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Modeling The Antecedents of The Quality of Lifeevidence Across the Globe

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Abstract

Science, technology and innovation (STI) are key to economic as well as social development especially in the areas of health, knowledge and standard of living. Extant literature explicitly states the crucial role STI have in propelling development and previous studies identified factors related to development but did not proceed to measuring the abilities of these factors to explain human development index (HDI). Through the lenses of National Innovation Capability Theory, Capability Approach Theory and Social Absorptive Capacities Theory, the researchers proposed and tested a model that predicts the quality of life by employing a positivist deductive quantitative mixed method cross-sectional archival research that involved data from 157 countries. General results revealed that the model is a good model as evidenced by model fit and quality indices and is able to account for or explain the variation in HDI by as much as 85%. Findings of the study provided an empirical model with metrics that can inform policy makers and program developers in the field of science, technology and innovation governance in its role to enhance the quality of life.

Keywords: Polytechnic University of the Philippines, quality of life, human development index, science technology and innovation governance

Introduction

Human development in recent decades has been accompanied by rapid changes in technology and these technologies have already brought enormous benefits (Technology and Innovation Report 2021, 2021, p. xiii; OECD, 2011; The Royal Society, 2011 as cited in Olsson & Meek, n. d.). The United Nations' Office of the Higher Commissioner on Human Rights (UNOHCHR) declared that "the right to development is an inalienable human right by virtue of which every human person and all peoples are entitled to participate in, contribute to, and enjoy economic, social, cultural and political development, in which all human rights and fundamental freedoms can be fully realized" (Declaration on the Right to Development", 1986, Art. 1, no. 1).

The concept of human development was introduced by Dr. Mahbub-ul-Haq (1934 – 1998) who described human development as "a process that enlarges people's choices and improves their lives" ("About Human Development — Measure of America: A Program of the Social Science Research Council", n.d., para. 1). This revolutionary idea on human development, which was initially met with skepticism (Sen, 1999), dethroned the earlier models of development ("Human Development", n. d.) so much so that the 18 Annual Human Development Report (from the 1990 maiden issue to 2005, 2007/2008, 2009) carried this theme or a part of it (Alkire, 2010). The succeeding reports (2010-2016, 2018-2019) still banner this theme.

The three dimensions or latent variables of human development (long and healthy life, knowledge and a decent standard of living) connote human capabilities – what people can do and what can they become" ("About Human Development — Measure of America: A Program of the Social Science Research Council", n.d., para. 3). They may be influenced by external factors which, in this study, also speak of capabilities. These capabilities may take the form of human and financial resources, assistive infrastructure, research-generated knowledge base and economic infrastructure.

Theoretical Background and Hypothesis Development

1. The National Innovation Capability Theory (Chang & Lin 2021). This theory (NICT,) states that "that national innovation capability of a country becomes the key of a core competition, economic growth and employment (Edquist, 2014 as cited in Iddris, 2015) and sustainable development capability" (Zheng, 2006 as cited in Gunadi et al., 2018) and its components can be measured through various aspects such as human resources, knowledge creation, knowledge dissemination and innovative financing (Commission of the European Communities, 2003 as cited in Gunadi et al., 2018). To operationalize this theory in this study, four measures (number of scientists per million people [R1MP], number of technicians per million people [T1MP and R & D expenditure as percent of GDP [R&DE%GDP] from the UNDP database were adopted.

Specific to the human resources are the researchers, scientists and technicians who generate new technical ideas that become the foundations of innovations. Engineers, including scientists and technician, "play a key role in supporting the growth and development of a country's economy as well as in improving the quality of life for citizens" (Cebr, 2016, p.1). As early as 2003, the United Nations Development Program (UNDP) indicated that countries with high human development index (HDI) have, on the average, 2,335 scientists, technicians and engineers per people while those countries with medium HDI have 588 scientists, technicians, and engineers per million people (UNDP, 2003 as cited in "ScienceDirect", 2015).

