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Education Quality and Technological Progress in the Business Sector at Different Stages of Economic Development

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ABSTRACT

Objective: To empirically investigate the relationship between education quality and technological progress in the business sector at different stages of economic development.
Research Design & Methods: We divided 160 countries into four groups by GDP *per capita*. The research period was 2007–2021. We use Spearman's correlation analysis to verify associations between nine indicators for education quality and ten indicators for technological progress.
Findings: Our outcomes show that if education quality does not improve, countries do not move up the economic development ladder. Adult literacy, primary education quality, adult skills, and women's average years in school have the strongest influence on technological progress.
Implications/Recommendations: Our paper contains many implications for those seeking to improve social well-being. For example, governments should ensure that women have access to

education on equal terms with men. Otherwise, they lose an important source of technological progress and impede the development of human capital. Greater emphasis should be placed on learning how to write and describe reality, read with comprehension, perform simple calculations without a calculator, and teach various learning methods. In the absence of these, the skills of primary, secondary and higher education graduates will not improve.

Contribution: The outcomes of our research, both theoretical and empirical, create a multi-faceted approach to the issue of the mutual influence of education and technological progress. They allow us to look at this problem from the perspective of subsequent stages of economic development.

Article type: original article.

Keywords: education quality, technological progress, stages of economic development, business sector.

JEL Classification: I25, O32, O33.

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1. Introduction

The education system should facilitate technological progress, a directional process that may occur linearly or stepwise. Romer (1990, 1996), a key progenitor of new growth theories, has emphasised that technological progress is the outcome of a shift from less to more productive ways of combining things into different configurations. This is usually the result of knowledge accumulation by the carriers of human capital. Main methods of knowledge accumulation include self-acquisition of knowledge, education in schools, vocational training, learning by doing, learning by mimicking, learning by doing innovation, learning through teamwork, and learning by imitating social groups.

Technology in new growth theories concerns how to transform knowledge into a more productive arrangement of things – in other words, innovation. Innovations are new approaches to technical, organisational, scientific, economic and social problems (e.g., Mazur-Wierzbicka, 2018; Valdivieso, Uribe Gómez & Ordóñez-Matamoros, 2021; Ober, 2022; Grabowski & Stawasz, 2023).

Technological capabilities are understood as those of a given entity, organisation or country in locating, acquiring, developing and using knowledge. Such capabilities determine the quality of decision-making, facilitate problem-solving and form the foundation for introducing innovations in current activities (e.g., Rudny, 2009; Song & Thieme, 2009; Hamdoun, Chiappetta Jabbour & Ben Othman, 2018; Ode & Ayavoo, 2020).

If a person learns and shares knowledge with others, he or she develops knowledge absorptive capacity – the ability to acquire knowledge from various sources in order to develop and use it in action (e.g., Kogut & Zander, 1992; Delfmann

& Koster, 2012; Heitor, Horta & Mendonça, 2014; Fernández-Esquinas *et al*., 2016; Majewska, 2017).

The aim of this paper is to empirically investigate the relationship between education quality and technological progress in the business sector at different stages of economic development. It consists of a theoretical introduction, a description of the research methodology, a presentation and discussion of research results and conclusions.

The research was conducted on 160 countries in years 2007–2021. According to United Nations, there are 195 countries in the world. Thus our research covers 82% of the general population. Countries were divided into four groups consisting of 40 economies according to their GDP per capita in US dollars in 2022. We studied the relationships between nine indicators of education quality and ten of technological progress.

2. A Theoretical Framework

A pioneer in the field of operations research, systems thinking and management sciences, Ackoff (1986) stressed that an underdeveloped country flooded with money temporarily becomes richer, but not necessarily more developed in the long run. That is because economic development is more about good quality teaching and a willingness to learn than about earning money. Hence, a developed country with a large number of skilled employees is able to increase the prosperity of its society more effectively than a less developed country that does not invest sufficiently in educating its future and current workforce.

In countries at the first stage of development, the formal labour market does not exist and human capital is only beginning to develop. The country's internal institutions and infrastructure are just beginning to take shape and most of its citizens are poor. For these reasons, technology has not accumulated locally. The country has created only a small number of assets, which are performing as endogenous advantages. The dominant sectors of the economy are agriculture and mining.

These countries start investing in human capital by creating a primary education system and teaching people to work systematically. The main goal is to increase the resources of semi-skilled workers and prepare staff who can teach children and young people in primary schools and various institutions of elementary education. Particular attention should be paid to increasing literacy and numeracy skills. In the meantime, secondary education should be developed and the teaching staff expanded to ensure continuity of education. UNCTAD emphasises that at this stage there is still a need to ensure that all girls and boys complete free, equitable and quality primary and secondary education. It is worth taking advantage of UNICEF programmes because the organisation has extensive experience in education

(Porter, 1991; Dunning & Lundan, 2009, 2010; Majewska & Buszkowska, 2014; UNCTAD, 2021b).

