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A Multi-Attribute Assisted Performance Deduction and Related Value in Triple Helix Innovation Networks

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Abstract

Typically, Triple Helix relations, between, Higher Education Institutions, Governments and Industry(s) are inferred from patents and research output. Systemic determination of the relationship is because of observations over a period. It is, however, possible to analyze this relation from a system present from the word-go. This then allows for the interaction to be analyzed on the basis of performance and logically gains for participation by all the agents. Several models have been proposed to deduce the Triple Helix Relation and these hold. This paper has however introduced a new dimension to the analysis, by viewing participation from an investor point of view with decision making being of a complex and deductive nature based on the performance of higher education systems or institutions. The TOPSIS supported performance deductions helps synthesis decision solutions that facilitates value determination of performance and its resultant impact on investment gains. Possible future implications for this, are also provided

Key Words: Triple Helix, Government, Higher Education Systems, Industry, TOPSIS, Decision Making.

Mathematical Subject Classification:

1. Introduction

The Triple Helix originated as a model of discontinuous innovation which is defined as the ability to renew innovation systems across technological paradigms (Etzkowitz, de Mello, & Almeida, 2005). The basic assumption of the triple helix model for explaining university-government-industry relations is that there exists a positive synergy among the actors in knowledge systems (Etzkowitz et al., 2005; Irawati, 2007). Irawati (2007), posits that the model considers higher education institutions as the centre of knowledge generation with a special emphasis on research output as the basic means of assessing performance.

Thus, higher education institutions are directly responsible for innovating development activities within the helix. Industry in this relation is the major customer of the innovation blow out because of university activities and seeks to harness this for its commercial gain. Government retains its role as policy maker seeking to regulate higher education institutions as well as industries, towards ensuring sustainable national development. The tangent of the three relations provides the ideal point where the probability of knowledge generation is high, industry participation is assured, and government is satisfied with the level of controls and resulting development within the economic system. Thus, the triple helix provides the novel direction for projecting the evolutionary path of higher education institutions and national innovation systems.

In recent works, Abramo and D’Angelo (2016a), argues that there is a growing community of scientometrics, with increasing impact on decision-making analysis. In the field of higher education, where institutional performance provides the nectar that signals partners to form symbiotic relations with higher education institutions, this has led to a proliferation of the adoption performance deduction approaches. Institutions are then, subjected to these approaches and ranked based on mean determined performance scores. In the case of Higher Education, research output tends to be the variable of concern. In their view, policy makers in higher education are left bewildered as to which ranking system or performance assessment method, provides a practical and true picture of institutions. This becomes a bigger issue in emerging economies where resource scarcity requires prudent allocation.

Taking cues from literary works, (Abramo, D'Angelo, & Viel, 2013; Aziz, Janor, & Mahadi, 2013; Holligan & Sirkeci, 2011; Larivière & Costas, 2015; Vaivode, 2015) there is a strong reason why higher education performance is based on research output. However, there is also the caution to adopt a holistic approach to assessing institutions to ensure a general view of performance.

In most instances, the decision to invest or not to invest in higher education has been strongly influenced by ranked performance. The lack of a homogenous approach to assessing the performance of higher education institutions provides several challenges, which must be countered for by researchers. This paper adopts a micro-analytic deduction of performance metrics which is then subjected to a Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to determine institutional performance in relation to the ideal performance per given period. The approach hinges on a multi-attribute approach. The value of performance is critical in the decision-making process as it can serve as a signal of levels of commitment that investment partners may wish to commit to the innovation partnership.