Expenditure on research and development (R&D) is a key indicator of countries' innovative efforts (Technology & Innovation Report 2021, 2021; OECD, 2013) and its adequacy ensures sustainable development. Since 2000, total global R&D expenditures have more than tripled in current dollars, from $676 billion to $2.0 trillion in 2018 ((Congressional Research Service, n.d.). As the study of Kawahara, Steenhuis and Ristori (2014) shows, there is a direct relationship between R & D spending and HDI. However, the study did not quantify the said relationship. In addition, most of the studies that deal with R & D expenditure dwelt on economic dimension as outcome variable and results vary: some are showing significant relationship (Sokolov-Mladenović et al., 2016; Gumuz & Celikay, 2015;Gülmez ve YardÕmcÕo÷lu, 2012 as cited in Tunaa , Kayacana and Bektaú, 2014; Özcan & Ari, 2014)as cited in Tunaa , Kayacana and Bektaú, 2014; Genç and Atasoy, 2010, as cited in Tunaa, Kayacana and Bektaú, 2014) especially in the case of countries with higher- and medium-level income (Inekwe, 2014 as cited in Tunaa , Kayacana and Bektaú, 2014). On the contrary there is at least one study that found out that R & D expenditure significantly influence economic growth in negative direction (Ozcan and Ari, 2014 as cited in Tunaa, Kayacana and Bektaú, 2014).

2. Social Absorptive Capability Theory (Cohen & Levinthal, 1990; Abramovitz, 1986). This study fused the Absorptive Capacity Theory of Cohen and Levinthal (1990) which

states that Absorptive capacity is a firm's ability to identify, assimilate, transform, and apply valuable external knowledge and the Social Capabilities Approach of Abramovitz (1986 as cited in Anderson & Palacio, 2017) which states that the potential to catch up under globalization is strongest for countries in which social capabilities are developed to allow successful use of technologies. Social capabilities include the production of knowledge and enable engagement of the knowledge generators (scientists, technicians and engineers) with the users of research such as the industry, the communities and notably, the policy makers (Mormina, 2019).

Publications make technical people and the lay alike to be aware of new knowledge and its application ("Why publications in academic journals matter | SU Business School", 2018). Through publications in open academic literature, knowledge is transitioned into practice (Olsson & Meek, n.d.). Publications facilitate diffusion of academic and industrial research generated knowledge to adopters. Through publications, "patented intellectual properties are disclosed and disseminated for pitching and for stimulating follow-up innovation" (Technology and Innovation Report 2021, 2021, p. 52). There is not much literature on the influence of research publication on human development. However, the study (Yakunina & Bychkov, 2015) that involved data from fifteen countries found out that research publications, being a components of innovation index, is a significant predictor of HDI. Together with other components of innovation index, it posted the third highest coefficient among the five predictors of HDI. In contrast to Yakunina & Bychkov study (2015), the current study isolated publication as a variable, hence, hypothesizing that

Anderson and Palacio (2017, p. 2) argued that "the application of technological innovations requires the formation of strong systems, among which is financial system". Access to finance is the prime stimulus to the three stages of innovation activity, namely: developing invention and conducting research, developing prototypes and commercializing inventions and technology diffusion and adoption (Demand for Innovation, 2021). Lack of access to financial resources hinders the commercialization of scientific discoveries and inventions (Daniel & Alves, 2019; Mir, Bagheri & Hashemi, 2018) and limit research and development institutions to producing and promoting low-level innovations which, consequently, dampen their competitive advantage that disable them, in a vicious cycle, to access external funding (Harel, Schwarts & Kaufmann, 2020). Economies that are innovation-driven are characterized by robust public and private investment and expenditure in this sector (Olsson & Meek, n. d.). Empirical evidence from a study conducted in some African countries showed that financing in the form of trade credit enhance innovation and its diffusion (Fombang & Adjasi, 2020).

Knowledge and innovation creation and its eventual commercialization and diffusion prosper in an environment of assistive infrastructure. In this study, assistive infrastructure pertains to those factors that enable the effectuation of scientific knowledge and innovation on human development. Abramovitz' Social Capability Theory (1986) suggested that technical competence is one of them. The idea of technical competence in this study pertains to ICT deployment, skills, R & D activity and industry activity (Technology & Innovation Report 2021, 2021).

ICTs refer to tools or techniques that allow recording, storing, using, diffusing and accessing electronic information (World Bank, 2002 as cited in Hamel, 2010) through which communication, processing and transmission of information and the sharing of knowledge by electronic means are facilitated (UNDESA-GAID, 2009 as cited in Hamel, 2010). The tremendous importance of ICT on human life is much pronounced today that humanity is experiencing the pandemic as it makes possible the delivery of educational services without having the learners and teachers come together in physical space. Research suggests that online learning has been shown to increase retention of information, and take less time (Li & Lalani, 2020), increase task engagement and decrease attrition (Deterding, Dixon, Khaled, & Nacke, 2011; Huotari & Hamari, 2012; Kapp, 2012 as cited in Nguyen, 2015).

