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Sustainable entrepreneurial culture in promoting innovation: a higher education perspective

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ABSTRACT

This research aimed to build a quadruple-helix partnership model between universities, government, industry, and community from the higher education (HE) perspective in creating various innovations to support sustainable regional socio-economic development. This study used exploratory quantitative research to develop, predict the model, and explain the empirical evidence. In addition to the model, this study found that institutional sustainable entrepreneurial culture (SEC) could be developed by transforming the university into an entrepreneurial university (EU) and applying sustainable development goals (SDGs) principles to teaching-researching-community service activities, management and governance, and institutional leadership. This study also confirmed that universities with an SEC cannot directly affect the emergence of various innovations sourced from knowledge and research results but must be mediated by internal consensus within academia and external consensus among partnership actors. The research contributions are aimed at: i) HE policymakers who will transform their institutions into EU as a first step in carrying out the university's third mission; ii) HE will build quadruple helix partnerships; and iii) Micro, small, and medium enterprise (MSME) which will take advantage of the innovations offered in the quadruple-helix. In addition, this research deepens the Etzkowitz partnership path model in which HE, a source of knowledge for innovation, becomes more focused in the form of SDGs-based EU.

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1. INTRODUCTION

In the last two decades, the regional socio-economic development model has begun to move in a conducive direction to achieving sustainability by basing it on increasing intellectual capital and supporting institutions, knowledge-based, university-led, and based on triple-helix (university, industry, government) interactions [1]. That task is stated to be accommodated through the development of entrepreneurial university (EU) [2]–[4] collaborating with elite circulation in the triple-helix order in the form of partnerships. Previous researchers stated that there have been efforts by the governments of Malaysia, Indonesia, India, and Brazil to provide institutional and organizational capacities that made the triple-helix a model of innovation and sustainable development [5]. The way we collaborate in society has evolved from a three-way partnership (between universities, industry, and government) to a four-way partnership that also includes the community. This model is called the quadruple-helix. [6].

Concerning the quadruple-helix, it has been found through previous research that universities can leverage a favorable innovation climate through the development of EU [7]. This can help in fostering and empowering communities [8], while also supporting the university's objectives in terms of commercialization and technology transfer [2]–[4], as well as its social mission [9]. Concerning the issue of sustainability, universities are alleged to have an essential role as crucial agents in the successful implementation of the sustainable development goals (SDGs) through the movement for sustainable cultural change, as well as curriculum development based on sustainability principles [10]. These sustainability principles are the principles that ensure our actions today do not limit the range of economic, social, and environmental options open to future generations [11]–[13]. Decision makers not only manage resources at one point in time, but all the time, so that future business uncertainties can be overcome by the resilience of a robust system [14]. In addition to acting as one of the critical agents in achieving the SDGs goals, universities are currently not only carrying out their missions as teaching and research universities, they are starting to transform into carrying out third mission as EU by commercializing research results and technology transfers [15].

Based on the referenced literature, several unique concepts were exposed, including entrepreneurial university (EU), SDGs, sustainable entrepreneurial culture (SEC), triple-helix, quadruple-helix, and innovation. However, there are few theoretical studies and empirical research linking these concepts comprehensively with the existence of universities as a source of knowledge and research products that will lead to positive contributions and benefits for regional social and economic development. This gap prompted the authors to formulate a research problem (RP): how can a sustainability-oriented EU partner with industry, government, and society in a quadruple-helix partnership to create various innovations to support regional socio-economic development in Indonesia?

Accordingly, this study aimed to build a quadruple-helix partnership model between universities, government, industry, and society from the perspective of higher education (HE) to support regional socio-economic development. Thus, the research questions (RQ) posed are: i) What is the relationship between EU and SDGs oriented HE in developing a SEC in HE? (RQ1); and ii) What is the relationship between SEC in universities and the creation of various innovations developed in quadruple-helix partnerships? Can it be direct, or does it need to be mediated by internal and external consensus? (RQ2). The solutions that are expected to be presented from this research are not only directed at university stakeholders in formulating partnerships or for micro, small, and medium enterprise (MSME) sustainability but also to develop a body of knowledge, especially about SDGs-based EU as a source of knowledge that forms an innovation ecosystem in the Etzkowitz triple-helix partnership model.

2. THE COMPREHENSIVE THEORETICAL BASIS AND THE CONCEPTUAL MODEL

2.1. Concepts of triple-helix, quadruple-helix, and quintuple-helix

The traditional role of higher education institutions which were initially assigned to teaching activities (1st mission), is increasingly developing into research activities (2nd mission) which, in the end, the results of the research return as a source of knowledge for academics in teaching. At the beginning of the academic revolution, there was an internal transformation where the teaching element included method material to revive new knowledge through research activities [16]. Furthermore, universities as knowledge producers face external challenges making a real contribution to socio-economic development through technology transfer (3rd mission) in the form of various reciprocal interactions between universities, industry, and government in the triple helix model [17], [18] which triggers innovation dynamics [19]. In order to facilitate the triple-helix interaction, the transformation of the university into an EU is crucial because the institution's entrepreneurial resources and capabilities are essential provisions in carrying out commercialization and technology transfer activities [2]–[4], [16].

The triple-helix focuses on the commercialization of knowledge, risk-taking, and innovation between universities, industry, and government [20]. The triple-helix model was expanded into a quadruple-helix by adding interaction with the community through media-based and culture-based [21]. The touch on the social side of institutional entrepreneurs who were born from EU through fostering and empowering communities [8] complements the EU limitations in responding to changes in social structures and environmental [22]. So, through the quadruple-helix interaction, EU carry out not only commercial missions but also social missions [9].

The quadruple-helix model now includes knowledge democracy, resulting in a quintuple-helix. The natural environment is now part of the model, interacting with knowledge and innovation [23]. It underlies the conclusion that the quintuple-helix appears as a package that represents a complete triple-helix interaction, namely the university's relationship with industry, government, society community, and the environment in responding to sustainability challenges [23].

The quintuple-helix concept, as proposed by Carayannis and Campbell [23], is a model that expands on the triple-helix dynamics to address economic, social, and environmental responsibilities. Another

researcher responded to this concept by suggesting a way to approach sustainability issues, decomposing and recombining the helical interactions into triple-helix interactions [24]. For example, the quadruple-helix interaction between university (U), industry (I), government (G), and community (C) can take the form of synergies between university-industry-government (UIG), university-industry-community (UIC), and university-government-community (UGC) [24], where each triplet can generate synergies.

2.2. Partnership pathways in triple-helix interactions

The triple-helix partnership model between universities, government, and industry [17] can be built through three partnership spaces: knowledge space (KS), consensus space (CS), and innovation space (IS) that interact [18]. The knowledge space is the center for the concentration of research resources, or research and development centers on specific topics where technological ideas can be generated. The consensus space is a place where various partnership actors from the industrial sector, government, universities, and communities in a particular area with different expertise backgrounds and perspectives can come together to generate new ideas in promoting economic and social development [18]. Other researcher states that from the HE perspective, it is necessary first to have an internal consensus to ensure internal support and agreement within the entire academic community towards the partnership agreement that will be undertaken [25]. The previous study confirms that the government and industry can easily support the spirit of the EU, but not among academics [18], [25].