At the second stage, faster development of the country depends on achieving threshold levels for socio-economic infrastructure, innovative activity accumulated outcomes and knowledge absorption capacity. Without it, the country cannot "take off." This means that success can only be achieved by countries whose governments invest in technological capabilities and help companies imitate foreign technologies. This leads to the creation of incremental innovations, which take the form of adaptive, modernising or improving changes. Good examples include: subsidies for domestic enterprises engaged in innovative activities, subsidies for the acquisition of more advanced technology, clusters and technology centers (Porter, 1991; Valdivieso, Uribe Gómez & Ordóñez-Matamoros, 2021; Grabowski & Stawasz, 2023).

The task of the education system at this stage is to transform low-skilled workers into highly-skilled ones. Investments in education and learning from the rest of the world enable better-skilled employees to work with more advanced capital goods. As a result, the share of more highly processed labour- and capital-intensive production is growing. Then the quality of exports increases that means higher profits from foreign trade. Production is more and more technologically complex, which increases demand for better-skilled workers (Porter, 1991; Dunning & Lundan, 2009, 2010; Zaitseva *et al*., 2017).

Drucker (2002) emphasises that in order to move from the second to the third stage of economic development, enough technicians must be educated. Such technicians include laboratory workers, rehabilitators, mechanics, medical staff, teachers, programmers, installers of various devices, and operators of specialised equipment, among others. He believes that every country is able to achieve this goal and thus accelerate technological progress – provided the vocational sector of secondary education increased to boost the number of trained technicians. Kamens and Benavot (2007) noted that the vocational sector of secondary education often includes multiple tracks and timetables, meaning that education, in such cases, is professionalised.

At the third stage, new domestic technologies have been developed and foreign technologies improved thanks to enterprises' innovative efforts. Government here seeks to maintain competitiveness in mature industries while supporting the development of innovations in emerging sectors. Endogenous advantages grow thanks to increased expenditure on innovative activities and education, in particular the development of higher education institutions. The share of products produced by medium- and high-skill workers grows.

Toffler and Toffler (1995) point out that the education system should be more individualised, i.e. adapted to a wider variety of student aspirations and abilities.

If this has not been done before, the structure of education system should be based on the results of forecasts regarding types of professions and activities needed in the future, changes in technical tools and systems and transformations in organisational structures of tomorrow's institutions. There should also be more emphasis on civil rights and the education of democratic institutions. Unfortunately, governments may be reluctant to do this because power is strongly centralised in a traditional industrial society.

The state should promote entrepreneurship and help develop institutional and technological environments, as they boost enterprise competitiveness by implementing the outcomes of innovative activities. In other words, government is advised to build a national innovation system to become a knowledge-based economy (Porter, 1991; Dunning & Lundan 2009, 2010; Majewska & Buszkowska, 2014; Majewska & Rawińska, 2018).

The father of the concept of post-industrial society, Bell (1976) wrote that knowledge and intellectual technology are at the center of post-industrial society and scientists should constitute a key social stratum that decides on future development trajectories. In such a society, the educational and scientific research base is developed but its size and quality are still growing.

To transform their societies into post-industrial ones, as Majewska and Nieżurawska-Zając (2021) write, governments must guarantee everyone free access to education and the opportunity to work in a profession – that is, they must guarantee an equal start in life. The education system should be improved so that it can help reduce social inequalities and prepare for life in a modern democracy.

At the fourth stage, companies' greater ownership advantages are increasingly dependent on the development of endogenous knowledge-intensive assets. This is accompanied by a gradual withdrawal from outdated production industries, especially those that harm the natural environment. As a result, domestic enterprises have competitive advantages in green manufacturing and technologically advanced products with a high content of embedded knowledge (Porter, 1991; Dunning & Lundan, 2009, 2010; Majewska, 2022; Mayenberger & Perez-Castillo, 2022; Bendig, Kleine-Stegemann & Gisa, 2023).

3. Materials and Research Methods

Before we begin, a word on the main limitations of our research. Technological progress and education quality are highly complex and multi-faceted phenomena. In the study of such phenomena, there is a high risk of endogeneity. The probability of omitting an important explanatory variable is particularly high in economic research because many factors co-occur and influence each other. Additionally, the choice of indicators by a researcher of economic phenomena is often limited by the availability of data.