In 1990, a new approach in advancing the quality of life was introduced. It asserted that it is all about expanding the richness of life (UNDP, 1990). People who are equipped with right skills and are provided an environment where they exercise their rational choices can optimize their potentials towards living a long, healthy and creative life, becoming knowledgeable, and having access to resources needed for a decent standard of living. Countries, enterprises and persons all perceive skills development as strategic in sustaining and balancing economic for human development (The (World Bank, 2021; ILO, 2010). Le Grand and Thalin (2013) suggested that skills requirements provide a better explanation for social stratification at the labor market (Darin-Mattsson & Kaherolt, 2017). Skill requirements are strongly associated to wages or income which in turn influences access to health care services.

Research and development (R&D) activity is very important for human potential and resource utilization efficiency. Therefore, the R&D capacity of country is important for human development (HD) of that country (Azuh, Ejemeyovwi, Adat & Ayanda, 2020; Ozcagalbas, 2017). An early study (Grossmann & Helpman, 1994 as cited in Blanco, Gu & Prieger, 2015) noted that improvement in technology through R & D has driven the inexorable rise in the living standards of developed countries in the long run.

Industrial activities (IndAct) are needed to produce frontier technologies (Technology and Innovation Report 2021, 2021) and these technological achievements are important to economic development (Ustabas & Ersin, 2016). This type of an advantage could result from the increasing returns and endogenous technological progress which in turn affect the standards of living (Frankel & Romer, 1999 as cited by Ustabas & Ersin, 2016).

The foregoing literature has not yet provided a piece of material that establishes an empirical connection between the World Development Indicators in the field of Science and Technology (WDIST), UNCTAD's Technology & Innovation indicators and indicators of human development index (UNDP) specifically in structural equation modeling. Therefore, this study will establish an empirical, data-driven model that predicts human development index using the most recent data from the aforecited sources. The following hypotheses were forwarded for testing:

H_1: R1MP, T1MP and R&DE%GDP constitute a latent factor that significantly predicts HDI.
H_2: The number of scientific publications constitutes a factor that significantly predicts human development index.
H_3: Access to finance constitutes a factor that significantly predicts human development
H_4: ICT, Skills, R & D activity and Industry activity constitute a latent factor that significantly predict HDI.
Figure 1 below shows the hypothesized model before subjecting the variables to exploratory factor analysis.

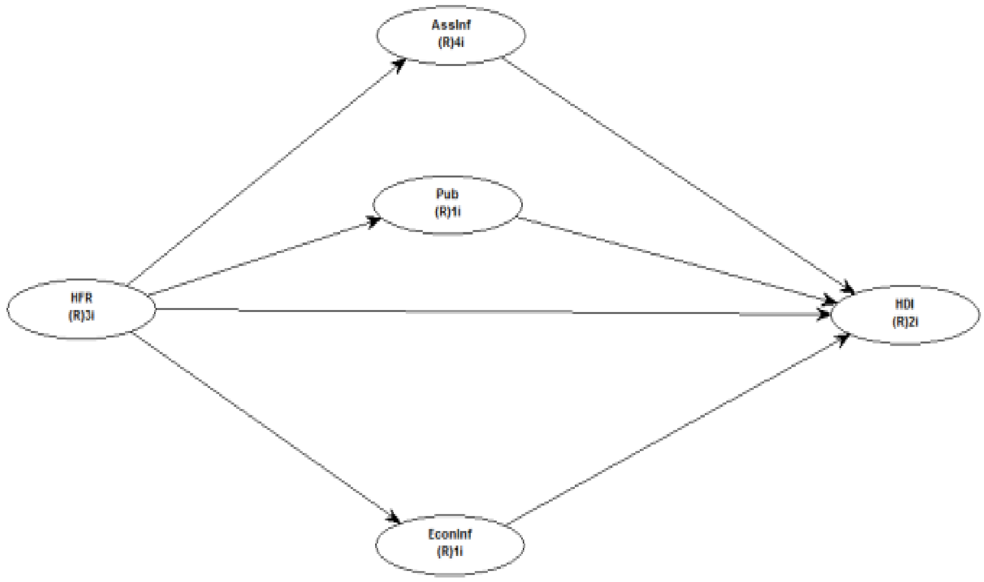

Figure 1. *The Conceptual Framework*

Method

The study sought to identify the latent factors and their respective variables using the World Development Science and Technology indicators (WDSTI) and the UNCTAD Technology and Innovation indicators (UNCTADTII). The resulting factors and their component variables were used to propose a model that predicted human development index (HDI).