Not all academics agree that universities should play an entrepreneurial role, and these academics believe universities should limit themselves to educational and research activities and avoid taking a broader view [18]. It underlies the need for consensus among the academic community before transforming into an EU in its third mission [25]. The innovation space where innovation mechanisms exist, such as business incubators, technology/knowledge transfer offices, research and testing centers, business startup funding companies, or the establishment of science techno parks, and others. This space is non-linear, where innovation can be started from research results, or vice versa, from the needs of society, industry, or government. Previous researchers confirm that technology transfer offices (TTO) have a role in forming entrepreneurial teams (ET) in universities, both directly and indirectly [26]. It was also confirmed that the TTO was able to embed the formation of ET in university spin-off arrangements [26]. The relationship is hypothesized: CS affects the IS (hypothesis 7).

2.3. Entrepreneurial university, sustainable development goals-oriented higher education, and sustainable entrepreneurial culture

After focusing on carrying out its two main missions as a provider of educational services (teaching universities) and creator of scientific knowledge through research activities (research universities), in the last 25 years, in line with the development of technology, generations, and the order of life, universities are faced with a new mission which is to play the entrepreneurial role (entrepreneurial university) in a changing society that is increasingly knowledge-based [16], where the mission is in the form of commercializing and transferring technology to the broader community. This mission is intended to answer the demands of the government, industry, and society so that universities become more independent as institutions (having the ability to cover their costs), while at the same time still being able to create benefits for the community, especially in supporting business innovation and improving national competitiveness through socio-economic development. Over time, this third mission has not only become a debate about the social impact of HE, but also about the meaning of HE [3].

The four main criteria for driving EU are: i) research quality; ii) an extensive network; iii) the diversification of sources of income; and iv) creation of entrepreneurial missions in official university documents, and the active promotion of entrepreneurial initiatives in the region [2]. Universities mushrooming in developing countries can be a boon for the country by placing the responsibility on institutions to network with industry, government, and community to increase the production and dissemination of valuable knowledge [27]. Other study states the synergy of HE institutions and the academic community in creating knowledge can trigger the success of academic entrepreneurship practices [28]. Increasing the commercialization of research is a top priority in the triple-helix policy agenda [29]. Based on a survey of 12 HEs in South Africa (out of 23 existing HEs), a triple-helix wedge was found as a result of dynamic UIG interactions, namely, joint ventures or partnerships in terms of: i) an integrated approach to research commercialization; ii) the provision of science and technology parks; and iii) technology support programs [29]. The relationship is hypothesized: EU directly affects the IS (hypothesis 1) and EU directly affects the SEC (hypothesis 3).

Concerning HE, a global perspective states that: i) HE is the key to implementing the principles of sustainability; ii) curriculum based on sustainability and cultural change are key to transforming the SDGs mindset; iii) interdisciplinary studies are the basis of the transformation towards sustainability; and iv) the

political environment and stakeholder interests of HE affect the implementation of sustainability [10]. In the last five years, researchers have begun to investigate the role and contribution of HE in achieving the SDGs. Although many academics agree with the strategic role which HE covers [30], they still emphasize the specific needs that are priorities for implementation in their respective departments [31]. The relationship is hypothesized: SDGs-oriented HE directly affects the IS (hypothesis 2) and SDGs-oriented HE directly affects the SEC (hypothesis 4).

The concept of an EU that focuses on knowledge capitalization, risk-taking, and innovation, allegedly has little role in social and environmental change [22]. Regarding this, empirical evidence states that a sustainable EU is ideal in an innovation ecosystem responding to sustainability issues [22]. Sustainable EU is based on the critical role of universities in achieving SDGs [10] which are integrated with EU so that they complement the university's mission which focuses on commercialization and technology transfer [2]–[4] with a social mission [9] to the community through fostering and empowering [8]. A SEC program in the education system is confirmed to positively affect students' attitudes toward social responsibility issues [32].

The main focus of sustainable entrepreneurship is to support the economy of life, social community, and preserve nature and the environment through the use of existing opportunities and resources to provide products, services, and processes that can yield economic and non-economic benefits for individuals, the economy and society [33]. Other researchers reveal that sustainable entrepreneurship will solve social and environmental problems by realizing successful businesses that use economic goals [34]. Based on the referenced literature review on regional socio-economic development from the perspective of SDGs-oriented HE and the helix innovation model, the authors propose a conceptual model as presented in Figure 1. There were eight hypotheses built on the conceptual model in Figure 1: i) EU directly affects the IS (H1); ii) SDGs-oriented HE directly affects the IS (H2); iii) EU directly affects the SEC (H3); iv) SDGs-oriented HE directly affects the SEC (H4); v) SEC directly affects the IS (H5); vi) SEC directly affects the CS (H6); vii) CS directly affects the IS (H7); and viii) SEC indirectly affects the IS through CS (H8).

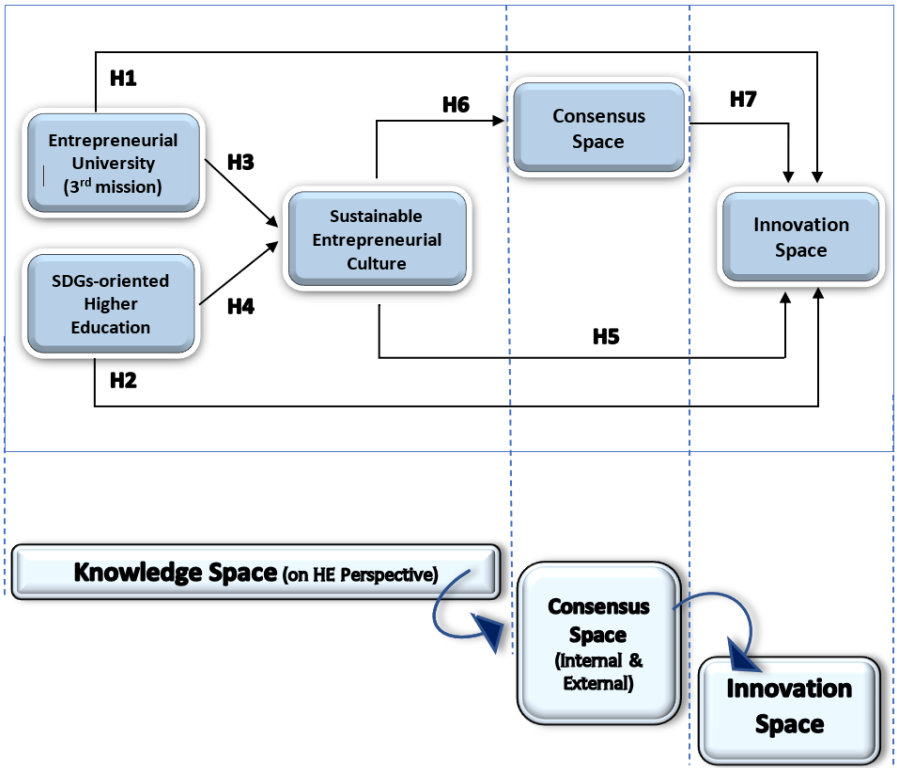


Figure 1. Research conceptual model

3. RESEARCH METHOD

This research exhibits a post-positivism paradigm with a deductive mechanism in scientific thinking. The nature of this research is building and predicting quadruple-helix partnership models, exploring, and explaining what is happening related to quadruple-helix partnerships in Indonesia. Thus, the approach used is exploratory quantitative research. A good predictive model will maximize the variance explained from the

