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Original Article

Influence of Investment in Fourth Industrial Revolution (4IR) Technologies on Cost of Production of Manufacturing Industries in Tanzania

Dr. Heriel E. Nguvava, PhD[1*]

[1] Institute of Tax Administration, P. O. Box 9321 Dar es salaam, Tanzania.
* Author's Email: hnguvava@yahoo.com

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ABSTRACT

The study assessed influence of investment in 4IR technologies on production costs of manufacturing industries in Tanzania. Specifically, the study set out to establish relationship and causality of investment in 4IR technologies on manufacturing industries' costs of production. To achieve the research objectives, the study used a quantitative descriptive design to generate the required data. Moreover, the study used structured questionnaires for cross-sectional survey, administered with 225 production managers of manufacturing industries in Tanzania. It used probability sampling in the form of cluster sampling. Additionally, the study used Pearson correlation and the Least Square methods to analyse the objectives of the study. The study found a statistically significant causal effect between investment in 4IR technology and manufacturing firms cost of production whereby, when manufacturing firms increase investment in 4IR technologies by 1 unit, the production cost of such firms will increase by 1.08 units. These results are supported by further findings from the Pearson correlation analysis between investment in industry 4.0 and cost of production of manufacturing firms which indicate positive relationship. When manufacturing firms increase investment in 4IR technology their cost of production will also rise. Implicitly, the emergence of 4IR to countries like Tanzania that are not sufficiently prepared on modern technology supportive infrastructures, policies, strategies and technology governance quality, may occasion a decline in production due to increase in costs of manufacturing firms. This study calls on the Tanzania Government to review and improve its Sustainable Industrial Development Policy of 2020 and the Integrated Industrial Development Strategy of 2025 to promote and support both resource-based industries and technological based industries and speed up industrialization within the country. The government should also improve its investment policies and align them with technological changes brought by 4IR, to attract more foreign direct investments thus further facilitate importation, adoption and imitation of 4IR technologies from developed countries that lead to production cost decline in long-run and enhance productivity of the manufacturing sector.

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INTRODUCTION

The world has lived four industrial revolutions, the first used steam engines for mechanical production, the second used electricity and division of labour to create mass production, the third introduced information technology and automated production processes, currently the world has reached the fourth industrial revolution (4IR). According to Schwab (2017), 4IR is digital transformation that widely affects work life across the world.

Frey and Osborne (2023) suggested that technological and economic changes over the past few centuries represent three major industrial revolutions, first, mechanical production in the late 18th century, second, usage of electricity for mass industrial production in late 19th century, third, personal computers and internet in the 1960s. Recent changes in the world of work are normally termed as the fourth industrial revolution or Industry 4.0 which is featured by key technologies such as artificial intelligence, genetic engineering, cloud computing, biotechnology, 3-D printing, nano-technology, internet of things among others. Bangens (2014) called 4IR as the second machine era. The suggested, the key difference from previous industrial revolutions, current technology is not aimed at replacing physical labour and support human being in doing their work but rather at replacing intellectual work and human workers altogether.

Despite the fact that, 4IR holds great optimism of becoming a driving force for industrial, social and economic growth, it is anticipated to pose a major threat and lead to changes in the patterns of production, employment and consumption, thus set broader socio-economic drivers of change in both developed and developing economies. These changes brought by 4IR may necessitate proactive adaptation by individuals, governments and corporations around the world (Runde, 2016)

According to the World Economic Forum (2016) many economies in the Sab-Saharan Africa have deepened their fear of the consequences of the 4IR. Inability to catch-up with the rise in production cost and production decline due to expensive technological transformation requirements, skills disruption, job dislocations and mass unemployment may undermine economic transformation and sustained growth. Most effects of the 4IR depend on how individuals, governments and corporations will react and accommodate technological transformation.

