. In the analysis, clustering is performed similarly to cluster analysis, the dependent variable becomes group-forming, non-quantitative, while independent variables have to be quantitative ones. There is no threshold in the literature for the matching of the grouping, in these investigations 80% agreement over the group is accepted. The equivalence of the original and discriminant analysis groups can be seen in *Table 2*.

Table 2
Classification results of discriminant analysis

		Group	*Discriminant groups*				*Total*
			Innovation leader (1)	*Strong innovators (2)*	*Moderate innovators (3)*	*Modest innovators (4)*	
Original clusters	Count	**Innovation leader (1)**	6	1	0	0	7
		Strong innovators (2)	2	6	1	0	9
		Moderate innovators (3)	0	0	14	1	15
		Modest innovators (4)	0	0	0	3	3
	%	**Innovation leader (1)**	85.7	14.3	.0	.0	100.0
		Strong innovators (2)	22.2	66.7	11.1	.0	100.0
		Moderate innovators (3)	.0	.0	93.3	6.7	100.0
		Modest innovators (4)	.0	.0	.0	100.0	100.0

Note: 85.3% of original grouped cases correctly classified.

Source: own calculations based on *WEF-GCI* (2017-2018)

The 35 countries analyzed by discriminant analysis correspond to the original classification of 85.3%. Based on the discriminant analysis, there are five countries who do not belong to the same cluster based on human characteristics and aggregate innovation performance. United Kingdom can be strong innovator based on its human characteristics, we note that this country belongs to this cluster in the previous European Innovation Scoreboard. France and Belgium could be innovation leader if we only look at human resources' conditions of innovation, while Slovenia become moderate innovators in this case. Turkey has more intensive innovative performance than its human capital endowment, it could be modest innovators based on human features.

5. CONCLUSION

The income and technological inequalities between countries can be derived from the differences in the country-specific characteristics of innovation's conditions. The role of human resources was emphasized in this paper because both creation and adaption of new technologies require appropriate human capital which is important in the era of fourth industrial revolution. We differentiated countries based on their aggregate innovation performance using Summary Innovation Index and then we analyze the disparities in the field of human resources. To measure the quantitative and qualitative features of human resources, the Global Competitiveness Index created by the World Economic Forum was used. The analysis includes eight variables, in order to show the significant differences between groups and the consistency of them, Independent-Samples T test and discriminant analysis were applied. Based on the results of Independent-Samples T test, we can conclude that variables of the human resources related to the corporate sector are the most important ones, i.e. the quality of management schools and the extent of staff training. In addition, we would like to know whether countries belongs to the same group based on their human resources' characteristics as their aggregate innovation performance. Based on the results of discriminant analysis, there are five countries (United Kingdom↓, France↑, Belgium↑, Slovenia↓, Turkey↓) who do not belong to the same cluster based on human characteristics and aggregate innovation performance. In sum, innovation follower should develop the informal ways of knowledge transfer rather than formal education. The role of human resources is even more appreciated in the fourth industrial revolution, so innovation followers will have opportunities to catch up with innovation leaders.

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REFERENCES

ACEMOGLU, D., AGHION, P. & ZILIBOTTI, F. (2006). Distance to frontier, Selection, and Economic growth. *Journal of the European Economic Association,* 4(1), 37–74.

ANDOR L. (2018): A digitalizáció és a munka világa. Mi várható a robotforradalom után? [Beyond the robot revolution: digitalization and the world of work]. *Magyar Tudomány*, 179(1), 47 – 54. DOI: 10. 1556/ 20 65. 179. 2018 .1.5

BARRO, R. J. & SALA–I–MARTIN, X. (1997). Technological Diffusion, Convergence, and Growth. *Journal of Economic Growth,* 2(1), 1–26.

BASU, S. & WEIL, D. N. (1998). Appropriate Technology and Growth. *The Quarterly Journal of Economics*, 113(4), 1025 – 1054.

CASELLI, F. & COLEMAN, W. J. (2006a). The World Technology Frontier. *The American Economic Review*, 96(3), 499 – 522.