endogenous latent constructs built on the conceptual framework; therefore, the researchers used variance-based structural equation modelling (VB-SEM) in the data analysis. The research objects were EU, SDGs-oriented HE, SEC, CS, and IS. Data was collected cross-sectionally from early June 2022 to early September 2022 from 300 HE faculty members as the respondents using a non-probability sampling technique. Research instrument used in this study is online questionnaire. Dissemination of the instrument was performed by using the uniform resource locator (URL) link which were sent through several platforms such as campus e-mail, Microsoft 365 SharePoint, Microsoft Teams group, WhatsApp messenger and WhatsApp group, and Telegram group messenger. All members of the above groups are faculty members, so the delivery of the questionnaire links will be guaranteed to be spread according to the objectives set in the sampling.

To maintain the objectivity of the research results, the researchers also compared the determination of the minimum sample requirement in smart partial least square version 4 (SmartPLS4) software using G*Power software and 10-times rules. First, researchers used G*Power software in determining the minimum sample size with the assumptions: using a high level of statistical power of 95%; the effect size level (f^2) of 0.15 is classified as medium [35]; α error probability of 0.05; and the largest number of predictors in the conceptual model presented in Figure 1 is in the IS of 4 predictors. Based on these assumptions, the recommended minimum sample size is 129. This value is below the number of samples that were collected by the researchers of 311 samples.

Secondly, using 10-times rules by calculating the most formative indicator in the CS variable for as many as eight indicators so that the minimum sample was 8×10=80 samples, or 10-times the most number of structural paths directed at specific constructions in the structural model [35], namely, the structural path to the IS, as many as four paths. Thus, the minimum sample requirement according to this rule was 4×10=40 samples. Based on the consideration of the minimum sample requirements, the researchers concluded that the number of samples used in this study of 300 met the minimum requirements for the research sample needs. Validity and reliability were tested on the research instrument at the pilot study stage. After the instrument was proven valid and reliable, it was distributed according to the specified sample. The variable operationalization is presented on Table 1 [1]–[3], [10], [18], [20], [25], [29], [33], [34], [36]–[47].

4. RESULTS AND DISCUSSION

4.1. Results

4.1.1. Demographic data

Table 2 presents demographic data from 300 faculty members as research respondents. Initially, the number of respondents was 311. After removing straight-line patterned data, the authors obtained 300 data that were worthy of being used as research data. Based on the demographic analysis in Table 2, respondents who mostly responded to the online questionnaire were lecturers who were young or under retirement age (productive age) in Indonesia (<55 years). These young lecturers were very familiar with the social media platform used as a channel for distributing online questionnaires in this study. Meanwhile, there is no non-response bias in the characteristics of educational level, where the master's level still dominates the education level of lecturers in Indonesia, and most of the lecturers' academic positions are currently assistant professors. Non-response bias also does not occur in gender characteristics.

Table 3 presents the values of excess kurtosis and skewness of all indicators on each observed variable. These two values are the primary measures of the normality of the data. The threshold skewness referred to in this study was -2≤ skewness ≤2, and the threshold for kurtosis was -7≤ kurtosis ≤7 [48], [49]. As seen in Table 3, all manifest variables have skewness and kurtosis values that are within the threshold; thus, all the data used in this study are proven to be normally distributed.

Table 4 shows that the conditions of the four variables EU, SDGs-oriented HE, SEC, and CS from HE institutions in Indonesia are in the medium to the high category. In comparison, the conditions for innovation (IS) are still very diverse, from low to high conditions, which means that innovations in Indonesian HEs are yet to be realized evenly. Universities in Indonesia that have begun to transform into EU are at the medium-scale stage. This means that campuses in Indonesia still need to carry out third mission fully, namely, commercializing research results and transferring technology/knowledge for the community's socio-economic development. Implementing the Tri Dharma, management and governance, and leadership in Indonesia HE also needs to be fully oriented to the principles of SDGs because it is still in a medium-scale category. Referring to Table 4 of the respondent's responses, the level of innovation carried out in several universities in Indonesia is in a very varied range, from low to high. It indicates the level of innovation that has yet to be carried out evenly.