Gross domestic product *per capita* in current prices (GDP pc) denominated in USD is the national measure of wealth we have used. GDP pc is a commonly used indicator of economic development and overall well-being. According to the World Bank, GDP pc provides a basic measure of the value of output per person, an indirect indicator of *per capita* income. The World Bank divides economies into four income groups: low income, lower middle income, upper middle income and high income. We have grouped the 160 countries in this study using the same division. Countries were divided into four groups of 40 according to their GDP pc in 2022: low GDP pc countries, 350 to 2,101; lower middle GDP pc countries, 2,122 to 6,568; upper middle GDP pc countries 6,639 to 20,107; and high GDP pc countries, 21,149 to 128,481.

Table 1. Description of Indicators for Education Quality

Variable	Code	Description
Primary education quality	PEQ	The mean score of harmonised learning outcomes at the primary level
Adult literacy	ADL	The percentage of people ages 15 and above who can both read and write to such a degree that they are able to understand a short simple statement about their everyday life
Secondary education quality	SEQ	The average of learning outcomes across math, reading, and science at both the primary and secondary level of education
Average quality of higher education institutions	HEQ	A composite measure, made from the score given to the top 1,000 universities in the QS World University Rankings and TES Higher Education World University Rankings, normalised by number of higher education institutions in the country
Skillset of university graduates needed by businesses	SUG	In your country, to what extent do graduating students from university possess the skills needed by businesses?
Women's average years in school	WSH	The average number of years of primary, secondary or tertiary education attended by women aged between 25 and 34 years old
Adult skills	ASK	The skill-base of the existing working-age population, which is a reflection of the historic quality of education as well as providing a base level for the short-term potential of the economy
Digital skills among population	DIS	In your country, to what extent does the active population possess sufficient digital skills (e.g. computer skills, basic coding, digital reading)?
Quality of vocational training	QVT	In your country, how do you assess the quality of vocational training?

Source: Legatum Institute (2019).

Following the literature, we assume that low GDP pc countries are at pre-agricultural and agricultural stage of economic development. Below average GDP pc countries are agricultural economies that have begun to industrialise. Upper average GDP pc countries are industrialised economies. High-income countries have entered a post-industrial stage and are building out their knowledge economy.

Table 2. Description of Indicators for Technological Progress

Variable	Code	Description
Human capital	HC	Captures the education, skills and health conditions possessed by population, and the overall research and development integration in society through the number of researchers and expenditure on research activities
Labour productivity	LPR	GDP output per worker in the workforce (population in employment)
Information and communication technology	ICT	Estimates the accessibility and integration of communication systems in the population
New business density	NBD	The number of newly registered limited liability corporations created per calendar year
Building quality control index by enterprises	QCI	A composite measure of the quality control and safety mechanisms in the construction regulatory system: a) quality of building regulations, b) quality control before, during, and after construction, c) liability and insurance regimes, and d) professional certifications
Structural change	SCH	Refers to the movement of labour and other productive resources from low-productivity to high-productivity economic activities
Patent applications	PA	The rate of applications for the exclusive rights to an invention, covering both products and processes as inventions
Export quality	EXQ	A composite measure estimating a country's export quality, based on both the a) value and b) quantity, of bilateral trades
High-tech manufactured exports	THE	The value of manufactured exports with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery, expressed as a percentage of the value of all manufactured exports
Gross domestic product *per capita*	GDP pc	An indicator of economic productivity

Source: Legatum Institute (2019), UNCTAD (2021a).

Tables 1 and 2 present the variable definitions and symbols. The main source of data was The Legatum Prosperity Index, an annual ranking developed by the

Legatum Institute. For GDP pc and such indicators as human capital, information and communication technology, structural change, data were also taken from UNCTAD. These four indicators are components of the Productive Capacities Index developed by UNCTAD. The indicator values sourced from UNCTAD and the Legatum Institute underwent standardisation. Only GDP pc is expressed in absolute values, which were transformed into natural logarithms.

The study adopted the same research method that UNCTAD (2021a) used to examine the interdependence between the Productive Capacities Index and key macroeconomic indicators, including the Sustainable Development Goals. It uses correlation analysis with Spearman's rank correlation analysis, a nonparametric measure of any monotonic relationship that exists between two variables. When calculating Spearman's correlation coefficient ρ, the mean rank is assigned in case of ties. There are two methods of calculating Spearman's correlation. Which you choose depends on whether the data does or does not have tied ranks. Our data is not rank-aligned, hence we used the following calculation formula:

$$\rho = 1 - \frac{6\sum d_i^2}{n(n^2 - 1)},$$

where:

d_i – difference in paired ranks,

n – number of cases.

The potential impact of outliers can be mitigated by using Spearman's correlation instead of Pearson's correlation. Outliers are extreme values that stand out significantly from the overall pattern of values in a dataset. They can distort statistical analyses and violate the assumptions used in the analyses.

