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Homophily in Southeast Asian University collaborations: evaluating internationalization and collaboration through bibliometric collaboration data

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ABSTRACT

This study investigates the influence of homophily rooted in institutional rankings on the structure and dynamics of international research collaboration networks among Southeast Asian universities and examines its implications for regional academic stratification and inequality. Utilizing bibliometric data from 175 universities certified by the ASEAN University Network, we employed social network analysis (SNA) to map collaboration patterns using centrality metrics (eigenvector, betweenness, closeness, and degree) and clique analysis. Our findings reveal a pronounced 'rich-get-richer' dynamic, in which top-ranked institutions, predominantly from Malaysia and Singapore, dominate collaboration networks, controlling 75.69% of the connections. Elite universities, such as Universiti Malaya (eigenvector centrality: 0.989) and the National University of Singapore (degree centrality: 0.224), function as structural brokers, reinforcing exclusivity and marginalizing lower-ranked institutions. Conversely, despite their numerical predominance, Indonesian universities exhibit a fragmented influence, whereas those in Cambodia, Laos, and Myanmar remain peripheral with near-zero centrality metrics. Clique analysis further underscores regional fragmentation, with large collaborative clusters ($\geq$21) dominated by Indonesian institutions, reflecting inward-oriented networks. This study identifies a stark core-periphery divide exacerbated by preferential attachment mechanisms and resource disparities that perpetuate academic inequality. These findings challenge the presumed egalitarian benefits of internationalization, highlighting how institutional ranking homophily entrenches stratification.

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1. Introduction

Research collaboration is an important indicator of internationalization for universities globally (Haley et al., 2024; Mwantimwa & Kassim, 2023). University-ranking institutions use research collaboration as an indicator for ranking assessment. This performance achievement has implications for fund allocation, policy support, and opportunities to improve academic facilities (Mwantimwa & Kassim, 2023). International research collaborations also enhance universities' global reputation and ranking, which in turn can attract more international students and researchers (Aithal & Kumar, 2020). This collaboration allows access to research resources and funding from international

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institutions, enriching the university's research and innovation ecosystem (Mwantimwa & Kassim, 2023; Wai-Chan, 2017).

In contrast, research collaboration cannot exist without a certain degree of similarity or compatibility among the researchers involved, an idea that is closely linked to the concept of homophily (Horta et al., 2022; Kwiek & Roszka, 2021). Homophily refers to the propensity of an individual to associate with others who have similar attributes, preferences, or values. This concept plays a significant role in fostering communication, building trust, and enhancing collaboration (Horta et al., 2022; Kwiek & Roszka, 2021). Recognizing the concept of homophily in research partnerships enables researchers to identify elements that promote and hinder collaboration and create more efficient strategies for fostering diverse and innovative research collaborations.

Research on homophily in academia tends to be limited to discussions on gender, Nobel laureates, geography, and similarities in backgrounds, which allow for a high degree of similarity or closeness (Gallotti & De Domenico, 2019; Hâncean & Perc, 2016; Horta et al., 2022; Zhou et al., 2024). Homophilia in the academic field is also related to the orientation of universities because individuals or institutions tend to collaborate if they have the same orientation as the university. It is not uncommon for proximity to university rankings to be a prerequisite for cooperation (Li & Yin, 2023). Institutions with higher rankings tend to be reluctant to collaborate with others. Institutions in the same ranking range tend to collaborate (Ku, 2019; Rodriguez & Pepe, 2008). The same thing happens at the individual level: researchers with a high H-Index and Impact Factor tend to be reluctant to collaborate with researchers with a lower reputation unless they have a supervisory relationship, long-term research colleagues, or peers who have deep trust and understanding in the same research field (Eddy, 2010; Ku, 2019; Rodriguez & Pepe, 2008).