Table 1. Variable operationalization

Variable	Item code	Item	Scale
X1: EU [1]–[3], [20], [36], [37]	LG1	Institutional entrepreneurship commitment to supporting local community, social, and economic development [37].	Likert
	LG2	Entrepreneurship and innovation activities are integrated into all departments, educators, and other centers within the institution [37].	Likert
	OC1	The capacity for entrepreneurship and innovation is managed by optimizing the institution's primary resources, such as human resources, expertise and knowledge, and funding [37].	Likert
	OC2	Awards/incentives from institutions for entrepreneurship and innovation activities carried out by the academic community [37].	Likert
	ES1	Provision of entrepreneurship and innovation infrastructure, such as the provision of business incubators, testing laboratories, research facilities, prototype support, IT services, technology/knowledge transfer offices, and others.	Likert
	DT1	Digital transformation culture to support the growth of innovation and entrepreneurship [37].	Likert
	DT2	Digital infrastructure to support entrepreneurship and innovation activities [37].	Likert
	DT3	Development of digital capabilities for staff, lecturers, and students [37].	Likert
	INT1	Joint degree development program with overseas universities [37], [38].	Likert
	INT2	Research activities/lecturer publications with researchers/partners from abroad [37], [38].	Likert
	INT3	Ways to develop extensive links with international research networks/innovation groups [37], [38].	Likert
	EEE2	Organizing lectures across business and non-business study programs through elective/specialized courses [39], [40].	Likert
	EEE3	Provision of student entrepreneurship activities by "learning by doing" through on-campus business incubators [40], [41].	Likert
	EEE4	Providing student entrepreneurship activities through "experiential learning" through internships/or collaborations with several companies [40], [41].	Likert
	EEE5	Obtaining business funding from outside the campus for student entrepreneurship activities.	Likert
	RPCS1	Increased research/publication skills.	Likert
	RPCS2	A culture of impactful research/publication collaboration.	Likert
	RPCS3	Institutional awards to researchers in the form of research funding in the form of internal grants, as well as financing/incentives for publications that have an impact.	Likert
	RPCS4	Providing free access to articles in reputable international journals or institutionally subscribed publishers.	Likert
	CS1	Implementation of community service activities [25].	Likert
	CS2	Realization of the publication of the results of community services activities as the lecturers' performance.	Likert
	CTT1	Public policies related to the commercialization and transfer of technology/knowledge as a form of implementing the universities' third mission in supporting regional social and economic growth [42].	Likert
	CTT2	Provision of technology transfer office/TTO within the institutional environment.	Likert
	CTT3	Support for the involvement of the academic community in commercialization and technology/knowledge transfer through a profitable royalty-sharing formula.	Likert
	CTT4	There is support for TTO services to provide intensive consultation for the academic community, which will involve commercialization and technology/knowledge transfer.	Likert
	CTT5	Appreciation for technology/knowledge transfer activities carried out by the academic community as one of the promotion criteria.	Likert
X2: SDGs-oriented HE [10], [43]	SDGs-LG1	Institutional support's commitment to achieving the SDGs agenda.	Likert
	SDGs-LG2	Integration of the SDGs agenda into every university's Tri Dharma activity: teaching, researching, and community service activities.	Likert
	SDGs-EEE1	Mobilizing students for activities that have an impact on social, economic, or environmental balance (sustainable issue).	Likert
	SDGs-EEE2	Integration of teaching topics into the focus of SDGs department/faculty.	Likert
	SDGs-R1	Integration of research/publication topic into the focus of SDGs department/faculty.	Likert
	SDGs-R2	Priority of institutional funding for research/publication topics that are relevant to the focus of SDGs department/faculty.	Likert
	SDGs-CS1	The topic of community service, which is integrated with the focus of the department/faculty SDGs.	Likert
	SDGs-CS2	Institutional funding priorities for scientific publication of the results of community service activities that are relevant to the focus of the SDGs department/faculty.	Likert
Y1: SEC [25], [33], [34], [44]	SEC-So	Sustainable social entrepreneurship culture.	Likert
	SEC-Ec	Sustainable economic entrepreneurship culture.	Likert
	SEC-En	Sustainable environment entrepreneurship culture.	Likert
Y2: CS [18], [25]	ICWA2	Internal consensus on the purpose and mission of research and technology transfer office/RTTO [45].	Likert
	ICWA3	Internal consensus regarding the partnership between university–government-community [29], [46].	Likert
	ECWQ1	External consensus in quadruple-helix regarding the university–government-industry partnership.	Numerical
	ECWQ3	External consensus in the quadruple-helix regarding the UGC partnership.	Numerical
Y3: IS [18]	IS_CTT	Innovation in Commercialization of research output and technology transfer.	Numerical
	IS_EI	Innovation in providing entrepreneurial incubator.	Numerical
	IS_VC	Innovation in providing the early venture capital firm.	Numerical
	IS_USO	Innovation in conducting university spin-off [47].	Numerical

Table 2. Demographic analysis

Characteristics		Total	Percentage (%)
Gender	Male	161	53.67
	Female	139	46.33
Age	<35 years	80	26.67
	36-45 years	106	35.33
	46-55 years	73	24.33
	56-65 years	35	11.67
	>65 years	6	2.00
HE status	Public university	92	30.67
	Private university	208	69.33
Working period in college	>30 years	13	4.33
	1-10 years	183	61.00
	11-20 years	74	24.67
	21-30 years	30	10.00
Academic position	Lecturer	43	14.33
	Assistant professor	222	74.00
	Associate professor	28	9.33
	Professor	7	2.33
Education level	Doctor	103	34.33
	Magister	197	65.67

Table 3. Descriptive analysis and data normality

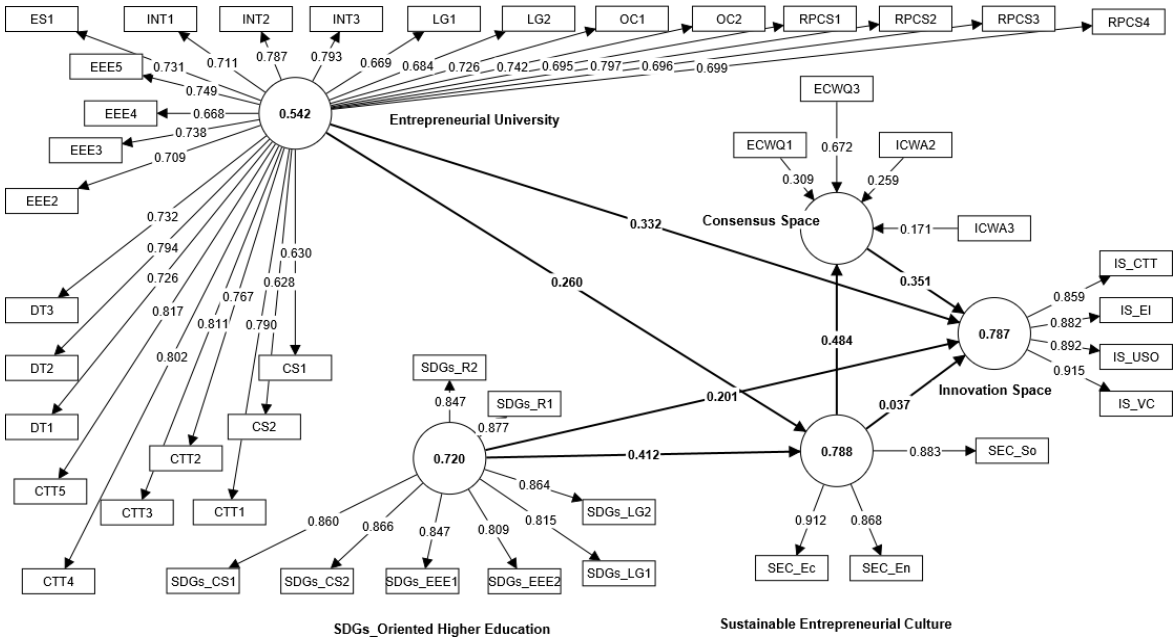
Construct	Code item	Mean	Standard deviation	Excess kurtosis	Skewness
EU	LG1	4.217	0.802	0.555	-0.880
	LG2	3.927	0.884	-0.463	-0.496
	OC1	3.933	0.873	0.878	-0.867
	OC2	3.803	0.972	-0.278	-0.538
	ES1	3.977	0.918	-0.397	-0.577
	DT1	4.010	0.900	-0.072	-0.654
	DT2	3.937	0.894	-0.229	-0.578
	DT3	3.967	0.923	-0.363	-0.598
	INT1	3.557	1.163	-0.476	-0.559
	INT2	3.717	1.124	-0.270	-0.699
	INT3	3.667	1.078	-0.520	-0.477
	EEE1	4.270	0.835	1.593	-1.199
	EEE2	3.930	0.986	0.129	-0.803
	EEE3	3.873	0.954	-0.043	-0.646
	EEE4	4.013	0.902	0.980	-0.904
	EEE5	3.633	0.986	-0.128	-0.491
	RPCS1	4.103	0.864	0.917	-0.950
	RPCS2	3.937	0.890	0.462	-0.787
	RPCS3	4.083	0.918	0.724	-0.971
	RPCS4	3.793	1.079	-0.139	-0.749
	CS1	4.267	0.810	1.414	-1.130
	CS2	4.083	0.846	0.323	-0.790
	CTT1	3.747	0.907	-0.131	-0.474
	CTT2	3.723	1.036	-0.025	-0.691
	CTT3	3.583	0.978	-0.256	-0.418
	CTT4	3.617	1.021	-0.180	-0.517
	CTT5	3.690	0.935	-0.292	-0.477
SDGs-oriented HE	SDGs_LG1	3.773	0.914	0.239	-0.615
	SDGs_LG2	3.717	0.950	0.184	-0.624
	SDGs_EEE1	3.763	0.913	0.091	-0.490
	SDGs_EEE2	3.743	0.915	0.334	-0.623
	SDGs_R1	3.713	0.926	-0.140	-0.462
	SDGs_R2	3.687	0.998	-0.118	-0.534
	SDGs_CS1	3.710	0.979	0.019	-0.547
	SDGs_CS2	3.653	0.993	0.152	-0.573
SEC	SEC-So	3.937	0.875	0.039	-0.596
	SEC-Ec	3.943	0.860	0.427	-0.743
	SEC-En	3.793	0.922	0.068	-0.603
CS	ICWA2	4.250	0.749	1.093	-0.924
	ICWA3	4.493	0.705	2.681	-1.498
	ECWQ1	3.183	1.308	-0.977	-0.334
	ECWQ3	3.540	1.158	-0.386	-0.563
IS	IS_CTT	3.290	1.125	-0.451	-0.463
	IS_EI	3.297	1.126	-0.560	-0.421
	IS_VC	3.217	1.187	-0.731	-0.330
	IS_USO	3.300	1.085	-0.529	-0.383