2. Objectives of the Study

Extant evidence shows that daily, individuals confronted with decision-making, are also provided with an abstract pot of alternatives from which choices must be made. The complexity of choice, information of, and on the alternatives, duration for and effect of choice as well as the constraints of the alternatives not selected tend to vary decision-making per any given dip into the choice-pot (Erdem & Keane, 1996; Letsholo & Pretorius, 2016; Paternoster & Pogarsky,2009). Per the argument of Cabrera et al (2015) two critical factors influence decision-making; value placed on the choice-alternatives and the possibility of selecting the best. The logic for their argument is that, in the ideal situation, decision-makers have all the information and mechanism to optimise choice. Wang et al. (2015), also argue that MCDM involves multiple decision criteria and, at the worst, these criteria might mutually influence one another to lead to a complicated situation. They state that decision making is a sophisticated art and decision makers indeed require some help to make good decisions. Therefore, the choice of participation within a Triple Helix must be built on empirically supported information. Performance is very relevant in this case, as it determines the value placed on the choice made and the alternative that could have been made.

The practice of educational leadership has its challenges not only in myriad events that arise, but also in working with various stakeholders in education, from students and their parents to academics, other administrators and support staff, to community members as well as funding agencies, and governments. With this practice comes an attending challenge of complexity to which the education leadership might respond status quo or in a variation of spot attempts at novel approaches, like additives people put in their vehicles to improve performance. In this, complexity that commits education and its leadership, to rely on tried and true practices or ad hoc patches of this or that approach now runs a great risk of failure or compounding problems. The application of systemic thinking arguably ensures a more productive approach to managing educational systems (Welford, 2016).

This paper provides a novel approach in determining the value of choice in a triple helix relation. The approaches introduced in this paper dictates empirically systemising productivity (performance) and as such, guide managers and investors to properly direct and apply resources to relevant sections of any educational system. The act of borrowing from diverse fields to explain phenomena in unrelated fields has provided complexities in the field of decision-making. Several models have been forwarded by scientometrics with a strong emphasis on the strengths and downplayed weakness to help decision makers make pragmatic decisions. This paper builds on the individual-centred grey model proposed by Zhang et al. (2008), for evaluating research performance; as an extrapolation of the general institution performance. The logic being that, a Higher Education Systems performance is directly correlated to the probability of government and industry participation in institutional activities. The coefficient of the sum of this interaction provides an indirect but empirically correct way of asserting stakeholder opinion (ranking) of any higher education system. This can further be reduced to determine at the micro level, the performance of a single institution within any cluster or even cross-cluster assessment. On the basis of this, we propose a synthesised model for assessing performance within higher education institutions and building on this, apply it to a stock model as the means for determining decision making and participation points within the triple helix relation.

Summarily, this paper is a numerical deduction of performance from a multi-attribute approach, with performance and affiliate ranking being determined by a weighted TOPSIS approach. This approach is subsequently used to determine the value of performance when the contributions of partners are considered. The impact of performance value on innovation capital is then modelled. We will then provide an analytical conclusion of the paper as well as possible research implications of the current work.

3. Literature

There has been a shift from an earlier focus on innovation sources confined to a single institutional sphere, whether product development in industry, policy-making in government or the creation and dissemination of knowledge in academia, to the interaction among these three spheres as the source of new innovative organisational designs and social interactions. This shift entails not only various mechanisms of institutional restructuring of the sources and development path of innovation, but also a rethinking of our main models for conceptualizing innovation, including innovation systems (national, regional, sectoral, technological, etc.) and the Triple Helix.

Overall, globalisation and constantly changing markets have meant that knowledge and innovation have become key factors in the sustainable development of any economy, whether local or global (Luengo and Obeso, 2013). The triple helix model seeks to explain national and/or regional economic development policies through research systems, social contexts or economic and/or social returns on projects funded by government decision makers or companies (Coronado et al., 2004; Etzkowitz and Brisolla, 1999; Malecki, 2005; Ritala and Huizingh, 2014). This model is associated with the concept of academic entrepreneurship (Meyer, 2003), which seeks to define the new entrepreneurial dimension of universities (Etzkowitz and Klofsten, 2005; Ritala and Huizingh, 2014).