Thus, the view that physical or geographical proximity drives homophilia through scientific collaboration should be reconsidered. University orientation also plays an important role in determining the pattern of collaboration, primarily because of the institutional ranking factor. This relates to the prestige of a researcher or university for collaboration (Torres-Olave et al., 2020). Universities in one region may not be within the same ranking range, making them less likely to collaborate (Bellantuono et al., 2022; Wang & Liu, 2023). This creates exclusivity in academic cooperation and widens the gap between institutions. For example, in the context of Southeast Asia, there is a significant gap between universities in different countries; some colleges are among the top-ranked in the world, while others are not listed in global rankings (Oldac & Yang, 2023). Even decades ago, research on research collaboration in Southeast Asia showed inequality between countries in the region, and Southeast Asia contributed only 4% of all international collaborations (Kumar et al., 2014). Therefore, this year is the right momentum to review this research. On the other hand, the measurement of collaboration is necessary because the concept of research productivity tends to be measured in Southeast Asian countries not based on the level of collaboration, but on citations (Sukoco et al., 2023). This regional discussion also makes it possible to identify patterns of homophily in research collaboration between countries and within a region, compare homophily in research collaboration between countries, and map the network of homophily research collaborations in a region.

2. Research questions

To what extent does homophily based on institutional rankings influence the structure and dynamics of international research collaboration networks among Southeast Asian universities, and how do these patterns contribute to regional academic stratification and inequality?

3. Literature reviews

3.1. Homophiles in research collaborations by university rankings

Individuals tend to collaborate with others who possess similar characteristics, a phenomenon known as homophily (Abramo et al., 2009). Highly ranked universities frequently engage in collaborative partnerships with institutions of comparable prestige (Bair, 1991) and establish exclusive networks that reinforce

their status and access to resources (Gunn & Mintrom, 2013). These elite institutions offer an environment rich in research infrastructure, funding, and reputation, which supports academic success (Burris, 2004). Collaboration with reputable organizations can enhance publication opportunities in prestigious journals, thereby increasing recognition within the global academic community (Iglič et al., 2017). Such collaborations provide access to advanced technological resources. The tendency of higher-ranking universities to collaborate primarily with one another has implications for knowledge diffusion and scientific progress. Scholars generally acknowledge the benefits of collaboration in advancing scholarly work and addressing complex problems.

Collaboration between highly ranked universities is often influenced by their desire to increase the visibility and impact of their research (Aldieri et al., 2018). Studies have shown that partnering with esteemed institutions can significantly expand researchers' professional networks and lend greater credibility to their findings (Gunn & Mintrom, 2013). In the highly competitive academic landscape, reputation and collaborative ties play pivotal roles in shaping career trajectories (Abramo et al., 2009; 2017). Such collaborative arrangements not only enhance the prestige associated with research output but also provide researchers with privileged access to superior research infrastructure, funding, and technological resources (Abramo et al., 2009; 2017). University rankings, in turn, exert a profound influence on shaping these patterns of research collaboration, as institutions strive to affiliate with peers of comparable standing to bolster their global prominence and academic standing (Jones et al., 2008)

This tendency towards collaboration among highly ranked universities can also result in the exclusivity and marginalization of lower-ranked institutions in research endeavors. The exclusivity of partnerships between elite universities creates an unequal distribution of academic knowledge and resources (Halffman & Leydesdorff, 2010). Research has demonstrated that more inclusive collaboration across institutional hierarchies fosters innovative ideas and approaches (Aldieri et al., 2018). This disparity in collaborative patterns highlights the need for policy interventions that encourage and incentivize partnerships between top-tier universities and lesser-known institutions (Barra et al., 2019). Promoting more inclusive and diverse research collaborations can improve the overall quality and impact of research outputs and cultivate a more dynamic and vibrant research ecosystem. Reducing the exclusivity of research networks and enabling greater interdependence between prestigious and lesser-known universities can lead to the cross-pollination of ideas, amplify the diversity of perspectives, and ultimately drive more impactful scientific advances (Morgan et al., 2018).