Table 4. Recapitulation of respondents' responses

Variable	Mean	Standard deviation	Range of mean (min-max)	Convert mean to score (min-max)	Range of score	Category
EU	3.89	0.94	2.95-4.83	1167.30	884.21-1450.39	Medium to high
SDGs-oriented HE	3.72	0.95	2.77-4.67	1115.96	831.41-1400.51	Medium to high
SEC	3.89	0.89	3.01-4.78	1167.30	901.60-1433.00	Medium to high
CS	4.01	0.92	3.09-4.92	1201.61	926.51-1476.71	Medium to high
IS	3.28	1.13	2.15-4.41	982.80	643.58-1322.03	Low to high

4.1.2. Measurement model analysis

Analysis of the measurement model can explain the specific relationship between latent variables and their respective manifests. The initial results obtained from the measurement of this outer model are the assessment of the validity and reliability of the constructs used. Assessments of the validity and reliability of the constructs need to consider the operationalization of the constructs carried out. If the construct uses reflective indicators, then the validity assessment uses content validity measurement consisting of convergent and discriminant validity. In contrast, the reliability assessment is carried out by measuring internal reliability using the value of Cronbach's alpha and composite reliability (CR) in each construct. If the construct uses formative indicators, the validity assessment is carried out by measuring substantive content, namely, by comparing the relative weight and the t-statistical significance of the indicators in the construct [35]. Evaluation of the measurement model with reflective indicators on Figure 2 adhered to the following rule of thumb [35]. The validity of the indicator on Table 5, used the outer loading criteria, where outer loading >0.70 is acceptable; 0.40-0.70 is considered for deletion only if deletion leads to an increase in CR and average variance extracted (AVE) above the recommended threshold value, and if the outer loading value <0.4, then the indicator is recommended to be removed.



Construct: Average Variance Extracted, Outer: Outer Loading, Inner: Path Coefficients

Figure 2. Measurement model

Table 5 presents the internal consistency reliability >0.70 is acceptable, also considering the value of Cronbach's alpha as the lower limit and CR as the upper limit of internal consistency reliability. The convergent validity using the AVE criteria was considered. The AVE is equivalent to the commonality of a construct. A value of AVE=0.50 or higher indicates that the construct explains more than half of the indicator variance. AVE<0.50 indicates more errors in the items than the variance explained by the construct. If AVE<0.50, then the item with the lowest outer loading for that construct should be removed.

Table 5. Convergent validity and internal consistency reliability

Construct	Item code	Outer loading	Cronbach's alpha	Rho-A	Rho-C	AVE
EU	LG1	0.669	0.966	0.967	0.968	0.542
	LG2	0.684				
	OC1	0.726				
	OC2	0.742				
	ES1	0.731				
	DT1	0.726				
	DT2	0.794				
	DT3	0.732				
	INT1	0.711				
	INT2	0.787				
	INT3	0.793				
	EEE2	0.709				
	EEE3	0.738				
	EEE4	0.668				
	EEE5	0.749				
	RPCS1	0.695				
	RPCS2	0.797				
	RPCS3	0.696				
	RPCS4	0.699				
	CS1	0.630				
	CS2	0.628				
	CTT1	0.790				
	CTT2	0.767				
	CTT3	0.811				
	CTT4	0.802				
	CTT5	0.817				
SDGs-oriented HE	SDGs_CS1	0.860	0.944	0.945	0.954	0.720
	SDGs_CS2	0.866				
	SDGs_EEE1	0.847				
	SDGs_EEE2	0.809				
	SDGs_LG1	0.815				
	SDGs_LG2	0.864				
	SDGs_R1	0.877				
	SDGs_R2	0.847				
SEC	SEC-Ec	0.912	0.865	0.867	0.918	0.788
	SEC-En	0.868				
	SEC-So	0.883				
IS	IS_CTT	0.859	0.910	0.911	0.937	0.787
	IS_EI	0.882				
	IS_USO	0.892				
	IS_VC	0.915				

The discriminant validity on Table 6 used heterotrait-monotrait (HTMT) and cross-loading criteria. The confidence interval of the HTMT statistic should not include a value of 1 for all combinations of constructs. The HTMT value >0.85 indicates a lack of discriminant validity [50]. This threshold is used when the variables are conceptually different. When the variables are conceptually similar, an HTMT value >0.90 indicates a lack of discriminant validity [51]. Cross-loading criteria provided that the outer loading value of a construct must be greater than cross-loading with other constructs.