Research Design

This positive deductive quantitative archival study employed a sequential mixed-method strategy. The first phase focused on subjecting the WDST indicators and the UNCTAD Technology and Innovation indicators to Principal Component Analysis (PCA) in order to establish which linear components exist within the data and how much does a particular variable contribute to the component. The resulting components were then used to propose a model that predicted HDI (Figure 1) through Structural Equation Modeling (SEM).

Data and Sources of Data

The first set of predictor variables (number of researchers per million people [R1MP], number of technicians per million people [T1MP], number of scientific articles [Pub] and R & D expenditure as % of GDP [R&DE%GDP]) were obtained from The World Bank's database while the second set (ICT Ranking [ICT], Skills Ranking [Skills], R & D Ranking [R&D, Industry Ranking [Ind] and Financial Ranking [Fin]) came from the UNCTAD Technology and Innovation Report 2021. The criterion Human Development Index (HDI) was obtained from the database of the United Nations Development Program. Countries with incomplete data based on the predictor variables were removed from the panel of data. Data cleaning resulted to 157 countries with complete data set.

Data Analysis

In order to reduce the dataset (predictor variables) into interpretable components, Principal Component Analysis (PCA) was employed using SPSS. Diagnostic statistics were

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computed and examined to evaluate if the data set was able to satisfy the assumptions of PCA.

The resulting components and the variables that load on each component were used as exogenous variables to predict HDI through Structural Equation Modeling which was executed using IBM Amos version 20. Model fit and quality indices were examined to determine the fitness of the model to the data set.

Results

PCA yields the following diagnostic statistics: (i) inter-correlations coefficients [$.186 \leq r_{xy} \leq .946$, $\rho < .001$] indicate that all variables can be included in subsequent analysis. (ii) VIF [$1.000 \leq \text{VIF} \leq 2.158$], 1.718 being the average, is far below the maximum acceptable VIF of 4 (Hair et al., 2010), (iii) Tolerance [$0.463 \leq T \leq 1.000$], 0.619 being the average, is higher than the lowest acceptable value of 0.2 (Hair et al., 2010). Both VIF and Tolerance indicate that there is no multi-collinearity among the variables. (iv) ocular inspection of the correlation matrix shows no evidence of singularity. (v) the Kaiser-Meyer-Olsim [KMO = .854] test indicates that patterns of correlations are relatively excellently compact (Hutcheson & Sofroniou, 1999 as cited by Field, 200) which further indicates that the sampling for multiple variables was adequate and PCA will likely yield distinct and reliable factors. (v) the Batlett's Test of Sphericity [$x^2 = 1683.068$, $p < .001$], which tests the null hypothesis that the original correlation matrix is an identity matrix [meaning, all correlations must be zero] is significant. Further, Bartlett's test confirms the adequacy of sampling for each variable, and this is substantiated by an ocular inspection of the diagonals in the Anti-image correlation matrix [$.661 \leq r_{xy} \leq .935$], the range being higher than the 0.5 criterion (Kaiser, 1974 cited by Field, 2000). (vi) a final check of the off diagonals in the Anti-image correlation matrix shows that the partial correlations are small and tend towards zero. In summary, all diagnostics of the PCA indicate that factor analysis is appropriate.

Following the recommended factor loading (Hair et al., 1998), four factor structures were extracted which can explain the variation by as much as 89.40%.