However, there is a need for awareness that the world is built on inequality. The world economy is composed of *center-periphery* countries that have knowledge and technology advantages and *periphery* countries that are dependent on these aspects (Wallerstein, 2011). In the context of research, developed countries have greater resources for funding, research infrastructure, and international scientific networks, thus playing the role of science (Altbach, 2007). Peripheral countries have the opposite position; they are the market for technology products in developed countries (Wallerstein, 2011). It is not surprising that this has resulted in inequality and dependence. Dependency theory asserts that this structural dependence reinforces the power imbalance in knowledge production (Dos Santos, 2019), whereas universities in *peripheral* countries tend to follow the agenda and methodology set by the central country (Quijano, 2000). Instead of developing a research framework that is relevant to local needs with the adoption and modification of frameworks from developed countries, it turns out to be trapped in the distorted narrative of local knowledge versus knowledge from the central country (Beigel, 2014; Connell, 2020), which is an attempt to understand that exclusivity is possible because of the inequality that occurs. Ranking can be an instrument for reproducing gaps in science.

The academic community must make concerted efforts to promote inclusivity in research collaboration (Dong et al., 2018). This can be achieved by implementing tailored policies that actively encourage and incentivize partnerships across institutional hierarchies, transcending the traditional barriers imposed by university rankings (Klein & Falk-Krzesinski, 2017). Funding bodies and research-granting agencies should also lend their support to foster collaboration between highly ranked universities and lesser-known institutions, recognizing the immense potential of such diverse partnerships to enrich the research landscape (Gunn & Mintrom, 2013). Existing research has consistently demonstrated that more inclusive collaborations involving a broader spectrum of institutions can significantly improve the overall quality, rigor, and impact of research outputs (Swartz et al., 2019). By reducing the prevailing exclusivity

that often characterizes research networks, the diversity of perspectives and approaches can be amplified, ultimately driving innovative scientific advancement. Researchers and policymakers must acknowledge and actively address the homophilic biases inherent in the academic community, where affiliations and institutional rankings can unduly influence collaboration patterns ((Nettasinghe et al., 2021). Embracing inclusivity in research collaborations is not merely a noble goal but also a strategic imperative to cultivate a more dynamic and impactful research ecosystem that benefits the global scientific community (Chinchilla-Rodríguez et al., 2018).

3.2. Internationalization as a benchmark for global research rankings and collaboration

Internationalization has become one of the primary benchmarks used to evaluate and rank universities globally, including in Indonesia (Cordova et al., 2015). Universities that demonstrate extensive international networks and collaborations tend to rank higher in prestigious rankings. Key factors contributing to this include robust research collaborations with foreign institutions, active student exchange programs, and a strong presence in international publications and scholarly output (Chinchilla-Rodríguez et al., 2018). High university rankings often reflect an institution's level of internationalization and its ability to engage with the global academic community. Extensive research has shown that participating in international research collaborations can significantly increase the visibility and impact of university scholars' work (Woldegiyorgis et al., 2018). Joint publications with foreign counterparts frequently have a heightened level of influence and citation impact compared with purely domestic research endeavors (Aldieri et al., 2018). Furthermore, international collaboration provides access to a wider range of resources, data, and technological capabilities that may not be readily available locally. Universities that are deeply engaged in these global research networks tend to exhibit greater levels of innovation, as they are exposed to diverse perspectives, methodologies, and emerging trends in their respective fields (Auerswald & Branscomb, 2008). Ultimately, the degree of internationalization demonstrated by a university plays a crucial role in shaping its reputation and appeal among prospective students and academic talent worldwide, further bolstering its standing in global rankings and its ability to attract top-tier human and financial resources (Egron-Polak, 2011). The academic landscape is increasingly defined by the imperative of internationalization, which has become a key benchmark for evaluating and ranking universities worldwide.