The *p*-value is the probability of observing a non-zero correlation coefficient in our sample data when the null hypothesis is true. In our study, Spearman's correlation coefficient was significant if the *p*-value is less than 0.05. In the case of correlation analysis, the null hypothesis is typically that the relationship observed between the variables is the result of pure chance – the correlation coefficient is really zero. The alternative hypothesis is that the correlation we have measured is legitimately present in our data – the coefficient is other than zero. Therefore, if you have a *p*-value less than 0.05, you would reject the null hypothesis. In other words, there is enough evidence to conclude that the relationship between the variables is statistically significant.

Correlation coefficients were calculated for all of the countries studied and the four GDP pc groups of countries. Because the interpretation of correlation coefficients differs according to the number of observations, we assumed the GDP pc groups of countries to be of the same size.

We also used a time-lag study method to estimate the correlation between the indicators of the quality of education in year t_0 and the proxies of technological progress in t_{+2}. For all of the countries studied, the number of observations in the period t_{+0} was 2,400 and in t_{+2} 2,080. For each of the four groups of countries, the number of observations in the period t_{+0} was 600 and in t_{+2} 520.

We adopted the following scale in interpreting the results of correlation analysis:

– the value lies below 0.19: a very weak/low correlation,
– the value lies between 0.20 and 0.39: a weak/low correlation,
– the value lies between 0.40 and 0.59: a medium correlation,
– the value lies between 0.60 and 0.79: a strong/high correlation,
– the value lies between 0.80 and 1: a very strong/high correlation,

The statistical analysis was carried out to verify the following hypotheses:

H1: The importance of higher education quality increases with economic development, while the importance of primary and secondary education quality decreases.

H2: Reducing educational inequalities between women and men helps speed up technological progress.

H3: Investing in quality adult qualifications is an important determinant of technological progress regardless of the stage of economic development.

4. Results

Table 3 shows that for all the countries studied, the interdependency between an increase in education quality and technological progress has been confirmed by Spearman's correlation in 2007–2021. At a level of 0.05, all correlation coefficients are positive and statistically significant. The strength of these correlational relationships persists over time.

Table 3. Spearman's Correlation Coefficients for All Researched Countries, 2007–2021

Indicator	HCt_0	LPRt_0	ICTt_0	NBDt_0	QCIt_0	SCHt_0	PAt_0	EXQt_0	HTEt_0	GDPt_0
PEQ	0.84	0.74	0.79	0.64	0.43	0.70	0.80	0.70	0.53	0.77
ADL	0.85	0.76	0.82	0.67	0.40	0.68	0.79	0.68	0.52	0.79
SEQ	0.78	0.75	0.75	0.61	0.42	0.70	0.78	0.65	0.53	0.76
HEQ	0.76	0.75	0.74	0.48	0.44	0.68	0.72	0.60	0.49	0.76
SUG	0.53	0.55	0.55	0.40	0.23	0.48	0.51	0.47	0.38	0.60
WSH	0.87	0.78	0.86	0.69	0.43	0.67	0.80	0.69	0.50	0.80
ASK	0.87	0.78	0.86	0.69	0.46	0.68	0.81	0.70	0.52	0.81
DIS	0.68	0.70	0.70	0.52	0.45	0.60	0.70	0.55	0.42	0.70
QVT	0.55	0.57	0.57	0.42	0.29	0.51	0.56	0.46	0.41	0.62

Table 3 cnt'd

Indicator	HCt_2	$LPRt_2$	$ICTt_2$	$NBDt_2$	$QCIt_2$	$SCHt_2$	PAt_2	PSt_2	$HTEt_2$	$GDPt_2$
PEQ	0.84	0.75	0.80	0.63	0.43	0.69	0.80	0.70	0.54	0.77
ADL	0.81	0.74	0.80	0.67	0.36	0.64	0.76	0.66	0.50	0.76
SEQ	0.77	0.73	0.75	0.62	0.40	0.68	0.76	0.64	0.53	0.75
HEQ	0.75	0.75	0.74	0.47	0.43	0.67	0.72	0.60	0.49	0.76
SUG	0.53	0.54	0.55	0.41	0.23	0.48	0.51	0.47	0.38	0.60
WSH	0.86	0.78	0.86	0.68	0.42	0.67	0.79	0.70	0.51	0.80
ASK	0.80	0.73	0.81	0.66	0.41	0.62	0.75	0.65	0.48	0.75
DIS	0.69	0.70	0.72	0.53	0.45	0.60	0.70	0.56	0.42	0.71
QVT	0.55	0.57	0.57	0.42	0.28	0.51	0.57	0.46	0.40	0.63

Notes: All correlations are statistically significant at $p < 0.05$.

Source: the authors' calculations.

12 correlation coefficients are very strong. In the case of women's average years in school and adult skills, there is a very strong correlation with the same four indicators of technological progress (human capital, ICT, patent application and GDP pc). A very strong correlation also holds for associations between human capital and primary education quality and adult literacy.