Table 6. HTMT statistics

	EU	IS	SDGs-oriented HE	SEC
EU				
IS	0.705			
SDGs-oriented HE	0.844	0.697		
SEC	0.648	0.594	0.688	

HTMT value <0.85 à $HTMT_{.85}$

The rules of thumb for evaluating the formative measurement model in this study were: i) collinearity statistics measurement by testing the variance inflation factor (VIF) value. The VIF value must be <0.5 to ensure that there is no collinearity [35]. If it does not, consider eliminating indicators, combining indicators into a single index, or creating high-level constructs to deal with collinearity problems; and ii) measurement of significance and relevance of the formative indicators through bootstrapping. The indicator will be used if the weight is significant and there is empirical support to maintain the indicator.

Indicators will be used when the weight is not significant, but the value of outer loading is relatively high (i.e., 0.50) or statistically significant. The formative indicator is considered for deletion if the indicator's weight is insignificant and the outer loading is relatively low (i.e., <0.5). The results of the measurement model for the formative indicators of the CS are presented in Tables 7 and 8. Based on the rule of thumb, the formative indicators of ECWQ1, ECWQ3, ICWA2, and ICWA3 were confirmed to be valid and reliable; thus, they can be used as a manifest variable CS in testing the structural model.

Table 7. Collinearity statistics (VIF) of outer model

Construct	Code item	VIF
Consensus space	ECWQ1	1.457
	ECWQ3	1.473
	ICWA2	1.324
	ICWA3	1.317

Table 8. Significance and relevance of the formative indicators

	Outer weight	t-value	p-value
ECWQ1	0.309	3.224	0.001
ECWQ3	0.672	8.220	0.000
ICWA2	0.259	2.906	0.004
ICWA3	0.171	2.153	0.031

4.1.3. Structural model analysis

a. Collinearity assessment

The high correlation between exogenous variables indicated collinearity in the research model. It confirms that there are problems in the research method that can have implications for errors in interpreting research results [52]. Furthermore, if this collinearity occurs in more than two exogenous variables, it is called multicollinearity. The rule of thumb related to collinearity referred to in this study is the value of VIF. The recommended VIF value <10 is said to be free from collinearity [53], [54], whereas Hair *et al*. [55] recommend a VIF value <5 to be said that the model is free from collinearity. Based on the value of collinearity statistics in Table 9, all VIF values <5; thus, this confirms that there is no collinearity in the model.

Table 9. Collinearity statistics: VIF

	CS	IS	SEC
CS		1.372	
EU		2.990	2.861
SDGs-oriented HE		3.187	2.861
SEC	1.000	1.840	

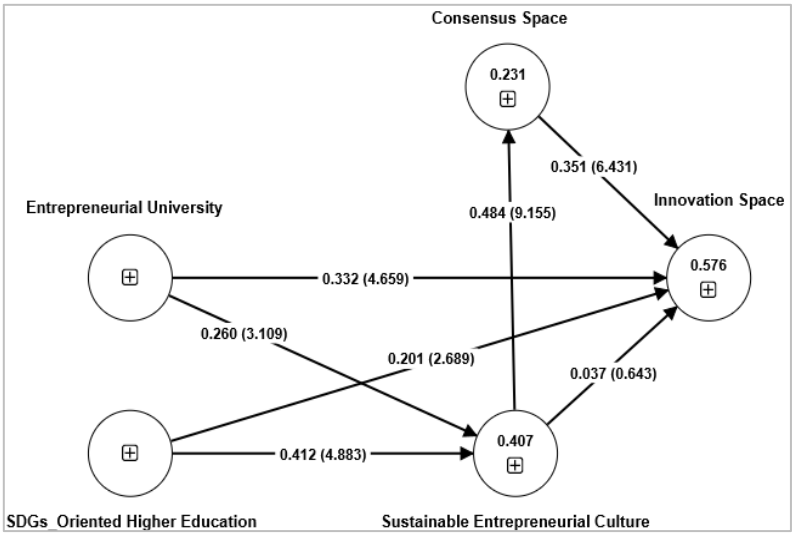
b. Structural model

Figure 3 shows the relationship that occurs between exogenous and endogenous latent variables. The values displayed are the path-coefficients in each relationship indicating the direct effect, which were then used to calculate the indirect effect and the total effect. The value on the path in brackets is the t-statistics value used to measure the significance of the effect between variables, and the value in the construct is the R^2-adjusted. The quadruple-helix partnership model in the HE perspective is confirmed to have a strength of 57.6% and categorized as a medium to strong predictive model [54] for HE in Indonesia that will carry out quadruple-helix partnerships to support regional socio-economic development.

Table 10 presents the results of testing the structural equation model. Table 10 significantly confirmed that the EU has direct positive effect on IS by 33.2%. It can be seen from the t-statistic value of 4.659 (>1.96) and p-value of 0.000 (<0.05). The results of this empirical evidence confirmed that the more effective a university was in carrying out its "entrepreneurial" mission, the higher the variety of innovations carried out by the university→H1 supported. The following findings confirmed that significantly SDGs-oriented HE has a direct positive effect on IS by 20.1%, with a t-statistic value of 2.689 (>1.96) and a p-value of 0.007 (<0.05). It confirmed that the more SDGs-oriented a university is, the greater the innovation can be made by the university→H2 supported.

EU has a significant direct positive effect on the SEC by 26.0%, with a t-statistic value of 3.109 (>1.96) and a p-value of 0.002 (<0.05). This empirical evidence confirmed that the more effective a university was in carrying out the "entrepreneurial" mission, the higher the SEC that occurred at the

university→H3 supported. SDGs-oriented HE has a direct and significant positive effect on the SEC by 41.2%, with a t-statistic value of 4.883 (>1.96) and a p-value of 0.000 (<0.05). This empirical evidence confirmed that the more HE institution is oriented towards the SDGs, the higher the SEC is at the university→H4 supported.



Note: construct: R-square adjusted, inner: path coefficients (t-value)

Figure 3. Structural model as "the quadruple-helix partnership model" (from the HE perspective)

Furthermore, it was confirmed that the SEC had a direct positive effect on IS by 3.7%, but the effect was insignificant. It was confirmed by the t-statistic value, which was only 0.643 (<1.96), and the p-value of 0.520 (>0.05). This empirical evidence confirmed that the SEC in universities did not directly affect the creation of various innovations significantly→H5 not supported. SEC was confirmed to have a direct and significant positive effect on CS by 48.4%. It was confirmed by the t-statistic value of 9.155 (>1.96) and the p-value of 0.000 (<0.05). The results of this empirical evidence confirmed that SEC in universities could significantly positively influence the consensus among the academic community to carry out various innovations→H6 supported.

Next, based on Table 10, it was found that CS had a direct positive effect on IS by 35.1% significantly. It was confirmed by the t-statistic value of 6.431 (>1.96) and p-value of 0.000 (<0.05). This empirical evidence confirmed that the consensus in universities could positively influence the creation of various innovations→H7 supported. Finally, it was confirmed that CS could mediate the SEC in providing a positive influence on IS by 17.0%, so that the SEC influence on IS, which was initially only 3.7%, was mediated by CS increased significantly to 20.7%. The results of this empirical evidence confirmed that even if a university already has a SEC, without a consensus from the academic community internally and externally, it would not be able to create various university innovations significantly. Thus, this consensus becomes vital→H8 supported.