The Tanzanian economy is characterized by poor infrastructure, low level of digital literacy and technological backwardness, labour intensive, low level of technical education, as pointed out by

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the Tanzania's Industrial Integrated Development Strategy of 2025. The economy is largely informal and still depends on agriculture. These characteristics will no more attract investment and productivity because 4IR poses a challenge to the economic growth catch-up theory since it revises the rules of manufacturing, Lee et al., (2019). The growth strategy which was based on the low- cost labour becomes irrelevant as innovation makes the cost of automation drop and smart productivity boost production.

Tanzania as many others Sub-Saharan African countries, is not well prepared to embrace 4IR thus its impacts expected to hit hard (Millington,2017). Due to high level of automation and technology, developed countries productivity level increase at low cost while developing countries productivity expected to decline due to high production costs. As a result of open market system, protectionism will not be sufficient to protect few local industries against inflow of cheap goods from developed countries. Few available industries will crumple, unemployment level will increase, developing countries become completely open market for foreign goods, and exportation of finished goods subsides as well as foreign direct investments.

The preposition that, industry 4.0 adversely affect manufacturing value added in country's not prepared to embrace it has been supported by Ngepah et al., (2024). Empirical evidence from their study "the impact of industry 4.0 on South Africa manufacturing sector" suggested a significant and negative correlation between the variables. The findings from the study suggested that, South Africa is characterized by deficiency of ICT capacities, inadequate secure data, unsubstantial medium and high-tech investment, inadequate knowledge capacity, absence of regulated system. Therefore, the study recommended, to deal with the negative and significant relationship between industry 4.0 and manufacturing value added, the government and policy makers must concentrate on building up the adaptability of both public and private institution, investing significant on fourth industrial revolution technologies and promoting technical education. According to this study, currently there is no notable manufacturing industries value addition in South Africa as a result of emergence of industry 4.0 rather the cost of manufacturing keeps on rising and revenue declining until government intervention through building of supportive infrastructure development and promotion of technical education for skills matching.

Kajewole et al. (2024) in their work titled "Does industry 4.0 and environmental quality asymmetrically affect South Africa's manufacturing sector? Afresh insight from non-linear autoregressive distributed lag model". In their analysis they revealed a positive but insignificant relationship between industry 4.0 technologies and manufacturing long term value addition. To fully reap benefits of investment in the Fourth Industrial Revolution, it is recommended governments and institutions to prepare and equip in terms of technology supportive infrastructures and enhances technology governance quality.

Tanzania as many other Sub-Saharan African countries is characterized by inadequate investment in technical education, low innovation level, un-preparedness of government and institutions to embrace Fourth Industrial Revolution in terms of Policy, Strategies, ICT infrastructures and Technology Governance Quality. Most large manufacturing firms in Tanzania have adopted, imitated and imported industry 4.0 technologies from developed countries but little attention has been given to analyse the effects of such technologies on manufacturing industries value addition (sales revenue and production cost). This study aims to provide insight on how investment on 4IR technologies made by manufacturing industries in Tanzania affect their cost of production and offer appropriate recommendations.

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THEORETICAL REVIEW

Guiding Theory

This study is guided by the Catch-up Theory. Conferring to Lee et al (2019), the core mechanism of the catch-up theory is the different sources of technological improvements among developed and developing economies. The technological progress of developed economies is primarily based on trial and error, or innovation. The costly and risky innovation results in moderate long-term growth. However, the developing economies can achieve technological progress through technology adoption and imitation, which costs much less than research and development (R&D), as there is a large technological gap between developing and developed economies. Therefore, in the early stage of catch-up, the technological growth rate of developing economies is much higher than that of developed economies. Only when the technology gap between latecomer economies and advanced economies narrows, the technology growth rate begins to slow down. The income growth rate is thus brought down.

In its simplest form as explained by Abramovitz (1986), the catch-up hypothesis states that a country should grow more rapidly if it is initially backward in its level of economic development. This stems from the fact that a country lag in technology carries a potential for rapid growth with imitation and adoption of technology than already advanced countries. This catch-up can take place through capital-embodied technical progress. The lagging country possesses an older, less modern capital stock. The discarding of this stock and its replacement by more modern equipment is accompanied by large productivity gains, larger than those achieved by countries which possessed up-to-date equipment in the first place.