In addition, there is a very strong interdependency between primary education quality and patent application as well as between adult literacy and ICT. We can thus conclude that adult literacy, primary education quality, adult skills, and women's average years in school have the strongest influence on technological progress in the countries studied.

Table 4 presents the results for countries at the pre-agricultural or agricultural development stage with low GDP pc. The highest positive correlation coefficients are observed for associations between human capital and indicators for technological progress. A strongest interdependency (0.61) occurs between human capital and adult skills. Adult literacy and women's average years in school share second place (0.55), while primary education is in third place (0.37) and digital skills among population in fourth place (0.32).

As might be expected, correlations with indicators for technological progress are stronger in most cases for primary education quality than for higher education quality. However, secondary education quality has a twice stronger impact on labour productivity than higher education and primary education quality. This has not yet translated into a structural change, which should appear at stage 2.

Table 4. Spearman's Correlation Coefficients for Low GDP pc Countries, 2007–2021

Indicator	HCt_0	$LPRt_0$	$ICTt_0$	$NBDt_0$	$QCIt_0$	$SCHt_0$	PAt_0	$EXQt_0$	$HTEt_0$	$GDPt_0$
PEQ	0.37*	0.14*	0.21*	0.27*	0.36*	0.24*	0.11*	–0.02	–0.09*	0.22*
ADL	0.55*	0.25*	0.38*	0.35*	0.16*	0.45*	0.05	0.12*	–0.05	0.29*
SEQ	0.13*	0.30*	0.19*	0.20*	0.16*	0.06	0.06	–0.05	0.06	0.32*
HEQ	–0.05	0.13*	0.10*	0.04	0.28*	0.15*	0.09*	0.12*	–0.02	0.11*
SUG	0.16*	0.15*	0.28*	0.22*	0.17*	0.24*	0.05	0.18*	–0.21*	0.24*
WSH	0.55*	0.30*	0.39*	0.39*	0.13*	0.44*	0.09*	0.10*	0.09*	0.41*
ASK	0.61*	0.31*	0.42*	0.44*	0.17*	0.48*	0.07	0.19*	–0.03	0.39*
DIS	0.32*	0.42*	0.39*	0.18*	0.29*	0.26*	0.22*	0.19*	–0.08	0.33*
QVT	–0.01	0.08*	0.17*	0.24*	0.29*	0.18*	0.17*	0.06	0.06	0.15*
Indicator	HCt_2	$LPRt_2$	$ICTt_2$	$NBDt_2$	$QCIt_2$	$SCHt_2$	PAt_2	PSt_2	$HTEt_2$	$GDPt_2$
PEQ	0.36*	0.13*	0.23*	0.24*	0.34*	0.24*	0.10*	–0.04	–0.08	0.23*
ADL	0.53*	0.25*	0.39*	0.35*	0.16*	0.44*	0.03	0.15*	–0.05	0.31*
SEQ	0.12*	0.31*	0.23*	0.19*	0.16*	0.06	0.04	–0.04	0.05	0.34*
HEQ	–0.08	0.13*	0.10*	0.02	0.28*	0.12*	0.08	0.12*	–0.05	0.11*
SUG	0.16*	0.15*	0.30*	0.23*	0.14*	0.25*	0.01	0.19*	–0.19*	0.25*
WSH	0.54*	0.30*	0.40*	0.38*	0.13*	0.44*	0.08	0.11*	0.10*	0.43*
ASK	0.60*	0.31*	0.44*	0.44*	0.17*	0.48*	0.05	0.21*	–0.02	0.41*
DIS	0.30*	0.41*	0.42*	0.19*	0.29*	0.26*	0.20*	0.22*	–0.09*	0.35*
QVT	–0.02	0.10*	0.19*	0.26*	0.30*	0.21*	0.16*	0.04	0.06	0.16*

* $p < 0.05$.

Source: the authors' calculations.

The correlation coefficients between indicators for education quality and patent applications, export quality and the value of manufactured exports with high R&D intensity are statistically insignificant or weak at this stage. This is because low GDP pc countries have the majority of advantages in natural resources. Labour- and resource-intensive goods dominate their production structure.

Table 5 presents the outcomes obtained for lower middle GDP *per capita* countries. The values of three correlation coefficients exceed 0.6. There are associations between adult skills with human capital (0.63) and ICT (0.63) as well as between women's average years in school and ICT (0.61). A medium correlation occurred in 12 cases, and for 5 of them the coefficients are higher than 0.5. There are correlations of adult literacy with human capital and ICT, women's average years in school with human capital and patent application, adult skills with patent applications.