Another thing that happened was that economic globalization also accompanied efforts to internationalize higher education (Altbach, 2013b). Knowledge is not merely a cognitive aspect but rather a competitive global market network (Marginson, 2006). Universities are increasingly integrated into transnational networks where academic knowledge is a commodity (Altbach & Knight, 2007). This situation not only opens widespread access to knowledge through international collaboration and cross-border scientific exchange but also creates a larger market for educational services, scientific publications, and technology produced by universities. This drives the need to rank and understand the visibility of a university. Schmidt assessed that the global university ranking system has deviated from the goals of higher education because it is more oriented towards promotion and manipulation of rankings rather than improving the quality of education relevant to the needs of students (Baker, 2020). If the ranking is intended only for promotion, it will also be related to research collaboration, which is the theme of this study (Shin & Kehm, 2012).

Global research collaboration has become an important factor in university ranking. Universities that participate in international research projects tend to be better known (Buckner, 2022). This collaboration allows researchers to access diverse data and methods, which can accelerate the research process and improve the quality of the results. Research has shown that international collaborations can produce more influential publications (Francisco, 2015). Universities that collaborate globally tend to have stronger academic networks, which help them remain internationally competitive. This collaboration also opens up opportunities for greater research funding (Varma & Sabharwal, 2018). Therefore, universities with strong global research collaborations are often ranked higher. Indonesia has increased its focus on internationalization to improve university rankings (Kusumawati et al., 2020). The government and universities work together to promote international research collaboration by introducing programs to encourage local researchers to collaborate with their foreign counterparts. These policies are beginning to show positive results as Indonesian universities become better known globally (Lakitan et al., 2012). However, challenges such as limited funding and infrastructure remain. International research

collaboration can help overcome these obstacles and improve the quality of education and research in Indonesia. Internationalization is expected to continue driving improvements in university rankings in Indonesia.

Global university rankings are heavily influenced by the degree of internationalization of these institutions. Universities that actively engage in international research collaborations tend to excel and achieve higher ranks (Tadjudin, 2000). Extensive research has consistently shown that collaborative endeavors can significantly enhance the quality and impact of scholarly output. Universities with expansive global networks have access to a wider range of resources, data, and technological capabilities, enabling them to remain highly competitive internationally (Altbach, 2013a). Moreover, internationalization plays a crucial role in enhancing the reputation and overall appeal of a university, making it a more attractive destination for students and academic talent worldwide (Hou et al., 2012). The level of internationalization and global research collaboration is widely recognized as a pivotal factor that shapes universities' rankings and global standing (Hou et al., 2012). Policies that actively encourage and incentivize international collaboration can be instrumental in helping universities grow and strengthen their global reach and influence. Universities must persistently work towards expanding and fortifying their international networks, as this will be a key determinant of their success and competitiveness in the increasingly globalized higher education landscape.

3.3. Knowledge gap in global higher education and the ASEAN region

The knowledge gap in higher education is a globally significant issue (Dickson, 2009). Developed countries tend to have better resources for research and education (Altbach, 2013b). Universities in developed countries often dominate the global rankings. The quality and number of scientific publications in developed countries are high (Hosni, 2004). This has created a knowledge gap between developed and developing countries. Developing countries often have limited funding and limited research facilities. This limitation affects the quality of higher education. Research has shown that international collaboration can help reduce this gap (Moshtari & Safarpour, 2023). However, many challenges remain to be overcome. Internationalization is an important solution for overcoming this knowledge gap.

The higher education gap is an important issue in the ASEAN region. Countries such as Singapore and Malaysia have superior universities compared to other ASEAN countries (Oldac & Yang, 2023; Ratanawijitrasin, 2015). Based on the QS World University Rankings 2025 and 2024, Singapore has the National University of Singapore, which is always among the top global universities. Malaysia has the University of Malaya, which excels at the international level. In contrast, countries such as Indonesia and the Philippines are still struggling to improve the quality of their higher education (Alcazaren & Robiños, 2022). Limited funds and facilities are among the main causes of this gap (Cynthia & Chong, 2023). Research shows that universities in developing ASEAN countries often lack access to sufficient resources (Crosling et al., 2024). This affects the quality of research and education they offer (Ratanawijitrasin, 2015).