In recent decades, for complex decisions in terms of the consideration of multiple factors, researchers have been focused on Multi Criteria Decision Making (MCDM). MCDM is a well-established branch of decision making that allows decision makers to select and rank alternatives according to different criteria and is divided into two categories: Multi-Objective Decision-Making (MODM) and Multi-Attribute Decision-Making (MADM) (Pirdashti et al., 2009). In MADM, several options according to some criteria are ranked and selected. Ranking and selecting will be made among decision alternatives described by some criteria (factors) through decision-maker knowledge and experience (Devi et al., 2009).

Using MADM techniques for improving decision making results are not a novel idea. There are several researches using MADM such as, TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) (Devi et al., 2009; Simanaviciene & Ustinovichius, 2010; Stevens-Navarro & Wong, 2006), SAW (Simple Additive Weighting) (Janic & Reggiani, 2002), AHP (Analytical Hierarchy Process) (Karami, 2011; Yeh, 2002; Agalgaonkar et. al, 2005), and Entropy (Andreica et. al, 2010). However, the authors focus on TOPSIS, since that is the method used for their work.

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), developed by Hwang and Yoon in 1981, is a simple ranking method in conception and application. The standard TOPSIS method attempts to choose alternatives that simultaneously have the shortest distance from the positive ideal solution and the farthest distance from the negative-ideal solution. The positive ideal solution maximizes the benefit criteria and minimizes the cost criteria, whereas the negative ideal solution maximizes the cost criteria and minimizes the benefit criteria. TOPSIS makes full use of attribute information, provides a cardinal ranking of alternatives, and does not require attribute preferences to be independent (Chen & Hwang, 1992; Yoon & Hwang, 1995). To apply this technique, attribute values must be numeric, monotonically increasing or decreasing, and have commensurable units.

In recent years, TOPSIS has been successfully applied to the areas of human resources management (Chen et. al, 2004), transportation (Janic, 2003), product design (Kwong & Tam, 2002), manufacturing (Milani et. al, 2005), and water management [Srdjevic et. al, 2004). In addition, the concept of TOPSIS has also been connected to multi-objective decision making (Lai, 1994) and group decision making (Shih et. al, 2001). The high flexibility of this concept can accommodate further extension to make better choices in various situations. A relative advantage of TOPSIS is the ability to identify the best alternative quickly. It is for this reason the authors have used TOPSIS to determine a numerical deduction and analysis of performance from a multi-attribute approach.

4. Proposed Model for Assessing Higher Educational Institutions Performance

Zhang et al. (2008), reviewed several literary works on the development of an extant model for assessing performance in universities. They conclusively summarised that evaluation of research performance of academics was one of the most important aspects in research project management and university performance assessment as a whole. Thus, research output, input processes, which strongly influence policies, guiding institutional development. Seeking a modelling approach to appreciating this interaction therefore provided the basis for a quantitative method to be developed to aid innovation negotiators, innovation intermediaries to actively base decisions on funding allocation decisions correctly. The model they developed was based on the molecular analysis of the performance of institutions with emphasis on the individual academic's research strengths and weaknesses.

Citing prior works, Abramo and D'Angelo (2016b), cautioned against the use of Mean Scores of research output as a valid method for institutional performance assessment, arguing that all size-independent indicators of assessment based on publication ratios be considered same. Their recommendation was to focus on efficiency indicators, which provides for the microanalysis of all variables within the larger frame of systems performance assessment. This is because it is logical to expect a strong correlation between quantity and impact.
Taking cues from literary works, (Abramo, D'Angelo, & Viel, 2013; Aziz, Janor, & Mahadi, 2013; Holligan & Sirkeci, 2011; Larivière & Costas, 2015; Vaivode, 2015) there is a strong reason why higher education performance is based on research output. However, there is also the caution to adopt a holistic approach to assessing institutions to ensure a general view of performance.
The basic models of performance review in the literature allude to the use of research output as the main component of the assessment of higher education institutions. Figure 1 shows that, however flawed they have been argued to be, the major institutional ranking methods consider more variables than research in the ranking of Higher Education Institutions.