CHUI, M., MANYIKA, J. & MIREMADI, M. (2015): Four fundamentals of workplace automation. Download at: http://www.mckinsey.com/business-functions/business-technology/our-insights/four-fundamentals-of-workplace-automation

EUROSTAT (2017): European Innovation Scoreboard 2017. Download at http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en (12 November, 2017)

FREY, C. B. & OSBORNE, M. A. (2013): The Future of Employment: How Susceptible are Jobs to Computerisation? Downloaded at https://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf (15 June, 2018)

HOLLANDERS, H. & ES-SADKI, N. (2017): *European Innovation Scoreboard 2017*. Downloaded at https://ec.europa.eu/docsroom/documents/24829/attachments/1/translations/en/renditions/native (7 December, 2017)

HOLLANDERS, H., ES-SADKI, N. & KANERVA, M. (2016): *European Innovation Scoreboard 2016*. Downloaded at https://publications.europa.eu/en/publication-detail/-/publication/6e1bc53d-de12-11e6-ad7c-01aa75ed71a1/language-en/format-PDF/source-31234102 (7 December, 2017)

JERZMANOWSKI, M. (2007). Total Factor Productivity Differences: Appropriate Technology vs. Efficiency. *European Economic Review*, 51(8), 2080 – 2110

KOVÁCS O. (2017): Az ipar 4.0 komplexitása – I. rész [The Complexity of Industry 4.0 – Part 1]. *Közgazdasági Szemle*, Vol. XIV. (July-August), 823 – 851.

KOZÁK A. (2016): A beilleszkedést segítő mentor megítélése – vizsgálati tapasztalatok a mentoráltak aspektusából. [Evaluation of the mentor helping the integration - experiences from the aspects of mentored people] *Debreceni Szemle*, 2016(3), 261-271.

MOKYR, J. (2004). *A gazdagság gépezete – technológiai kreativitás és gazdasági haladás.* [The Lever of Riches: Technological Creativity and Economic Progress]. Budapest: Nemzeti Tankönyvkiadó.

MOKYR, J. (2005): Long–term Economic Growth and the History of Technology. In: Aghion, P. – Durlauf, S. (eds): *Handbook of Economic Growth.*, The Netherlands, Amsterdam, Chapter 17, 1113 – 1180.

OBÁDOVICS CS. (2004). *A vidéki munkanélküliség térségi eloszlásának elemzése*. [Analysis of the regional distribution of rural unemployment.] Doctoral dissertation. Gödöllő: Szent István University, Doctoral School of Management and Business Administration.

SAJTOS L. & MITEV A. (2007). *SPSS kutatási és adatelemzési kézikönyv*. [SPSS research and data analysis manual]. Budapest: Alinea.

SCHWAB, K. (2016): The Fourth Industrial Revolution. World Economic Forum.

SIMAI M. (2018): A felsőoktatás jövője, az élethosszi tanulás és a globális kihívások. [Future of higher education, life-long learning and global challenges.] *Magyar Tudomány*, 179(1), 90 - 98. DOI: 10 .1556/ 20 65.179. 2018 .1.10

SZALAVETZ A. (2018): Ipari fejlődés és munka a tudásalapú társadalomban. [Industrial development and work in knowledge-based economy.] *Magyar Tudomány*, 179(1), 55 – 60. DOI: 10. 1556/ 20 65.179. 2018 .1.6

WILLIAMSON, S. D. (2009). *Makroökonómia*. [Macroeconomics.] Budapest: Osiris.