This gap creates a major challenge for ASEAN countries in improving the quality of their higher education. Governments and educational institutions must work together to overcome these limitations (Ratanawijitrasin, 2015). Internationalization programs and research collaborations are effective solutions (Tham, 2013). Policies that support greater access to global resources are required (Van der Wende, 2007). ASEAN countries should strengthen their international networks to improve their visibility and the quality of their research (Saengsawang et al., 2024). Singapore and Malaysia serve as exemplary advanced models for other nations in the ASEAN region (Oldac & Yang, 2023). Higher education institutions in ASEAN should prioritize the enhancement of the caliber of their educational offerings and research initiatives (Mok, 2012). Research has shown that increased international collaboration can help to address this knowledge gap.

The potential for exclusivity in international research collaborations must be critically considered. Universities in developed countries often benefit from such collaborations (Knobel et al., 2013). The involvement of highly ranked institutions can create dominance, inhibiting equal participation from other universities. Research has shown that this dominance can lead to unequal access to resources and research findings. Developing countries are often passive beneficiaries of such collaborations

(Khan et al., 2018). This can strengthen existing gaps, rather than reduce them. Limited funding and infrastructure in developing universities add to this challenge (Obasuyi & Rasiah, 2019). This collaboration gap can limit research capacity-building opportunities in developing countries (Van der Veken et al., 2017). It is important to consider the impact of exclusivity on international research collaborations (Van der Veken et al., 2017).

3.4. Geopolitics of research collaboration

International scientific collaboration is not in a vacuum but is influenced by global and geopolitical dynamics. Science, which is considered non-political, is closely related to political issues such as climate change. The collaboration of entities is determined by political and economic interests. None of these are free of value, as glorified by science itself. History records that World War II was the beginning of strict collaboration between the Allied and Axis Blocks (Maas & Hooijmaijers, 2009). After World War II, the scientific bloc became isolated between the contestation between the Western Bloc (United States) and the Eastern Bloc (Soviet Union), which manifested itself in the Cold War and the Space Race (Oreskes & Krige, 2014; Wyland, 2022). When the Cold War ended, research collaboration between the United States and China grew rapidly in the late 20th century until it peaked around 2010, but it dimmed along with the economic and political tensions between the two countries (Jia et al., 2022; Lee & Haupt, 2020). International scientific collaboration is never free from the influence of global political and economic dynamics.

Research geopolitics also has a reciprocal relationship with a country's Gross Domestic Product (GDP) (Hou et al., 2021). Researchers from countries with high GDP tend to partner with other countries with equivalent or higher GDP (McCoy et al., 2008). In contrast, high GDP tends to correlate with a country's university ranking because developed countries have the certainty of property rights, freedom of doing business, and freedom of investment (Lu, 2014). It is not surprising that a country's progress and GDP are among the considerations for establishing international collaboration between universities, in addition to scientific considerations (Ubfal & Maffioli, 2011). For example, in Southeast Asia, Singapore and Malaysia have relatively high GDP in the region, with universities that have high world rankings, such as the National University of Singapore (NUS) and Universiti Malaya (UM) (Sukoco et al., 2023). They also tend to collaborate with reputable universities in developed countries. In contrast to Indonesia and Thailand, which have lower GDP, universities from these countries tend to be more limited in collaborating with universities with high reputations in the world (Sukoco et al., 2023). The amount of GDP of a country also determines the fiscal space for research needs (Sanganyado, 2021). The higher the GDP, the higher the available research funds, and vice versa, the lower the GDP, the lower the research funds. International scientific collaborations tend to be exclusive, regardless of other scientific and academic considerations.