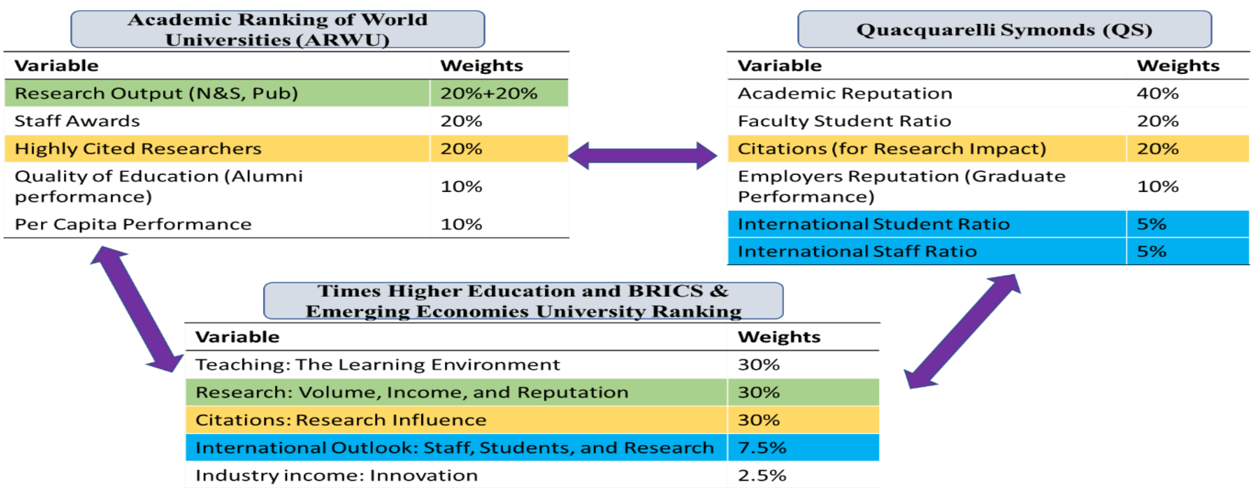

Figure 1: Comparative analysis between three major higher education ranking systems; Source: (Pavel, 2015)

On basis of the above, and based on commonalities, we determined and propose that weights of higher education performance assessment parameters to be considered as shown in Table 1.

Table 1: Synthesized Summary of Critical Variables in Assessing General Higher Education Performance

Critical Ranking Variable	Calculated Average Weights from Figure 1 (ARWU, QS and THE)	Proposed Equitable Average Weight
Research	0.32	0.30
Income	0.07	0.15
Internationalization	0.07	0.20
Awards	0.23	0.15
Academic Quality	0.31	0.20
Total	1	1

Thus, we base our model on a value-weighted index of all attributes of performance assessment. These may be expanded to accommodate future identified factors. Given that the coefficient of performance is a weighted index, expansion or contraction of the factors will not affect the performance analysis.

4. Numerical Deduction of Performance Variable Metrics

4.1 Funding

$$\mathcal{F} = \frac{1}{\tau\omega_1} \sum_t a_{1t} \cdot b_{1t} \quad (1)$$

Where

- $\mathcal{F}$ = Funding performance
- ω_1 = national standard of funding that a university should generate per a given period(t).
- a_{1i} = actual funding generated by an institution (in the case of cluster considerations, the average for the cluster should be used)
- τ = "Staff" component of the national standard for "Staff-Student Ratio".
- b_{1i} = average weights of funding sources determined by contributions from:
  - National funding (government allocation)
  - Industry Support
  - Internally Generated Funding

4.2 Awards

$$A = \frac{1}{\tau\omega_2} \sum_l a_{2l} \cdot b_{2l} \quad (2)$$

Where

- A_1 = Awards Performance
- ω_2 = average rate of publications to patency as a result of research leading to nominations for consideration of award (l).
- a_{2l} = actual quantity of type $l$peer recognised nominations
- τ = National Average of staff per faculty.
- b_{2l} = factor of publications type (calculated as an average of publications of an Institutions / Faculty and or Program), based on (at least one of these)
  - Journal Rank
  - Number of Citations
  - Average Impact Factor