WORLD ECONOMIC FORUM (2016): The Future of Jobs. Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution. Global Challenge Insight Report. Downloaded at http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf (15 June, 2018)

APPENDIX 1
The results of Kolmogorov-Smirnov test

Null Hypothesis	Sig.	Decision
The distribution of Quality of primary education is normal with mean 4.808 and standard deviation 0.78.	0.949	Retain the null hypothesis.
The distribution of Primary education enrollment is normal with mean 96.990 and standard deviation 2.82.	0.243	Retain the null hypothesis.
The distribution of Secondary education enrollment is normal with mean 112.426 and standard deviation 17.08.	0.267	Retain the null hypothesis.
The distribution of Tertiary education enrollment is normal with mean 69.487 and standard deviation 16.42.	0.887	Retain the null hypothesis.
The distribution of Quality of education system is normal with mean 4.230 and standard deviation 0.93.	0.963	Retain the null hypothesis.
The distribution of Quality of math and science education is normal with mean 4.767 and standard deviation 0.64.	0.952	Retain the null hypothesis.
The distribution of Quality of management schools is normal with mean 4.805 and standard deviation 0.83.	0.470	Retain the null hypothesis.
The distribution of Extent of staff training is normal with mean 4.443 and standard deviation 0.76.	0.741	Retain the null hypothesis.

Asymptotic significance are displayed. The significance level is 0.05.
Source: own calculations based on *WEF-GCI* (2017-18)

Appendix 2
Descriptive Statistics of between groups comparison

Variables	*Performance groups*	N	Mean	Std. Deviation	*Performance groups*	N	Mean	Std. Deviation	*Performance groups*	N	Mean	Std. Deviation
Quality of primary education	*Innovation leader*	7	5.538920	.7633676	*Strong innovators*	9	5.148437	.4189054	*Moderate innovators*	16	4.421660	.6885140
	Strong innovators	9	5.148437	.4189054	*Moderate innovators*	16	4.421660	.6885140	*Modest innovators*	3	4.138774	.4024406
Primary education enrollment	*Innovation leader*	7	99.106780	.6450624	*Strong innovators*	9	97.519325	2.1990278	*Moderate innovators*	15	96.659546	2.2321718
	Strong innovators	9	97.519325	2.1990278	*Moderate innovators*	15	96.659546	2.2321718	*Modest innovators*	3	92.116516	4.7655968
Secondary education enrollment	*Innovation leader*	7	126.843444	18.3912518	*Strong innovators*	9	116.879330	20.6334261	*Moderate innovators*	16	106.535581	10.0949202
	Strong innovators	9	116.879330	20.6334261	*Moderate innovators*	16	106.535581	10.0949202	*Modest innovators*	3	96.835167	3.9704871
Tertiary education enrollment	*Innovation leader*	7	70.470437	12.4518972	*Strong innovators*	9	69.975885	20.3278704	*Moderate innovators*	16	68.718462	17.2493576
	Strong innovators	9	69.975885	20.3278704	*Moderate innovators*	16	68.718462	17.2493576	*Modest innovators*	3	69.819815	14.9725640
Quality of the education system	*Innovation leader*	7	5.319871	.5555321	*Strong innovators*	9	4.736122	.5320721	*Moderate innovators*	16	3.633631	.6362098
	Strong innovators	9	4.736122	.5320721	*Moderate innovators*	16	3.633631	.6362098	*Modest innovators*	3	3.349446	.5328444
Quality of math and science education	*Innovation leader*	7	5.389188	.6582694	*Strong innovators*	9	4.995186	.3391068	*Moderate innovators*	16	4.410187	.5340741
	Strong innovators	9	4.995186	.3391068	*Moderate innovators*	16	4.410187	.5340741	*Modest innovators*	3	4.537605	.6280566
Quality of management schools	*Innovation leader*	7	5.749261	.4013058	*Strong innovators*	9	5.223720	.4965062	*Moderate innovators*	16	4.388113	.5771982
	Strong innovators	9	5.223720	.4965062	*Moderate innovators*	16	4.388113	.5771982	*Modest innovators*	3	3.565905	.3777334
Extent of staff training	*Innovation leader*	7	5.302547	.2882542	*Strong innovators*	9	4.980261	.3865256	*Moderate innovators*	16	3.953935	.4681865
	Strong innovators	9	4.980261	.3865256	*Moderate innovators*	16	3.953935	.4681865	*Modest innovators*	3	3.434741	.2029784

Source: own calculations based on *WEF-GCI* (2017-18)