Research and education collaboration is also dynamic and context-dependent. During the Cold War, the United States government awarded many doctoral scholarships to students from Southeast Asia. These students graduated from the United States, returned to their home countries, and became policymakers (Adhikarya, 1980). For example, in the Indonesian context, a group of Indonesian scholars who graduated from the University of California, Berkeley, later became architects of the Indonesian economy during President Soeharto's leadership (Revrison, 2006). In the field of communication, there has been a shift in the scientific paradigm from European-centric to American-centric, marked by the change in the name of the publication department to the Department of Communication Science in universities in Indonesia (Pratama, 2019). In the context of health and humanity, such as US-China scientific collaboration in COVID-19 research, it has increased and surpassed previous collaborations (Lee & Haupt, 2021). That is, geopolitics determines, but there are other things that also affect, for example, humanity.

4. Methods

This study aims to explore a map of the homophily network of research collaboration between universities in Southeast Asia so that this research can refer to the initial exploration efforts of the conditions in the region. Based on previous studies on homophily in the academic realm, this study used co-authorship analysis using bibliometric data from scientific articles on a certain population (Gallivan & Ahuja, 2015; Horta et al., 2022; Kwiek & Roszka, 2021). This study seeks to develop co-authorship-based

research by utilizing social network analysis, because this method allows the identification of interaction patterns and deeper relationships between institutions, as well as uncovering the dynamics and factors that affect scientific collaboration in the Southeast Asian region (Stoica, 2018).

On the other hand, the concept of homophily is closely related to network analysis studies; therefore, the researcher proposed several indicators that will be the measurement of this research, namely centrality degree, centrality betweenness, centrality closeness, eigenvector, and cliques. Centrality Degree is the number of direct connections a node has, indicating how connected it is in the network (value ≥ 0; higher = more direct connections) (Borgatti & Everett, 2000, 2006; Freeman, 2002). Centrality Betweenness is the frequency with which a node is on the shortest path between other pairs of nodes, measuring its role as a connector or bridge (range 0–1; 0 = non-connector, 1 = all paths passing through the node) (Borgatti & Everett, 2000, 2006; Freeman, 2002). Centrality Closeness is the average of the shortest distance from a node to all other nodes, indicating how easily it reaches the entire network (Borgatti & Everett, 2000, 2006; Freeman, 2002). Eigenvector Centrality is a measure of the importance of a node based on the quality of its connections to other important nodes, not just the quantity of connections (range 0–1; higher = connected to important nodes) (Borgatti & Everett, 2000, 2006; Freeman, 2002). Cliques are subgroups in a network where each node is directly connected to all the other nodes in that group (size ≥ 3 nodes; the larger, the more cohesive the subgroup) (Borgatti & Everett, 2000, 2006; Freeman, 2002).

The researcher used collaborative data from scientific articles indexed by Scopus from 175 universities certified by the ASEAN University Network in 10 countries: Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam. The ASEAN University Network (AUN) standards were selected as the basis for university selection because these universities have met regionally recognized quality standards. The AUN website states that there are 214 accredited institutions, but researchers have only found 213 universities. The researcher then reduced from 213 universities to 182 because it did not find the Scopus ID Institutional in 31 universities. This is important because this study uses the SCIMAGO JR Institutional Ranking to juxtapose institutional identities and university rankings. SCIMAGO JR ranks using Scopus data, so the Institutional Scopus ID is the key to connecting information from the two sources. Data collection will be conducted between August and September 2024.

The reduction process was then resumed by excluding universities that have an Institutional Scopus ID but do not have a SCIMAGO JR Institutional Ranking to obtain a list of universities that can be mapped based on ranking. Universities in Laos, Myanmar, and Cambodia do not have a SCIMAGO JR Institutional Ranking; therefore, only universities from seven ASEAN countries were used in this study. Based on this reduction from 182 universities with an Institutional Scopus ID, only 100 were recorded in the SCIMAGO JR Institutional Ranking, which was used as a data source.

The researcher then collected data by opening the Scopus ID Institution one by one and downloaded the collaborator information and the number of documents that became links between institutions to collaborate in the form of an adjacency matrix format. The name of the university with the ranking as an attribute will be the node, whereas the number of documents will be the number of links connecting the nodes or universities. The data were then processed using Phyton, which calculates centrality degree, centrality betweenness, centrality closeness, eigenvector, and clique measurements. The output meets the research objectives of depicting a collaboration map and the collaboration gap between ASEAN scientific publications.