4.3 Internationalization

$$I = \frac{1}{\tau\omega_3} \sum_t a_{3t} \cdot b_{3t} \quad (3)$$

Where

- I = Internationalization
- ω_3 = national standard of internationalization (staff "α"; student "β" and Off-shore campuses/MoUs "ϕ") that a university is allowed per a given period (t)
- a_{3t} ="Average of Actual Presence" of international participation $\left[\frac{(a_{3t\alpha}+a_{3t\beta}+a_{3t\phi})}{T}\right]$,
  - T=Total number of institutions in any higher education system
  - t = period/time under consideration
  - α,β, ϕ = actual numbers of Internationalization
- τ = National Average of staff per total number of higher education institutions.
- b_{3t} = average weight of actual participation deduced as: $\left[\frac{(\alpha+\beta+\emptyset)}{\gamma}\right]$
  - Where "γ" = number of international communities or countries participating in in any higher education system per any given period

4.4 Academic Quality

$$Q = \frac{1}{\tau\omega_4} \sum_k a_{4k} \cdot b_{4k} \quad (4)$$

Where

- $Q =$ academic quality
- ω_4 = expected average of national graduate output expected within a higher education system

  - calculated as an average of total enrolment against number of institutions within a cohort period[1].
- a_{4k} = actual graduate output within a higher education system per given period
- τ = National Average of staff per Institution.
- b_{4k} = factor of graduate quality determined as a weighted average of
  - Working Area (that is level of companies/agencies within which they work)
  - Rate of employment in a given cohort of graduates
  - Employment Opportunity within the country

4.5 Research

Publications (Authored Research/Books/Reports)

$$R_p = \frac{1}{\tau\omega_5} \sum_j a_{5j} \cdot b_{5j} \tag{5}$$

Where

- $\boldsymbol{R_p} =$ Authored research, books, commissioned reports etc
- ω_5 = national standard quantity of publications expected from a higher education institution per set period
- a_{5j} = quantity of type j publications
- τ = National Average of staff per faculty.
- b_{5j}= factor of publications type$j$ (calculated as an average of publications of an Institutions / Faculty and or Program), based on
  - Journal Rank
  - Number of Citations
  - Average Impact Factor
  - Inter – Institutional Co-authorship
  - Cross-Border Co-authorship

Patents

$$R_{AP} = \frac{1}{\tau\omega_6} \sum_k a_{6k} \cdot b_{6k} \tag{6}$$

Where

- $\boldsymbol{R_{AP}} =$ Research linked patents
- ω_6 = average adopted or adoption rate of industry of research and patents.
- a_{6k} = quantity of type k applications and patents developed from research in a period
- τ = National Average of staff per faculty.
- b_{6k} = factor of applications.

Research is therefore calculated as $R = \sum(\mathrm{R_p} + \mathrm{R_{AP}})$

5. TOPSIS Determined Performance Value

Multiple Attribute Decision Making (MADM) approaches are becoming increasingly the go to method for decision science researchers. As decision making in human systems peak in complexity, it becomes more and more difficult for single parameters to provide credible information required to resolve decision problems. The decision maker, to maximise the likelihood that the final solution to a problem is optimally the best possible considering all possible factors that may influence the decision and its resultant impact on the system. Typically, the MADM analysis involves an aggregation of a set of parameters that is considered a decision matrix, which derives value by being paired to a weighting condition.

Our approach assumes that the performance parameters form a decision matrix that when matched to the weights in Table 1, will provide the valued performance of each higher education institution. The resolution of this matching to weight adopts the TOPSIS approach developed by Hwang (1981). It is worth noting that weight determination is very

[1]The Gross Enrolment Ratio can also be used, as this is an average of expected participation

important in decision making, arbitrarily assigned weights without strong supporting logics, may render the final decision non-effective in resolving the decision problem.
The TOPSIS approach starts by first normalizing the malt attribute decision matrix, now considered as the indicator matrix (Tang, Shi, & Dong, 2019). Thus, assuming that our indicator matrix building on equations 1 to 6 is of the form P(m×n); where m and n are performance indicators.