Table 1

Rotated Component Matrix

Factors	Component			
	1	2	3	4
Technicians per 1M People	0.8563			
Researchers per 1M people	0.8363			
Expenditures for R&D	0.8338			
Industry Ranking		0.8327		
ICT ranking		0.6946		
Skills ranking		0.6629		
R & D Ranking		0.5622		
Scientific articles			0.9465	
Finance ranking				0.8797

Factor 1 is labeled as Human and Financial Resources. Factor 2 is labelled Assistive Infrastructure. Factor 3 is labeled Publications and Factor 4 is labeled as Economic Factor. These factors were used in the Structural Equation Modeling as shown below. Structural Equation Modeling was run using warpPLS and yielded the following results:

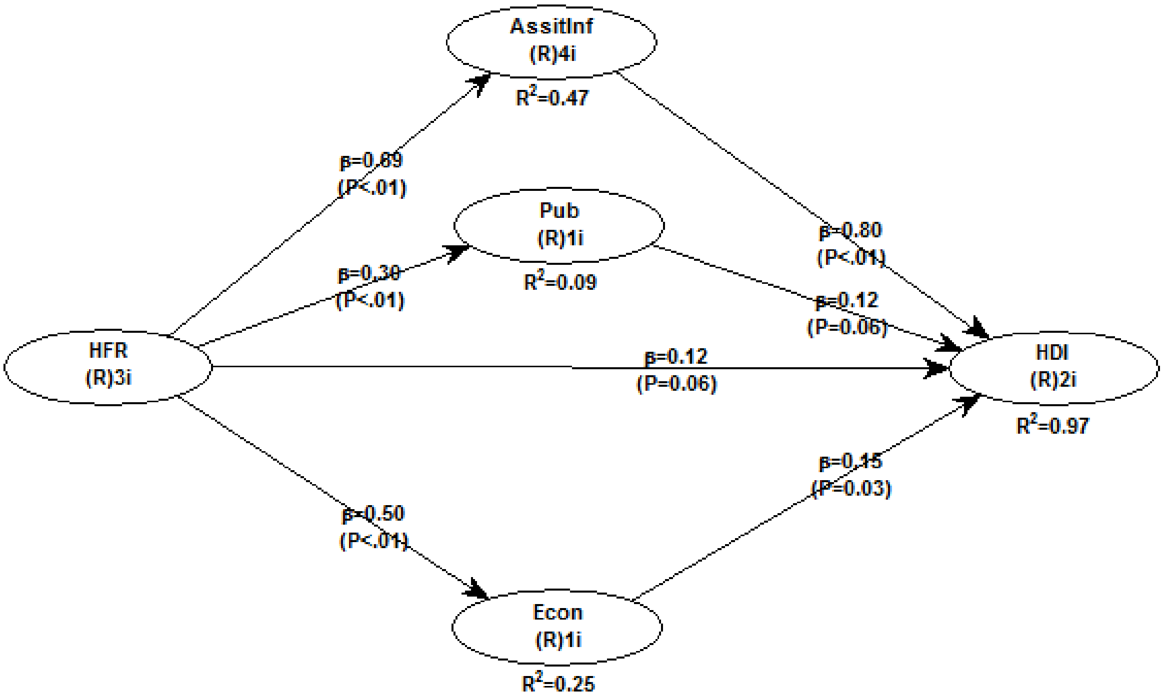

Figure 1. *The Hypothesized Model to Predict HDI*

Because of the insignificant pathways: Pub → HDI (β = 0.12. ρ = .06) and HFR → HDI (β = 0.12, ρ = .06), there is a need to modify the model. The new model proposed was:

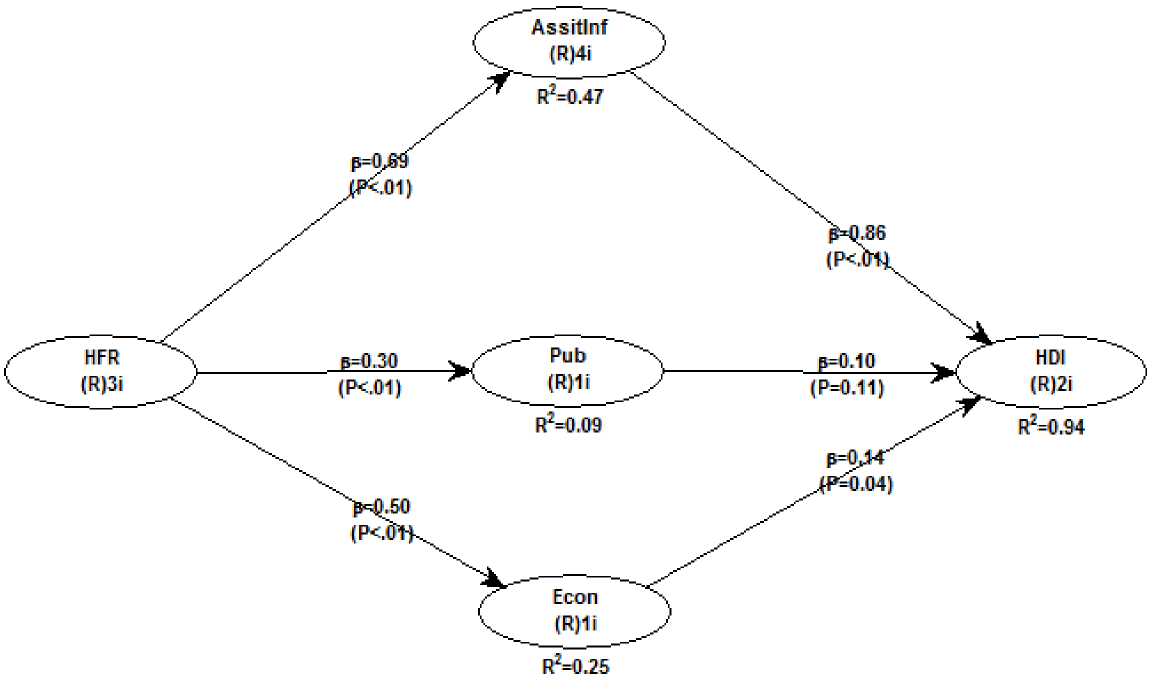

Figure 2. *The Revised Model 2*

However, the path Pub → HDI is insignificant (β = 0.11, ρ = .11. The new model proposed is shown.

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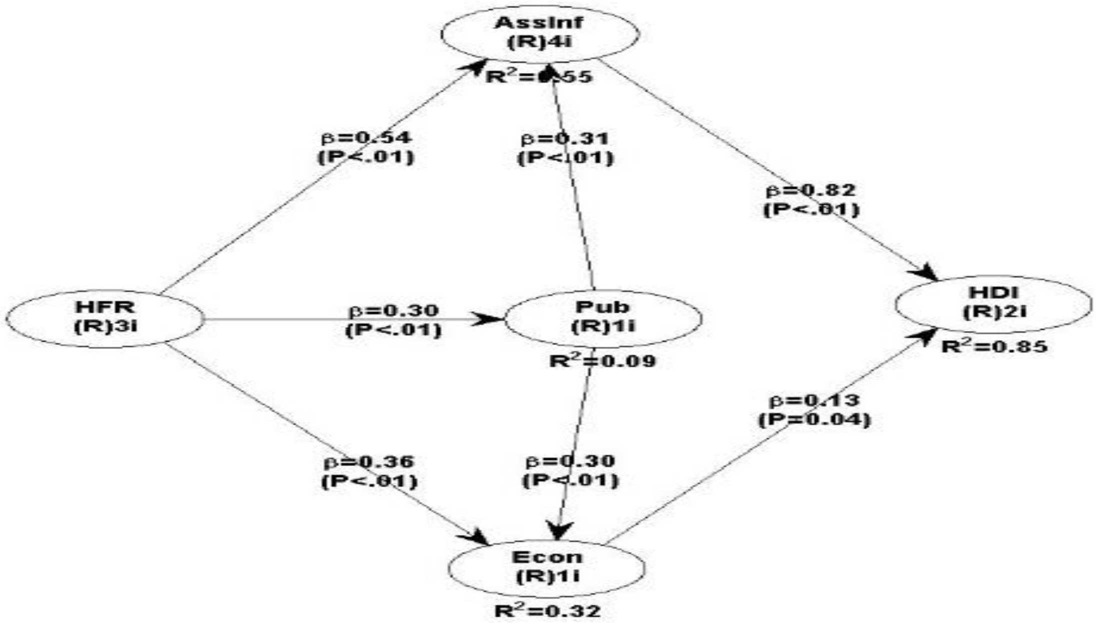