5. Results

This study analyzes the pattern of collaboration between universities in Southeast Asia using bibliometric data to reveal the influence of homophily on international collaboration. Researchers have used metrics such as eigenvector centrality, betweenness centrality, closeness centrality, degree centrality, and cliques to assess universities'strategic positions in the network. The researchers divided the results of the analysis into two parts: an overall network analysis that describes the structure and connectivity of the university, and a click analysis that identifies subgroups of close collaboration based on geographical factors or institutional rankings. This approach helps illustrate the macro and micro dynamics in a collaborative network.

Table 1. Distribution of institutions by country in ASEAN.

Country	Number of institutions
Indonesia	92
Malaysia	70
Vietnam	65
Philippines	64
Thailand	42
Singapore	33
Myanmar	12
Cambodia	8
Brunei	3
Laos	3
Other	6,758

Table 2. Centrality metrics by country.

Country	Eigenvector centrality	Betweenness centrality	Closeness centrality	Degree centrality
Brunei	0.052	0.0065	0.3398	0.0152
Cambodia	0.0006	0.0	0.2579	0.0002
Indonesia	0.0078	0.0006	0.2825	0.0016
Laos	0.0177	0.0039	0.3002	0.0071
Malaysia	0.0285	0.0035	0.3217	0.0066
Myanmar	0.0009	0.0019	0.268	0.0018
Philippines	0.0031	0.0015	0.2837	0.002
Singapore	0.0074	0.0013	0.2945	0.0025
Thailand	0.0036	0.0001	0.2839	0.0007
Vietnam	0.0063	0.0008	0.2836	0.0023

5.1. Whole network analysis metrics

5.1.1. Regional collaboration patterns of universities in ASEAN by country

Based on the data analysis that has been carried out, the following is a detailed explanation of the Homophilic Pattern in Regional Collaboration which can be shown in Table 1.

Most institutions came from the 'Other' category, with a total of 6,758 institutions. In Southeast Asia, Indonesia has the largest number of institutions (92), followed by Malaysia (70), Vietnam (65), the Philippines (64), and Thailand (42). Singapore recorded 33 institutions, whereas Myanmar recorded 12. Cambodia contributed eight institutions, while Brunei and Laos each recorded three institutions. This data shows significant differences between countries, with Indonesia leading in terms of the number of institutions in Southeast Asia.

The analysis of centrality metrics shows that Brunei has the highest eigenvector centrality in the network, at 0.052, which reflects a significant influence in the collaboration network. Malaysia also stands out, with a relatively high closeness centrality value of 0.3217, indicating easy access to other institutions in the network, thereby facilitating collaboration. In addition, Laos has an eigenvector centrality value of 0.0177 and a closeness centrality of 0.3002, indicating its strategic role despite its smaller size compared to Brunei and Malaysia. In general, ASEAN countries, such as Brunei, Malaysia, and Indonesia, have higher centrality metric values, indicating their important role in collaboration networks (see Table 2).

5.1.2. The university's strategic position in the collaboration network

The researchers then identified the top 15 universities based on eigenvector centrality, visualized their rankings, and analyzed the relationship between eigenvector centrality and degree centrality. Regional influence metrics were calculated to compare universities in Southeast Asia with those in other regions. The results of this analysis and visualization provide in-depth insights into the strategic position of universities in Southeast Asia in the global collaboration network. The following are the results and visualizations obtained from this study.

Based on Table 3, which features the top 15 universities by eigenvector and degree centrality, this analysis provides insight into the strategic position of universities in collaboration networks. Universiti Kebangsaan Malaysia, Universiti Sains Malaysia, and the University of Indonesia stand out with high eigenvector centrality values, demonstrating their significant role in bridging relationships between institutions (see Table 3). To clarify the relationship between the two metrics, the following scatter plot visualization displays the correlation between eigenvector centrality and degree centrality, where the

Table 3. Eigenvector centrality Metrics by top 15 universities in ASEAN.