RESEARCH METHODOLOGY

Research Philosophy

This study embraced ontology paradigm as a way of looking at the social reality that is composed of certain philosophical assumptions to guide and direct thinking and actions as pointed out by Mertens (2010). A research approach is usually influenced by ontological and epistemological assumptions or stances of the researcher. This study has adopted the positivism ideology. The philosophical stance adopted (positivism) aims to utilize hypotheses to test existing theories for generalization purposes.

Research Design

This study applied quantitative descriptive design. Specifically, it deployed quantitative and statistical aspects of data organization, presentation and analysis through figures, numbers and tables. Deductive reasoning was employed by this study whereby the researcher collected data during investigation of the problem and subjected the data from investigation to analysis before drawing inferences and logical conclusions. A survey strategy was opted for the above design.

Area of the Study

The study was carried out in Tanzania. A total of 61,110 manufacturing industries were involved in the study. The number represents the sum of manufacturing industries in Tanzania by June 2020. A sample size was then drawn from such a population, since it was unrealistic to reach every manufacturer.

Data Collection Methods

This study employed different data collection methods. Both primary and secondary data were collected. Structured questionnaires for survey were administered with production managers of manufacturing industries to collect primary data. The study also used secondary data to complement primary data. The main sources were documentary review of various official documents and reports (i.e., manufacturing industries' survey reports from the National Bureau of Statistics [NBS], the Tanzania Investment Reports from the Tanzania Investment Centre (TIC), relevant to the research problem.

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Population and Sampling

The targeted population was all manufacturing industries in the country by June 2020. The targeted sampling unit were production managers of manufacturing industries. Since the study population was known with reliability and sampling frame easily determinable, the study adopted a probabilistic sampling method. Specifically, the study used the cluster sampling technique. A sample of 225 manufacturing industries was used in this study to generate the required data. This study allowed the variability results of 5% (margin error), 90% confidence interval at all times, using the Cochran Formula for sample calculation as shown below;

$$n_0 = \frac{Z^2pq}{e^2}$$

Whereby; *e* is the desired level of precision (margin of error), *p* is proportion of population, *q* is 1-*p* and *z* is the z value of 90% confidence level.

Pre-Testing of Questionnaire

Pre-testing was conducted in circumstances that were similar to the actual data collection and on population members in the likeness of those sampled. Pre-testing of questionnaires using a total of 26 production managers of manufacturing industries, which was almost 10% of the total sample size, preceded the actual manufacturing industries survey. Sudman (1983) suggested the use of 20-50 cases during pre-tests as sufficient for discovering major errors in a questionnaire and ensure data validity.

Data Analysis

Descriptive Statistics

Primary data was analysed quantitatively. Measures of central tendencies, skewness and kurtosis of data covering the study period (2012 to 2021), were conducted using descriptive statistics.

Estimation Approach

The Least Square method was used to analyse the study objective. The model helped to estimate changes in dependent variable (Cost of Production) when an independent variable change (Capital Investment in 4IR technologies). Regression analysis describes the relationship between variables by fitting a line to the data observed. Prior to regression analysis, stationarity of time series properties was tested using Augmented Dickey Fuller (ADF), to understand the behaviour and patterns of the data.

To assess the influence of investment in 4IR technologies by manufacturing industries on cost of production, the following estimation model was used:

$$Y_t = \beta_o + \beta_1 X_t + e_t \quad \textbf{1}$$

Where;

Y_t Stands for the outcome variables (Production cost) and X_t stands for Capital Investment in 4IR technologies. β_0 is the constant term and β_1 is the coefficient relating the explanatory variable, and e_t stands for error term.

Description of Variables

Dependent Variables (Y)

Production Cost

It has been measured as the actual annual production cost of manufacturing industries in Tanzania during the period under review (2012-2021).