Figure 3. *The Revised and Final Model.*

Table 1

Model Fit and Quality Indices

Model Fit and Quality Indices	Value	*ρ*	Criterion	Interpretation
Average Path Coefficient (APC)	0.196	< .001	.01 ≤ ρ ≤ .05	significant
Average R^2 (ARS)	0.169	< .001	.01 ≤ ρ ≤ .05	significant
Average Adjusted R2 (AARS)	0.445	< .001	.01 ≤ ρ ≤ .05	significant
Average VIF (AVIF)	1.609		acceptable if ≤ 5. ideally if ≤ if 3.3	ideal
Average full collinearity VIF (AFVIF),	3.735		acceptable if ≤ 5. ideally if ≤ 3.3	acceptable
Tenenhaus GoF (GoF)	0.646		small if ≥ 0.1. medium if ≥ 0.25. large if ≥ 0.36	large
Sympson's paradox ratio (SPR)	1.000		acceptable if ≥ 0.7. ideally if = 1	ideal
R-squared contribution ratio (RSCR)	1.000		acceptable if ≥ 0.9. ideally if = 1	ideal
Statistical suppression ratio (SSR)	1.000		acceptable if ≥ 0.7	acceptable
Nonlinear bivariate causality direction ratio (NLBCDR)	0.857		acceptable if ≥ 0.7	acceptable

Results show that the model has a good fit to the data and all indices indicate that the model has a good quality. Tenenhaus' goodness-of-fit (GoF) shows that the model has a large explanatory capacity. The final model was able to explain HDI by as much as 85%.

Discussion

The role of scientists, engineers and technicians in human development cannot be overemphasized. Indeed, human capital is the most strategic factor for human and social development (Oztacalbas, 2017). CEBR (2015) argued that these technical people play a key role in moving a country towards economic development and in improving the quality of life for its citizens. Highlighting the status of countries with high to very high HDI are the statistics on the number of scientists, engineers and technicians which is four time the number of countries with medium HDI (UNDP, 2003 as cited in "ScienceDirect", 2015)

This study revealed that country's expenditure for R & D (as % of GDP) is directly related to HDI confirming the observation that countries across the globe seem to be cognizant of this as evidenced by the tripling of expenditure on R & D since the start of the 21st century (Congressional Research Service, n.d). In a matter of 18 years (2000-2018), the investment in R & D almost tripled. Countries must be seeing the tradeoff on human development, especially in quality of schooling, health and economic well-being of people, hence, this trend. Results of the current study showed that next to researchers, it is the budget for R & D that matters as evidenced by the weight of this indicator on the factor HFR. This finding lends support to the earlier studies which found out there is a direct relationship between R & D spending and HDI. (Sokolov-Mladenović et al., 2016; Gumuz & Celikay, 2015; Gülmez ve YardÕmcÕo÷lu, 2012 as cited in Tunaa, Kayacana and Bektaú, 2014; Özcan & Ari, 2014) as cited in Tunaa , Kayacana and Bektaú, 2014; Genç and Atasoy, 2010, as cited in Tunaa, Kayacana and Bektaú, 2014) especially in the case of countries with higher- and medium-level income (Inekwe, 2014 as cited in Tunaa, Kayacana and Bektaú, 2014). The finding, however, is contrary to the study of (Ozcan and Ari (2014 as cited in Tunaa, Kayacana and Bektaú, 2014) and this is especially true for countries that are beginners in innovations. Registration and Patenting may be eating a lot of budgets in R & D.

For HFR to significantly influence HDI, there seems to be a need for science, technology and innovation to be disseminated before it impacts on HDI since there is no direct path from HFR to HDI. Publications of scientific articles enable technical people to transmit scientific knowledge to lay people, communities, industries and policymakers to aware of new findings and to transition to practical applications for adoption, application, foundation for further innovation and policymaking. This finding confirms the previous study conducted by Mormina (2019), ("Why publications in academic journals matter | SU Business School" (2018) and Technology and Innovation Report 2021 (2021). In contrast to a previous study ((Yakunina & Bychkov, 2015) wherein publication is but one of the components of a predictor of HDI, this study isolated the indicator and found out that it can indirectly influence HDI in two ways; through AssistInf and through Econ.

The model also confirmed the hypothesis that the financial standing of a country significantly predicts human development. For the knowledge and innovation created by the researchers, scientists, engineers and technicians to spill over to the general public, there is a need for availability of finance to private sector which is engaged in research, either as an academic institution or private industries. Better access to finance could accelerate the use, adoption and adaption of frontier technologies (Technology & Innovation Report 2021, 2021). Findings of the study lends support to Anderson and Palacio (2017, p. 2) who argued that "the application of technological innovations requires the formation of strong systems, among which is financial system". Access to finance is the prime stimulus to the three stages of innovation activity, namely: developing invention and conducting research, developing prototypes and commercializing inventions and technology diffusion and adoption (Demand for Innovation, 2021). Lack of access to financial resources hinders the commercialization of scientific discoveries and inventions (Daniel & Alves, 2019; Mir, Bagheri & Hashemi, 2018) and limit research and development institutions to producing and promoting low-level

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innovations which, consequently, dampen their competitive advantage that disable them, in a vicious cycle, to access external funding (Harel, Schwarts & Kaufmann, 2020). Economies that are innovation-driven are characterized by robust public and private investment and expenditure in this sector (Olsson & Meek, n. d.). Empirical evidence from a study conducted in some African countries showed that financing in the form of trade credit enhance innovation and its diffusion (Fombang & Adjasi, 2020).