The indicator matrix can therefore be written as:

$$P = \begin{pmatrix} \mathcal{F}_1 & A_1 & I_1 & Q_1 & R_1 \\ \mathcal{F}_2 & A_2 & I_2 & Q_2 & R_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \mathcal{F}_n & A_n & I_n & Q_n & R_n \end{pmatrix}_{m\times n}$$

The decision matrix that will be applied to our TOPSIS approach then takes the form

$$g = \left(\begin{array}{ccccc|c} \mathcal{F}_1 & A_1 & I_1 & Q_1 & R_1 & w_1 \\ \mathcal{F}_2 & A_2 & I_2 & Q_2 & R_2 & w_2 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \mathcal{F}_n & A_n & I_n & Q_n & R_n & w_n \end{array}\right)$$

Thus, normalizing P, is obtained as

$$\mathrm{P_{ij}} = \frac{\mathrm{x_{ij}}}{\sqrt{\sum_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{x_{ij}^2}}} \qquad (7)$$

Next, calculate the weighted normalization matrix as

$$g_{ij} = P.w \qquad (8)$$

Where w is a vector matrix, whose elements are the weights of the performance attributes. Thus, the positive ideal solution $Z^+$and the negative ideal solution Z^-can be obtained as

$$Z^+ = \{g_1^+, g_2^+, \dots, g_n^+\} = \left\{\left(\max_i g_{ij} \,\middle|\, j \in K_1\right)\left(\min_i g_{ij} \,\middle|\, j \in K_2\right) \mid i = 1, \dots, m; j = 1, \dots, n\right\} \qquad (9)$$

$$Z^- = \{g_1^-, g_2^-, \dots, g_n^-\} = \left\{\left(\max_i g_{ij} \,\middle|\, j \in K_1\right)\left(\min_i g_{ij} \,\middle|\, j \in K_2\right) \mid i = 1, \dots, m; j = 1, \dots, n\right\} \qquad 10$$

Such that K_1 and K_2 are the benefit and the cost indicators of performance respectively. The distance of each indicator from the positive ideal or negative ideal can then be calculated as

$$\boldsymbol{S_i^+} = \sqrt{\sum_{j=1}^{m} (\boldsymbol{g_j} - \boldsymbol{g_{ij}^+})^2},\ \boldsymbol{i} = \mathbf{1}, \dots, \boldsymbol{m}; \boldsymbol{j} = \mathbf{1}, \dots, \boldsymbol{n} \qquad (11)$$

$$\boldsymbol{S_i^-} = \sqrt{\sum_{j=1}^{m} (\boldsymbol{g_{ij}} - \boldsymbol{g_j^-})^2},\ \boldsymbol{i} = \mathbf{1}, \dots, \boldsymbol{m}; \boldsymbol{j} = \mathbf{1}, \dots, \boldsymbol{n} \qquad (12)$$

Thus, the relative proximity of each institutions performance to the ideal performance can be calculated as

$$O_i = \frac{S_i^-}{S_i^- - S_i^+}, i = 1, \dots, m \qquad (13)$$

Finally, to determine best performing higher education institutions, simply rank institutions based on the results obtained in (13).

6. Determining the Value of Performance in a Triple Helix

It is important to know which institutions are at the top in any cluster of innovation networks, however, national governments as well as potential investors are always interested in knowing the value of performance of these institutions. Valued performance of higher education institutions, we believe will provide the critical incentive that will establish the dyadic relations through which innovation is generated, diffused and or adopted.
Building on our earlier deduction, of a TOPSIS determined performance of higher education institutions; we consider performance as $\boldsymbol{O_i}$ within a specified period (t) and a prior history of $(1 - t)$ with performance dynamics being

reflected in change in time and institutional ranks. Let us then suppose that industry (I) and government (G) institutions are partners necessary for any Higher Education Systems (U)[2] performance to change per any period.