Independent Variable (X)

Investment in Modern Technology

This variable captures an investment made/spending by manufacturing firms in Tanzania for all the components of the 4th Industrial Revolution (artificial intelligence, nanotechnology, genetic engineering, bio-technology, 3-D printing, internet of things and cloud computing as few examples), with regard to the modernisation of manufacturing techniques.

Reliability of data

Cronbach's alpha was used to test the reliability coefficient, which calculates internal consistency by examining how each test item relates to each

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other and to the entire test., where "_ > .9 – Excellent, _ > .8 – Good, _ > .7 – Acceptable, _ > .6 – Questionable, _ > .5 – Poor, and < .5 – Unacceptable". Cronbach's alpha reliability coefficient, given as a value between 0 and 1, was employed in this study. The scale's items may be internally consistent when Cronbach's alpha is close to 1.0.

PRESENTATION OF FINDINGS AND DISCUSSION

Time Series Properties

Stationarity of time series data denotes that a variable's mean, variance, and auto correlation remain constant across time. During this study, all variables were stationery at lag (0). Using the ADF test at this point all the variables P-Value were less than 0.05 and the value for the ADF unit root test statistic was higher than that of 5% critical value.

Table 1: Unit Root Test

Variable	P-Value	Remarks
Capital invested in 4IR Technology	0.0000	Lag (0)
Cost of production	0.00233	Lag (0)

Source: Author (2024)

Reliability test

This study performed the reliability test on its variables. This test was conducted so as to ensure the internal consistency of the variables of study. Cronbanch's Alpha test was employed in this study. The test results portrayed a scale reliability coefficient greater than 0.65 which means the variables were consistent and reliable to be used for further statistical predictions.

Table 2: Reliability test

Item	Value
Average interitem covariance	.0007149
Number of items in the scale	2
Scale reliability coefficient	0.675

Source: Author (2024)

Descriptive Statistics

This study maximum and minimum values are very close to the mean of the sample; this is an indication that most observations of this study are not dispersed far from their mean. This finding has been complemented by the standard deviation approaching zero (very low dispersion). In the table below, the skewness of variables (capital invested in 4IR technologies and cost of production of manufacturing industries in Tanzania) is portrayed by values approaching zero indicating asymmetry distribution of named variables, that is normal distribution of study data. To ensure reliability and consistency of data, all variable data were transformed to logarithm.

Table 3: Descriptive Statistics

Variable	Observations	Mean	Std. Dev.	Min	Max	Pr(Skewness)	Pr(Kurtosis)
Log_tech	10	26.95366	0.0194808	26.92522	26.97458	0.6659	0.1403
Log_cpd	10	29.27204	0.1259779	29.05401	29.42062	0.4448	0.4289

Source: Author (2024)

Where;

Log_tech is Capital Invested in 4IR Technologies by manufacturing industries in Tanzania

Log_cpd is Annual Cost of Production of manufacturing industries in Tanzania

Two Way Graph on Investment in Technology and Cost of Production

Figure 1 below presents the relationship of manufacturing industries investment on 4IR technologies and their related cost of production