Table 10. Summary of hypotheses testing

	Path	Std. Beta	Std. Error	t-value	p-value	Bias	Confidence interval 2.50%	Confidence interval 97.50%	Description
H1	EU→IS	0.332	0.071	4.659	0.000	0.005	0.198	0.475	Supported
H2	SDGs-HE→IS	0.201	0.075	2.689	0.007	-0.002	0.051	0.344	Supported
H3	EU→SEC	0.260	0.084	3.109	0.002	0.002	0.095	0.425	Supported
H4	SDGs-HE→SEC	0.412	0.084	4.883	0.000	0.000	0.242	0.578	Supported
H5	SEC→IS	0.037	0.058	0.643	0.520	-0.005	-0.084	0.148	Not supported
H6	SEC→CS	0.484	0.053	9.155	0.000	0.005	0.378	0.585	Supported
H7	CS→IS	0.351	0.055	6.431	0.000	0.002	0.243	0.456	Supported

Note: two-tailed test.

From this study, the authors confirmed that SEC in HE could be developed by transforming universities into EU that simultaneously apply SDGs principles in their teaching, research, community service activities; management and governance; and institutional leadership. It answers RQ1. Another finding of this research is that universities with a SEC cannot directly affect the emergence of various innovations sourced from knowledge and research results. However, these need first to be mediated by internal consensus within academia and followed by external consensus among partnership actors. It answers RQ2 that the relationship between SEC in universities and the creation of various innovations developed in quadruple-helix partnerships needs to be mediated by internal and external consensus.

The following finding in this study was the addition of an internal consensus dimension to the results of previous research, which formulates three non-linear spaces forming the partnership path, namely, knowledge, consensus, and IS [18]. Initially, the consensus was stated as an external consensus only, namely, an agreement from various partnership actors of a region in generating/supporting new ideas to promote innovation for regional socio-economic development [18]. This addition considers that many academics still believe that universities should prioritize research and publication activities and avoid other commercial activities [25]. The internal consensus formed is manifested in ICWA2 and ICWA3. From ICWA2, there is a consensus from the academic community in understanding the purpose of providing a technology transfer office on campus is to commercialize research results, generate income for independent institutions, commercialize start-ups formed by the community, and become integrators universities in contributing to regional socio-economic development.

In ICWA3, there is a consensus of the academic community to build partnerships with the government and the community, including joint research, project collaboration, business incubator management, business assistance, business establishment and development consultation, involvement of social innovation programs, product/service development, and others. Meanwhile, the external consensus manifest that is ensured to be valid and reliable is the realization of partnerships between university-government-industry (ECWQ1) and university-government-society communities (ECWQ3) in research, project collaboration, patent collaboration, transfer of knowledge/technology, commercialization of results, and startup development. It is in line with the finding states that the triple-helix transitions to quadruple or quintuple can be decomposed and recombined into triple-helix again, where each helix can synergize.

c. PLS-predict

When research aims to build predictive models using PLS, researchers will need a measure of predictive power [35]. This measure indicates the predictive relevance of the model out of the sample. When the PLS path model has predictive relevance, it can accurately predict the data not used in model estimations. In the structural model on Figure 3, the value of $Q^2>0$ for endogenous latent variables indicates the predictive relevance of the path model for certain dependent constructs. Table 11 presents the results of PLS predict. Furthermore, these results were analyzed using the Guidelines for interpreting PLS-predict results [56].

Table 11. PLS predict analysis

	Q^2predict	PLS-SEM_RMSE	LM_RMSE	Description
ECWQ1	0.080	1.259	1.226	Moderate predictive power
ECWQ3	0.114	1.094	1.179	
ICWA2	0.064	0.727	0.774	
ICWA3	0.043	0.692	0.741	
IS-CTT	0.287	0.953	1.011	High predictive power
IS-EI	0.297	0.948	0.969	
IS-USO	0.438	0.816	0.888	
IS-VC	0.442	0.890	0.928	
SEC-Ec	0.327	0.708	0.757	High predictive power
SEC-En	0.287	0.782	0.834	
SEC-So	0.327	0.720	0.754	

PLS-predict analysis refers to the guidelines for interpreting PLS-predict results [56]. The value of Q* in all indicators >0, meaning all indicators have relevant predictive power. The prediction error was distributed symmetrically. It can be seen from the skewness value in the SEC, CS, and IS manifests, which were in the range of -2< skewness <2; thus, the distribution was normal, or the prediction error was symmetrical. Because the prediction error was distributed symmetrically, the root mean square error (RMSE) value was used to analyze the model's predictive power. Furthermore, the value of PLS-SEM_RMSE was compared against LM_RMSE, and the results show that: i) the SEC construct has high predictive power; ii) the CS construct has moderate predictive power; and iii) the IS construct has high predictive power.

4.2. Discussion

The quadruple-helix partnership model from the HE institution perspective, as the novelty of this research, was successfully developed by the authors and has undergone a complete and structured method stage. As presented in Figure 3, the model stated that partnerships between universities, government, industry, and communities can positively and significantly be formed through the development of knowledge-based innovations through institutional SEC. Furthermore, the institutional SEC could trigger various non-linear innovations between partnership actors for regional socio-economic development, mediated in advance by internal consensus between academia in the HE institutions and external consensus between partnership actors. In Indonesia, it has been empirically confirmed that quadruple-helix partnership consensus between universities, government, industry, and communities occurred in different triple-helix combinations: i) a triple combination between UIG; and ii) a triple combination between universities, government, society community. It was in line with the findings of research by Leydesdorff and Smith [24].

Empirical evidence, significantly confirmed that several universities in Indonesia that have transformed into EU have the following characteristics, namely: i) university leadership and governance that is committed to EU transformation; ii) optimizing organizational capacity for EU transformation; iii) giving awards; iv) entrepreneur support; v) strengthening digital transformation; vi) strengthening internationalization activities; vii) provision of eclectic entrepreneurship education; viii) strengthening research and community service, as well as strengthening the publication of research results and community service; ix) promotion of commercialization and transfer of technology/knowledge.

Leadership and governance, consisting of institutional entrepreneurship commitment to transfer technology and commercialize research/entrepreneurial education results, as well as the existence of commitment to innovation in various forms of services/processes/products to support local community, social, and economic development; entrepreneurship and innovation activities are well integrated into all departments, educators, and other centers within the institution [37]. Organizational capacity, reflected in the capacity for entrepreneurship and innovation being well-managed through optimizing the institution's primary resources such as human resources, expertise and knowledge, and funding [37]. The provision of awards/incentives from institutions for entrepreneurship and innovation activities carried out by the academic community [37]. Entrepreneur support, reflected in entrepreneurship and innovation infrastructure, such as business incubators, testing laboratories, research facilities, prototype support, information technology (IT) services, and TTO, are well developed within the institution. Digital transformation and capability, reflected on digital transformation culture in supporting the growth of innovation and entrepreneurship, is built conducive in an institutional environment; the availability of digital infrastructure to support entrepreneurship and innovation activities within institutions; the development of digital capabilities for staff, lecturers, students are realized regularly [37].