$$G_t = (G_t^m, G_t^u)$$

where G_t^m is the measure of direct investment in higher education by government while G_t^u is the indirect[3] contributions of government such as policies and regulations that foster partnership with non-government agencies or indicate institutional stability. Under the same assumptions, industrial contribution to $\boldsymbol{O_i}$ at any point in time can be written as

$$I_t = (I_t^m, I_t^u)$$

where I_t^m is the measure of direct investment in higher education while I_t^u is a measure of the indirect contributions that industry commits to improving $\boldsymbol{O_i}$ at any point in time. Indirect industrial commitment may be observed through acceptance of students on attachment programs, as well as allocation of industrial space and facilities for faculty to develop and or test innovations.

Subsequently, performance of higher education institutions in relation to government and industry input maybe considered as

$$\begin{matrix} A_1(G_t, n_t, z_t) \\ A_2(I_{t,} n_t, z_t) \end{matrix} \qquad (14)$$

In this equation, A denotes an assumed constant return to scale in the vector of performance in the triple helix system. The random variable z_t is a shock variable at period (t).

Considering there is a nonlinear dynamic relationship between the actors in the helix, performance can therefore, be a good extrapolation index, of how higher education yields capital for government and industrial partners.

Consider B as a two-dimensional function displaying constant returns to scale for any of the partners direct investments as i_t, then z_t as an identified shock to the system at any period. The shock variable may for example be represented by political change, review of economic policies relating to research and development activities by central government as well as change in leadership of industrial partners. Shock variables may be allocated a value of either 1 or 0 for being present or absent, thus total shock will be total number of shock instances observed within the system per period. It is safe therefore to assume that there are at least two components of each participant's contribution to the dynamics of performance for any higher education institution. This is observed as

$$\begin{matrix} G_{t+1} = B_1(i_t, G_t, z_t) \\ I_{t+1} = B_2(i_t, I_t, z_t) \end{matrix} \qquad (15)$$

To identify the two dimensional coordinates of government for example, we can safely assume that the coordinates of B_1 depends only on i_t^{1m} and G_t^{1m} while the second coordinate depends only on i_t^{1u} and G_t^{1u}.

Systemically then, and in reference to (14) and (15), we can then deduce that

$$\begin{matrix} Government: G_{t+1}^{1m} = (1 - \varphi_{1m})G_t^{1m} + i_t^{2m} - B_{1m}\left(\frac{i_t^{1m}}{G_t^{1m}}, x_t\right)G_t^{1m} \\ Industry: I_{t+1}^{2m} = (1 - \varphi_{2m})I_t^{2m} + i_t^{2m} - B_{2m}\left(\frac{i_t^{2m}}{I_t^{2m}}, x_t\right)I_t^{2m} \end{matrix} \qquad (16)$$

Where; φ_m is the assumed rate of depreciation; and B_m measures investment, lost in the generation of new performance related innovation. This can be abstractly written with adjusted cost as

$$\begin{matrix} B_1(G_t, i_t, x_t) = \begin{bmatrix} 1-\varphi_{1m} & 0 \\ 0 & 1-\varphi_{1u} \end{bmatrix} G_t + i_t \\ B_2(I_t, i_t, x_t) = \begin{bmatrix} 1-\varphi_{2m} & 0 \\ 0 & 1-\varphi_{2u} \end{bmatrix} I_t + i_t \end{matrix} \qquad (17)$$

Value of performance in a triple helix at any given point of investment can be denoted as V_t; and is expressed as a relationship between direct investment and performance. Continuing, if investment is i_t and higher education performance is reflected in $\boldsymbol{O_i}$, then deductively at period zero, value is

$$V_t = E\sum_{t=0}^{\infty} Y_{t,0}\left[A_1\left((G_t,\ O_{it}, z_t) - O_{it} * i_t - O_{it}\right) + A_2\left((I_t,\ O_{it}, z_t) - O_{it} * i_t - O_{it}\right)\right] | F_0 \qquad (18)$$

Further, we hold that decision making in a triple helix partnership is based on performance-determined stochastic factors hinged on value of performance. Thus $Y_{t,0}$ accounts for initial investment at period zero. This factor is

[2] Higher Education System, Universities, Research Institutes, Knowledge Generation Platforms are used interchangeably in this section.