The assistive infrastructure serves as indirect path for the products of scientists, engineers and technicians to influence human development as measured by HDI. Knowledge and innovation creation and its eventual commercialization and diffusion prosper in an environment of assistive infrastructure. Consistent with the literature, findings reveal that a society with assistive infrastructure such as ICT, R & D activities, skills and industry activity makes a country to possess social capability (Abramovitz, 1986) that enables it to effect scientific knowledge and innovation for the benefits its people. ICT, for instance, affords people greater access to digitally stored information for their perusal (World Bank, 2002 as cited in Hamel, 2010). The current pandemic emphasizes the utmost importance of ICT in human lives especially in the field of education wherein the teaching – learning process takes place in the digital world for the pandemic prohibits physical interaction between teachers and learners. Because ICT allows recording, storing, using, diffusing and accessing electronic information (World Bank, 2002 as cited in Hamel, 2010), learners can retrieve learning materials with ease given the affordances of appropriate technologies. In online learning, evidence shows that retention is better, given the lesser amount of time (Li & Lalani, 2020). More so, online learning is more engaging (Deterding, Dixon, Khaled, & Nacke, 2011; Huotari & Hamari, 2012) which is sustained over time (Kapp, 2012 as cited in Nguyen, 2015), hence, the quality education.

Skills constitute another dimension of assistive infrastructure that impinge on the quality of life as they provide differential social stratification and better access to the opportunities in the labor market. This confirms the findings of Darin-Mattsson & Kaherolt (2017) and Le Grand and Thalin (2013). People having the right skills which they can exercise in the proper environment have higher probability of having better quality of life that is characterized by living a long, healthy and creative life, becoming knowledgeable, and having access to resources needed for a decent standard of living as the skills - opportunity chemistry is said to be strategic in balancing economic and social development (The (World Bank, 2021; ILO, 2010). With the appropriate knowledge and skills in the prevailing technological sphere, people can have ease in exploiting the may affordances the technological world has; enabling them to access educational, health and job opportunities.

The current study found out that through Industry activities, researchers, scientists, engineers and technicians influence the quality of life by providing tools and insights to produce goods and services for the general public. Thus, this study supports earlier studies which found out industrial activities turn out frontier technologies that enable people to live in a 21st century world Technology and Innovation Report 2021, 2021). These technological advancements are crucial to economic progress (Ustabas & Ersin, 2016). This, in turn, positively affect the standards of living (Frankel & Romer, 1999 as cited by Ustabas & Ersin, 2016).

In addition, the current study confirms the hypothesis that R & D activities positively influence HDI. Research and development (R&D) activity is very important for human potential and resource utilization efficiency. This confirms the findings of Azuh, Ejemeyovwi, Adat & Ayanda (2020) and Ozcagalbas (2017) who argued that the R&D capacity of country is important for human development of that country and Grossmann & Helpman (1994 as cited in Blanco, Gu & Prieger, 2015) who noted that improvement in technology through R & D has driven the inexorable rise in the living standards of developed countries in the long run.

Conclusions

The paper established an empirical model that predicted HDI based on World Bank's World Development Indicators in Science and Technology, UNCTAD's Technology and Innovation Report data from and the UNDP human development index. Findings inform that for countries to realize the SDG goals of ending poverty, protecting the planet, and ensuring prosperity for all, countries must establish and maintain an ecosystem where R & D initiatives will thrive. This ecosystem is characterized by (i) government supporting the R & D sector in the form of policies and financing, (ii) private sector support in the form of financial institutions providing R & D sector greater and better access to financing that will accelerate the knowledge and innovation creation, (iii) industry support in the form of product processing and development, and (iv) government support in terms of policies that incentivize firms that support, directly or indirectly, the R & D. sector. Future research may warrant further disaggregation of the current indicators to find out underlying patterns, trends or insights not revealed by the current model.

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