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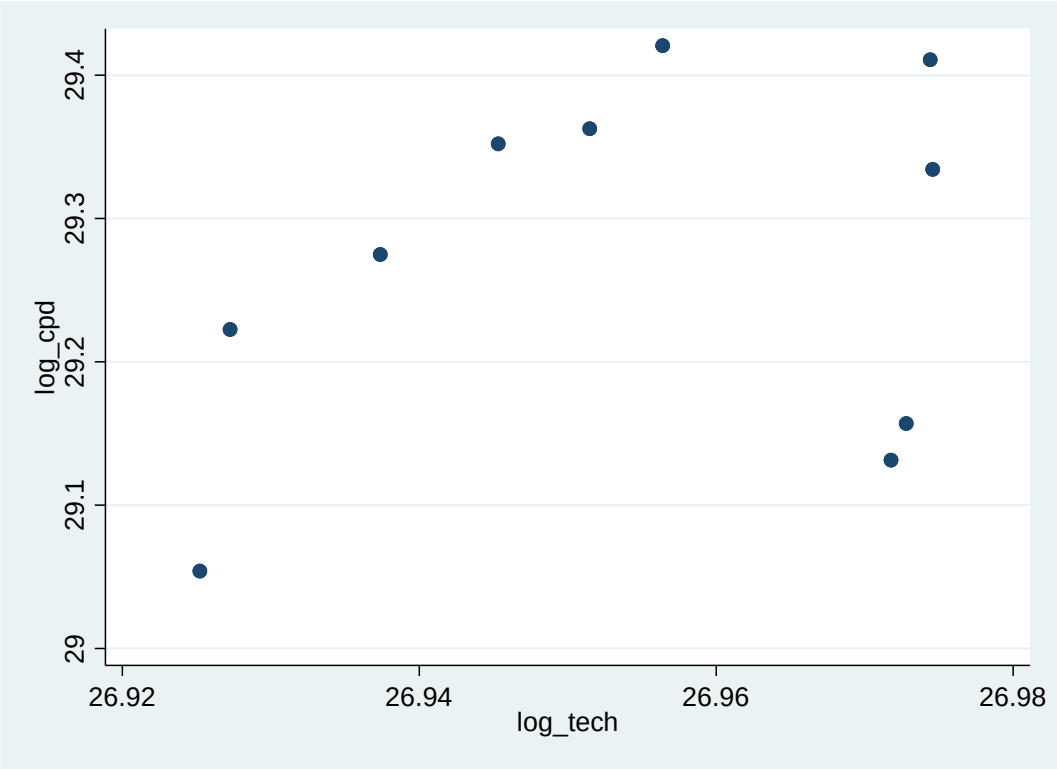
during similar period. According to catch-up theory (Abramovitz, 1986) developing countries like Tanzania invest less in Research and Development but they imitate, adopt and transfer technology from developed countries and quickly catch-up to developed economies in terms of technology. Due to poor Infrastructural preparedness and heavy initial capital outlay to acquire technology, the production costs of manufacturing firms is expected to rise, reaches maximum and start declining. A different behavior has been witnessed in Tanzania manufacturing firms since 2012 where the production cost drastically rose within six years, reaches maximum and declined in the seventh year but drastically rose again from year eight onwards. The manufacturing cost behavior witnessed in Tanzania does not support the catch-up theory as narrated by (Abramovitz, 1986).

Figure 1: Capital Invested in 4IR Technologies and Cost of Production



Source: Author (2024)

Where;

Log_tec is Investment in 4IR Technologies

Log_cpd is Production Costs of Manufacturing Industries

Correlation Analysis Results

The correlation analysis results from table 4 below complements the two-way graph with a correlation coefficient of 0.2913 indicating a positive increase of production cost due to increase in investment in 4IR technologies by manufacturing industries in Tanzania. Therefore, the production cost increases due to heavy capital outlay requirements by manufacturing firms. This study finding differ with the findings by Runde (2016) and Lee et al (2019) on effects of modern technology on production. They both suggested investment in modern technology by manufacturing firms results to economies of scale, manufacturing industries will be able to increase output given the same level of cost or maintain the same output level at reduced cost despite presence of Research and Development cost (R&D) for developed countries. In their analysis they further suggested that, it's even cheaper for developing economies like Tanzania since they spend very

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little in R&D rather they acquire modern technology through adoption, imitation and importation. This study suggests that, the reason for production cost to rise in manufacturing firms in developing countries like Tanzania is infrastructural preparedness to support 4IR technologies and skills mismatch. Kajewole et al (2024) in their work titled "Does industry 4.0 and environmental quality asymmetrically affect South Africa's manufacturing sector? Afresh insight from non-linear autoregressive distributed lag model". In their analysis they revealed a positive but insignificant relationship between industry 4.0 technologies and manufacturing long term value addition. They have similar recommendations as current study, to fully reap benefits of investment in the Fourth Industrial Revolution, it is recommended governments and institutions to prepare and equip in terms of technology supportive infrastructures and enhances technology governance quality.