Table 5. Spearman's Correlation Coefficients for Lower Middle GDP pc Countries, 2007–2021

Indicator	HCt_0	$LPRt_0$	$ICTt_0$	$NBDt_0$	$QCIt_0$	$SCHt_0$	PAt_0	$EXQt_0$	$HTEt_0$	$GDPt_0$
PEQ	0.41*	0.16*	0.43*	0.35*	0.06	0.10*	0.35*	0.29*	0.11*	0.18*
ADL	0.54*	0.32*	0.59*	0.33*	0.16*	0.10*	0.41*	0.41*	0.31*	0.40*
SEQ	0.22*	0.27*	0.24*	0.42*	0.39*	0.26*	0.45*	0.19*	–0.06	0.15*
HEQ	0.16*	0.22*	0.15*	–0.15*	0.14*	0.13*	0.29*	0.03	0.17*	0.08
SUG	0.01	–0.03	0.06	0.02	–0.03	0.10*	0.01	–0.01	0.26*	0.15*
WSH	0.58*	0.38*	0.61*	0.29*	0.16*	–0.03	0.57*	0.46*	0.20*	0.39*
ASK	0.63*	0.35*	0.63*	0.27*	0.20*	0.07	0.53*	0.48*	0.29*	0.38*
DIS	0.13*	0.01	0.09*	–0.02	0.39*	0.34*	0.39*	0.14*	0.10*	–0.16*
QVT	0.02	0.02	0.09*	0.03	0.00	0.21*	0.07	0.05	0.23*	0.17*
Indicator	HCt_2	$LPRt_2$	$ICTt_2$	$NBDt_2$	$QCIt_2$	$SCHt_2$	PAt_2	PSt_2	$HTEt_2$	$GDPt_2$
PEQ	0.39*	0.16*	0.44*	0.34*	0.05	0.07	0.33*	0.28*	0.12*	0.19*
ADL	0.53*	0.32*	0.62*	0.33*	0.15*	0.08	0.38*	0.40*	0.32*	0.42*
SEQ	0.20*	0.29*	0.26*	0.43*	0.40*	0.24*	0.44*	0.19*	–0.08	0.14*
HEQ	0.14*	0.24*	0.12*	–0.16*	0.12*	0.13*	0.30	0.02	0.16*	0.08
SUG	0.01	–0.05	0.06	0.00	0.00	0.12*	0.04	–0.02	0.29*	0.14*
WSH	0.56*	0.39*	0.62*	0.29*	0.16*	–0.04	0.56*	0.45*	0.20*	0.38*
ASK	0.61*	0.36*	0.65*	0.27*	0.19*	0.06	0.51*	0.47*	0.30*	0.38*
DIS	0.14*	0.02	0.12*	–0.01	0.40*	0.33*	0.39*	0.13*	0.12*	–0.15*
QVT	0.01	0.01	0.07	0.02	–0.01	0.23*	0.07	0.03	0.23*	0.16*

* $p < 0.05$.

Source: the authors' calculations.

Compared to countries with lower GDP *per capita*, the strength of interdependence between primary education quality and ICT and between patent application and export quality has increased significantly. In these cases correlations are still stronger than those for higher education quality. However, there is a statistically significant and positive correlation between higher education quality with human capital and high-tech manufactured export. The correlation between higher education quality and labour productivity, ICT and patent application is also strengthening.

As we suggested earlier, the largest changes in the values of correlation coefficients are observed for secondary education quality compared to primary and higher education quality. This applies especially to structural change (by 0.20), new business density (by 0.22), building quality control index by enterprises (by 0.23), export quality, and patent applications (0.39).

Table 6 shows the results obtained for upper middle GDP pc countries. There is neither a strong nor a very strong correlation, though a medium correlation occurs six times. The highest positive correlation coefficients are again observed for associations between human capital and indicators for technological progress. There are four other medium correlations, including ones for ICT with women's average years in school and adult skills as well as patent applications with primary and secondary quality education.

Table 6. Spearman's Correlation Coefficients for Upper Middle GDP pc Countries, 2007–2021