[3] Indirect contributions may be considered as present or absent thus allowing them to have a dummy value of either 0 = absent or 1 = present. The total sum of all *present* indirect contributions can then summarily be considered as the measure of indirect contributions.

stochastic and varies depending on the state of economy within which the educational system operates at any given period (t); the Economic Performance Index (Khramov & Lee, 2013) of any country or region can provide a good indication of this. Invariably, $Y_{t,0}$ also provides a good indicator for adjusted risk. The total knowledge in the system, at time any point in time $t = 0$ is represented as F_0. Thus F_0 is a reflection of patent counts, total publications, innovation-linked products etc. Performance expectations E; $(0 \leq E \geq 1)$, is an abstraction of expectation of partners in relation to valued performance.

Using Lagrangian deductions, [18] resolves to

$$V_t = E \sum_{t\geq 0}^{\infty} \gamma_t \, [H + T] \quad (19)$$

Where

$H = A_1(G_t, O_{it}, z_t) - O_{it} \cdot i_t - O_{it} - \lambda_t \cdot G_{t+1} - B_1(i_t, G_t, z_t)$ and
$T = A_2(I_t, O_{it}, z_t) - O_{it} * i_t - O_{it} - \lambda \cdot I_{t+1} - B_2(i_t, I_t, z_t)$
Where G_0 and I_0 are initial partnership conditions for higher education performance. The conditions for this provides a first order empirical and valuation relations. In this vain we recommend the consideration of first order valued performance investment decision as conditionally being hinged on the value of O_{it} and determined as:

$$O_{it} = \left[\left(\frac{\partial A_1}{\partial i} \, (i_t, G_t, x_t)^{\lambda_t}\right) + \left(\frac{\partial A_2}{\partial i} \, (i_t, I_t, x_t)^{\lambda_t}\right)\right] \quad (20)$$

Inferring from [9] and [10] we can specifically separate the conditions for valuing input for each partners

$$\begin{aligned} &Government: \frac{\partial B_1}{\partial i}\left(\frac{i_t^{1m}}{G_t^{1m}}\right) x_t = 1 - \frac{O_{it}^{1m}}{\lambda_t^{1m}} \\ &Industry \quad : \frac{\partial B_2}{\partial i}\left(\frac{i_t^{2m}}{I_t^{2m}}\right) x_t = 1 - \frac{O_{it}^{2m}}{\lambda_t^{2m}} \end{aligned} \quad (21)$$

7. Conclusion

We have tried to argue that the modelling of participation within a triple helix and levels of participation can be extrapolated as a function of performance of universities within the system. The prior deductions of the helix has been strongly skewed towards analysis from the perspective of research and patency linked factors. Investment is a viable means of explaining participation and plotting relationships between the various actors within a triple helix. The structure of this can be systemised over any given period. The point of decision to participate, level and intensity of participation can be mathematically shown as being aligned to performance linked ranking of higher education institutions.

What we have tried to substantially show is that triple helix system that forms on holistic performance deductions is much more useful in serving as an incentive for participation decision making. Further, it provides a possible platforms to determine yield to inputs from Government and Industry. The application of proposed weights in determining performance and investment, allows for inter, intra and cross system assessment of triple helix relations of various higher education systems.

In subsequent research, the model proposed in this paper shall be applied to practical settings to provide insight into how they theoretically apply in real life and simulated situations. Again, it will be interesting to see how innovation intermediaries will impact on performance and indirectly industry government participation within any higher education system. The adoption of a performance model for assessing triple helix relations may provide clarity in projecting the evolutionary path of higher education institutions towards becoming entrepreneurial institutions. These thoughts will be investigated further in future studies of the triple helix relation.

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