Table 4: Correlation Analysis

	Log_tech	Log_cpd
Log_tech	1.0000	
Log_cpd	0.2913	1.0000

Source: Author (2024)

Where;

Log_tec is Investment in 4IR Technologies

Log_cpd is Production Costs of Manufacturing Industries

Regression Results

From table 5 the regression summary and ANOVA analysis, it was revealed that, the findings are highly statistically significant with a t-statistic of less than 0.05 at 95% confidence interval. According to these findings, when manufacturing firms increase investment in Fourth Industrial Revolution technologies by 1 unit, the production cost of such firms will increase by 1.08 units.

These findings do not support the work by Abramovitz (1986) who insisted that the fundamental mechanism for catch-up economic theory is differences in technological improvements between developed and developing countries. In his work, it was suggested that, technological progress of developed countries depends on costly and risky trial and errors which result to moderate but long-term growth while developing economies achieve technological progress by imitation and adoption which cost much less than research and development. Thus, production cost was expected to be decreasing or increasing at a decreasing rate.

This study finding is highly supported by Ngepah et al (2024) who concluded that, industry 4.0 adversely affect manufacturing value added in country's not prepared to embrace it. Empirical evidence from their study "the impact of industry 4.0 on South Africa manufacturing sector" suggested a significant and negative correlation between the variables. The findings from the study suggested that, South Africa is characterized by deficiency of ICT capacities, inadequate secure data, unsubstantial medium and high-tech investment, inadequate knowledge capacity, absence of regulated system. Therefore, the study recommended, to deal with the negative and significant relationship between industry 4.0 and manufacturing value added, the government and policy makers must concentrate on building up the adaptability of both public and private institution, investing significant on fourth industrial revolution technologies and promoting technical education. According to this study, currently there is no notable manufacturing industries value addition in South Africa as a result of emergence of industry 4.0 rather the cost of manufacturing keeps on rising until government intervention through building of supportive infrastructure and promotion of technical education for skills matching.

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Table 5: Regression Summary

Log_cpd	Coef.	Std.Err	t	P> | t |	R-squared
Log_tech	1.086014	.0014256	761.79	0.000	.89239

Source: Author (2024)

Where;

Log_tec is Investment in 4IR Technologies

Log_cpd is Production Costs of Manufacturing Industries

CONCLUSION AND RECOMMENDATIONS

The objective of this study was to assess influence of investment in 4IR technology on manufacturing firms cost of production in Tanzania for the 2012 – 2021 period. The study used primary annual data for the 2012 - 2021 period to estimate the degree of causality and capture the effects of investment in 4IR technology on manufacturing firms cost of production. Specifically, the study has found a statistically significant causal effect between investment in 4IR technology and manufacturing firms cost of production whereby, when manufacturing firms increase investment in Fourth Industrial Revolution technologies by 1 unit, the production cost of such firms will increase by 1.08 units. These findings are supported by the Pearson correlation analysis results between the two variables which indicate positive relationship between production cost and investment in industry 4.0 technologies.

Therefore, in less developed countries like Tanzania, that are not fully prepared to embrace the fourth industrial revolution by ensuring availability of technology supportive infrastructures, policies, strategies, enhanced technical education for skills matching, the emergence of fourth industrial revolution will have adverse effect on manufacturing cost of production. This study recommends to the Tanzanian Government to review and improve its Sustainable Industrial Development Policy of 2020 and the Integrated Industrial Development Strategy of 2025 to promote and support not only resource-based industries, but also technological based industries, to speed up industrialization within the country. The government should also improve its investment policies and align them with technological changes brought by 4IR, to attract more foreign direct investments, importation, adoption and imitation of 4IR technologies from developed countries that lead to enhanced productivity and revenue generation in the manufacturing sector.

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