Internationalization activity [37], [38] reflected on institutions facilitating lecturers, researchers, and students to carry out educational/teaching, research/publication activities, and widely integrated international partnerships; the procedure for developing extensive relationships with international research networks and innovation groups is well conveyed by the institution to lecturers, researchers, and students. Eclectic entrepreneurship education [57], reflected in availability of embedding entrepreneurship education and learning interdisciplinary [39], [40], [57]; the availability of eclectic entrepreneurship education and learning patterns through “learning by doing” and “experiential learning” [40], [41], [57]; the institution facilitates obtaining business funding from outside the campus for the initial funding of student entrepreneurial activities [57]. The results of this study, among others, are in line with the findings, which state that the entrepreneurial climate of the institution can strengthen the relationship between entrepreneurship education and a sustainable entrepreneurial mindset among students [58].

Research/publication and community service, reflected in the realization of efforts to regularly increase research/publication expertise for lecturers, researchers, and students [25]; creating an impactful research/publication collaboration culture [25]. The realization of institutional awards to researchers in the form of research funding in the form of internal grants, as well as financing/incentives for impactful publications [25]; providing free access to lecturers, researchers, and students to articles in reputable international journals or publishers subscribed to by the institution. The implementation of community service activities periodically and continuously [25]; and the realization of publication of the community service activities results.

Commercialization and technology/knowledge transfer [42], reflected on the availability of general policies related to commercialization and the transfer of technology/knowledge to the academic community as a form of implementing the third missions of the universities in supporting regional social and economic growth [1], [37], [39], [42]. The availability of a technology/knowledge transfer office with a clear organizational structure; availability of support for the involvement of the academic community in the commercialization and transfer of technology/knowledge through a profitable royalty sharing formula [1],

[37], [39], [42]. There is support from TTO officer to provide intensive consultation for the academic community who will be involved in the commercialization and transfer of technology/knowledge. The availability of awards for technology/knowledge transfer activities carried out by the academic community by taking them into account as one of the promotion criteria [1], [37], [39], [42]. Furthermore, another finding regarding providing intensive consultation for the academic community involved in the commercialization and transfer of technology/knowledge is in line with the prior study. Confirmed that good internal communication becomes a successful strategy in EU development because it straight connects to psychological factors of academics related to self-efficacy in developing entrepreneurial competencies [59].

Furthermore, the characteristics of SDGs-oriented HE in Indonesian that have been confirmed to be valid and reliable contributing to the formation of a SEC are: i) the availability of institutional support commitments towards achieving the SDGs agenda; ii) the department/study program integrates the SDGs agenda into every Tri Dharma activity; iii) the mobilization of students for activities that have an impact on social, economic, or environmental balance (sustainable issue); iv) integrated teaching topics with the main focus of department/faculty SDGs; v) integrated research/publication topics with the main focus of department/faculty SDGs; vi) institutional funding priorities for research/publication topics relevant to the main focus of the department/faculty's SDGs; vii) the topic of community service is integrated with the main focus of the SDGs of the department/faculty; and viii) institutional funding priorities for scientific publication of the results of community service activities being relevant to the main focus of the department/faculty's SDGs [10], [43]. This study's results in aligning SDGs into teaching activities align with previous research, which stated that aligning curriculum development at the study program level with SDGs is vital as an internal quality assurance standard [60].

Sustainable entrepreneurial culture means the entrepreneurship culture which contributes to the solution of social and environmental problems through the realization of successful businesses, using economic goals as both means and ends; and integrating sustainable development into organizational goal-setting and processes [25], [33], [34], [44]. Institutional sustainable entrepreneurial culture related to teaching, research, community service activities; technology/knowledge transfer activities; or faculty member innovation activities, confirmed valid and reliable according to the empirical evidence in this study are: i) sustainable social entrepreneurship culture, reflected on mainly contributing to social problem-solving issues, such as poverty, a healthy and prosperous life, quality education, and gender equality. It is in line with previous study state the view of life that prioritizes equal rights and obligations, equal treatment for all citizens in producing knowledge, and the emergence of responsibility for the environment encourage sustainable knowledge invention and innovation [23]; ii) a sustainable economic entrepreneurship culture, reflected on main contributions to sustainable economic development issues, such as decent work and economic growth, industry, innovation, and infrastructure, and partnerships to achieve goals; and iii) a sustainable environment entrepreneurship culture, reflected on the main contributions to sustainable nature/environment conservation issues, such as sustainable cities and settlements, responsible consumption and production.

5. CONCLUSION

The model stated that partnerships between UIG and communities can positively and significantly be formed through the development of knowledge-based innovations through institutional SEC. Furthermore, the institutional SEC could trigger various non-linear innovations for regional socio-economic development, mediated in advance by internal consensus between academia in the HE institutions and external consensus between partnership actors. Furthermore, partnerships consensus between universities, government, industry, and communities in Indonesia occurred in different triple-helix combinations, namely: a triple combination between UIG; and a triple combination between universities, government, community.

Empirically, in several universities in Indonesia, a SEC could be developed through transforming universities into EU that simultaneously apply SDGs principles to the teaching-researching-service community activities, management and HE governance, and entrepreneurial-oriented leadership. So, EU carry out not only commercial missions (commercial entrepreneurship) but also social missions (through social entrepreneurship). The practical contribution of this study is intended, among others, for: i) HE policymakers who will transform their institutions into EU as the first step in carrying out the university's third mission; ii) HE policymakers who will build partnerships with government, industry, and society to produce various innovations beneficial for sustainable regional socio-economic development; and iii) MSME will develop their business by utilizing various innovations offered in the quadruple-helix partnership. In addition, this research also makes a theoretical contribution to the body of knowledge related to SEC, mainly referring to the SDGs-oriented EU and its positive implications for regional socio-economic development, especially in developing countries.

The limitations of this research are the researcher only took samples from HE under the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia. In contrast, the researcher did not take HE under the Ministry of Religion of the Republic of Indonesia to sample. The HE used as research subjects were only universities and institutes, while academies, polytechnics, and vocational high schools were not used as studies. The quadruple-helix partnership model involves four main partnership actors: universities, government, industry, and the community. In this research, the focus of the study is only from the HE perspective. Further researchers can develop this model by adding three other partnership perspectives (government, industry, or community) to complement the quadruple-helix model. This study uses quantitative methods in modeling and analysis. Researchers believe that if this research is continued with a qualitative approach, it will enrich the findings obtained.

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