Indicator	HCt_0	LPRt_0	ICTt_0	NBDt_0	QCIt_0	SCHt_0	PAt_0	EXQt_0	HTEt_0	GDPt_0
PEQ	0.53*	0.25*	0.38*	0.04	0.34*	0.25*	0.41*	0.29*	0.27*	0.23*
ADL	0.44*	0.07	0.36*	–0.05	0.05	0.01	0.31*	0.11*	0.21*	0.17*
SEQ	0.47*	0.35*	0.33*	–0.12*	0.15*	0.38*	0.50*	0.25*	0.32*	0.30*
HEQ	0.47*	0.19*	0.33*	–0.10*	0.41*	0.35*	0.24*	0.26*	0.37*	0.27*
SUG	–0.08	–0.07	–0.04	–0.07	0.01	–0.08	–0.13*	–0.12*	0.14*	0.14*
WSH	0.42*	0.16*	0.57*	0.11*	0.22*	0.05	0.23*	0.14*	0.09*	0.22*
ASK	0.43*	0.08	0.53*	0.09*	0.28*	0.03	0.28*	0.15*	0.15*	0.16*
DIS	0.13*	–0.02	0.21*	–0.05	0.23*	–0.06	0.20*	–0.03	0.17*	0.14*
QVT	–0.07	–0.10*	0.00	–0.03	–0.05	–0.21*	–0.06	–0.22*	0.11*	0.16*
Indicator	HCt_2	LPRt_2	ICTt_2	NBDt_2	QCIt_2	SCHt_2	PAt_2	PSt_2	HTEt_2	GDPt_2
PEQ	0.54*	0.24*	0.40*	0.02	0.33*	0.25*	0.40*	0.31*	0.29*	0.21*
ADL	0.43*	0.07	0.39*	–0.03	0.04	0.02	0.29*	0.12*	0.24*	0.16*
SEQ	0.51*	0.34*	0.35*	–0.11*	0.15*	0.39*	0.50*	0.26*	0.34*	0.28*
HEQ	0.48*	0.18*	0.33*	–0.12*	0.43*	0.35*	0.25*	0.25*	0.38*	0.27*
SUG	–0.09	–0.08	–0.05	–0.08	0.00	–0.08	–0.12*	–0.15*	0.12*	0.15*
WSH	0.39*	0.16*	0.57*	0.12*	0.22*	0.06	0.20*	0.14*	0.11*	0.21*
ASK	0.40*	0.07	0.54*	0.10*	0.27*	0.03	0.25*	0.15*	0.16*	0.15*
DIS	0.13*	–0.03	0.23*	–0.06	0.22*	–0.07	0.19*	–0.04	0.16*	0.15*
QVT	–0.08	–0.09*	0.00	–0.03	–0.04	–0.19*	–0.05	–0.23*	0.10*	0.18*

* $p < 0.05$.

Source: the authors' calculations.

From among all levels of education, primary education quality is most closely related to changes in human capital, ICT, and export quality. Secondary education quality is most closely related to changes in labour productivity, structural change, patent applications and GDP pc. Higher education quality is most closely related to changes in the quality control index and high-tech manufactured exports.

Only in this group of countries is there such a weak positive correlation or such a strong negative correlation between the skillset of university graduates and vocational training quality with indicators for technological progress. Furthermore, the strength of the correlation decreased in 58 cases. We can therefore conclude that the worst situation occurs in industrialised countries. This will be explained in the results discussion section.

Table 7 presents the findings obtained for the highest GDP pc countries. Almost all correlation coefficients are statistically significant and positive, with the exception of associations between indicators for education quality and new business density.

Table 7. Spearman's Correlation Coefficients for High GDP pc Countries, 2007–2021

Indicator	HCt_0	LPRt_0	ICTt_0	NBDt_0	QCIt_0	SCHt_0	PAt_0	EXQt_0	HTEt_0	GDPt_0
PEQ	0.51*	0.11*	0.43*	0.11*	–0.07	0.52*	0.62*	0.68*	0.45*	0.24*
ADL	0.69*	0.29*	0.50*	0.27*	–0.12*	0.41*	0.69*	0.54*	0.41*	0.56*
SEQ	0.63*	0.07	0.46*	0.15*	–0.06	0.50*	0.59*	0.54*	0.52*	0.28*
HEQ	0.51*	0.47*	0.48*	0.27*	–0.10*	0.42*	0.46*	0.38*	0.32*	0.57*
SUG	0.52*	0.54*	0.49*	0.31*	–0.11*	0.26*	0.55*	0.43*	0.41*	0.73*
WSH	0.65*	0.02	0.60*	0.27*	–0.05	0.31*	0.56*	0.37*	0.43*	0.34*
ASK	0.68*	0.10*	0.60*	0.30*	–0.02	0.31*	0.62*	0.42*	0.49*	0.43*
DIS	0.38*	0.25*	0.37*	0.35*	–0.20*	0.04	0.39*	0.19*	0.40*	0.47*
QVT	0.60*	0.53*	0.53*	0.15*	–0.07	0.49*	0.67*	0.53*	0.38*	0.72*
Indicator	HCt_2	LPRt_2	ICTt_2	NBDt_2	QCIt_2	SCHt_2	PAt_2	PSt_2	HTEt_2	GDPt_2
PEQ	0.57*	0.15*	0.41*	0.10*	0.02	0.53*	0.61*	0.64*	0.43*	0.32*
ADL	0.50*	0.25*	0.45*	0.27*	–0.27*	0.31*	0.61*	0.49*	0.38*	0.41*
SEQ	0.62*	0.05	0.46*	0.25*	–0.08	0.44*	0.54*	0.47*	0.53*	0.28*
HEQ	0.54*	0.50*	0.46*	0.20*	–0.10*	0.47*	0.47*	0.41*	0.32*	0.58*
SUG	0.54*	0.54*	0.48*	0.35*	–0.11*	0.26*	0.53*	0.40*	0.42*	0.76*
WSH	0.59*	0.03	0.53*	0.24*	–0.10*	0.33*	0.55*	0.37*	0.42*	0.31*
ASK	0.53*	0.09*	0.51*	0.25*	–0.12*	0.26*	0.56*	0.39*	0.43*	0.33*
DIS	0.40*	0.25*	0.38*	0.36*	–0.19*	0.05	0.39*	0.18*	0.41*	0.49*
QVT	0.60*	0.54*	0.53*	0.15*	–0.08	0.50*	0.67*	0.53*	0.36*	0.72*

* $p < 0.05$.

Source: the authors' calculations.

The correlation coefficient values exceed 0.70 only in two cases – GDP pc with skillset of university graduates and vocational training quality. Furthermore, these two education quality indicators are the strongest correlated with labour productivity among other indicators for technological progress.

Taking into account all levels of education, primary education quality is the most strongly correlated with patent applications and export quality, secondary education quality with human capital and high-tech manufactured exports, higher education quality with labour productivity, building quality control index and GDP pc. The outcomes also show that the importance of literacy, adult skills and women's average years in school in stimulating technological progress are not decreasing. We can therefore conclude that the mutual interaction of higher education quality and skillset of university graduates with indicators of technological progress is the strongest in countries with the highest GDP pc.

5. Discussion

The research results confirm that the increase in education quality translates into technological progress. They are consistent with the findings of a number of other researchers (Saviotti, Pyka & Jun, 2016; Volchik, Oganesyan & Olejarz, 2018; Agasisti & Bertoletti, 2022; Karabayev *et al*., 2023).

The findings do not confirm H1 as true. They indicate that the importance of higher education quality increases alongside economic development, but the importance of primary and secondary education quality does not decrease. This is because primary education quality influences secondary education quality and this is ultimately reflected in the skills of university graduates.

The research results do confirm H2. In our study, women's average years in school are one of five education quality indicators most strongly correlated with technological progress in 160 of the countries studied. The validity of H2 is also confirmed by Global Gender Gap Reports.

As for H3, the findings prove that investing in the quality of adult skills is an important determinant of technological progress regardless of the stage of economic development (e.g., Kamprath & Mietzner, 2015; Grenčíková, Kordoš & Navickas, 2021; Spöttl & Windelband, 2021). For example, the OECD (2018) indicates that future-ready students will need a broad range of skills, including cognitive and meta-cognitive skills (e.g. critical thinking, creative thinking, learning to learn and self-regulation); social and emotional skills (e.g. empathy, self-efficacy and collaboration); and practical and physical skills (e.g. using new information and communication technology devices).

As one might expect, industrialised countries are lagging. There are likely reasons for this. One is the significant concentration of power in the hands of a small number of men who do not want to change the prevailing situation. They may prefer autocratic management and for various types of schools to function as factories churning out appropriately trained graduates (e.g., Costa, Pádua & Moreira, 2023; Khosravi, Yahyazadehfar & Sani, 2023). Another reason is that some industrialised countries seek to forcefully maintain the competitive advantage in resources-, labour-, and capital-intensive commodities that are easy to imitate instead of investing in education and innovative activities. In the case of these competitive advantages, price competition rules the day, making entrepreneurs reluctant to introduce labour-saving innovations (e.g., Majewska & Rawińska, 2018; Kwon, 2019).

6. Conclusions

Our findings have confirmed that without improving education quality it is impossible to move to more advanced stages of economic development. They also suggest that greater prosperity can be achieved by providing women with the same educational opportunities as men and creating better educational conditions for children. Taking these measures leads to a greater majority of society being able to read and write, a necessary condition for social development since the beginning of human history. Literacy in our study also opens the door to ICT and is strongly correlated with improving human capital at every stage of economic development.

The research results also suggest that countries at the second stage must exceed the threshold level for knowledge absorption capacity, which ultimately widens technological capabilities. This cannot be achieved without investing in education quality.

These outcomes allow us to conclude that improving skillset of university graduates and increasing higher education and vocational training quality are the primary conditions for becoming a post-industrial society with a knowledge economy, where the professionalisation of management, democracy and human rights reign.

In future work, we intend to deepen the analysis of the links between the indicators of education quality and technological progress separately for each stage of economic development.

Authors' Contribution

The authors' individual contribution is as follows: Maria Majewska 40%,
Ewa Mazur-Wierzbicka 40%, Nelson Duarte 20%.

Conflict of Interest

The authors declare no conflict of interest.

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