No	Rank	Quartile	Node	Eigenvector centrality	Degree centrality
1	278	Q1	The National University of Malaysia	0.988888889	0.211111111
2	189	Q1	Universiti Sains Malaysia	0.941666667	0.209027778
3	354	Q1	University of Indonesia	0.893055556	0.192361111
4	288	Q1	University of Malaya	0.890972222	0.236805556
5	204	Q1	Universiti Putra Malaysia	0.890277778	0.197916667
6	904	Q1	Universitas Airlangga	0.880555556	0.185416667
7	410	Q1	Universiti Teknologi Malaysia	0.858333333	0.194444444
8	707	Q1	MARA University of Technology	0.81875	0.186805556
9	25	Q1	National University of Singapore	0.79375	0.223611111
10	502	Q1	Gadjah Mada University	0.78125	0.168055556
11	733	Q1	Sebelas Maret University	0.779861111	0.1625
12	1097	Q1	Bandung Institute of Technology	0.735416667	0.165972222
13	552	Q1	Diponegoro University	0.729166667	0.1625
14	860	Q1	Brawijaya University	0.727083333	0.160416667
15	1458	Q1	Sepuluh Nopember Institute of Technology	0.716666667	0.161111111

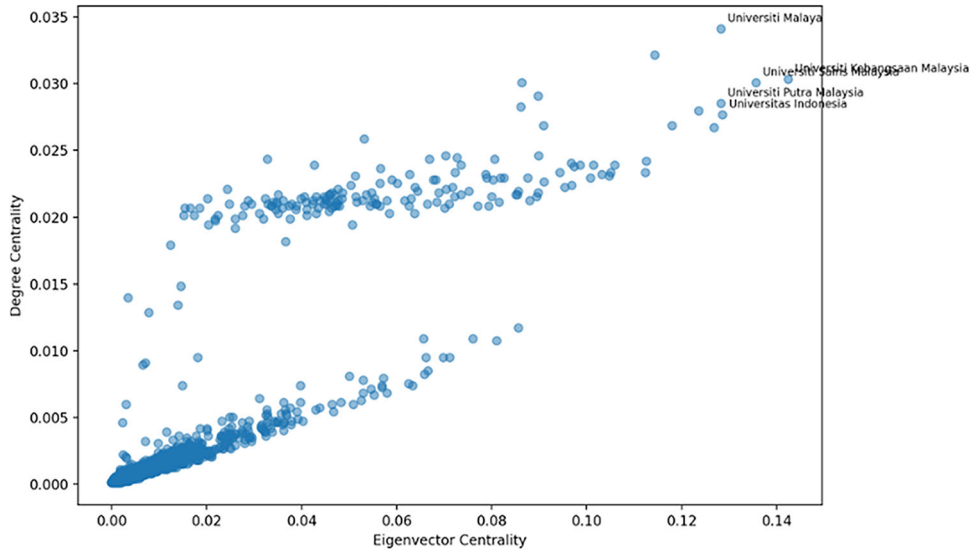

Figure 1. Relationship Eigenvector and Degree Centrality.

universities with the highest scores from the table occupy a strategic position at the top-right end of the graph. This correlation indicates that universities with a high degree of centrality tend to have significant eigenvector centrality, reinforcing their role as centers of influence in the network.

The results of the network analysis reveal interesting patterns related to the influence and interconnectedness of institutions in Southeast Asia. Based on the results of eigenvector and degree centralities, several universities stand out as centers of influence in global networks. Universiti Kebangsaan Malaysia leads with the highest eigenvector centrality of 0.1424 and degree centrality of 0.0304, followed by Universiti Sains Malaysia ranked 189 (0.1356, 0.0301) and University of Indonesia ranked 354 (0.1286, 0.0277). These three universities have extensive connections with other influential institutions, emphasizing their strategic role in supporting international collaborations see Figure 1.

In the context of direct connectivity, Universiti Malaya, ranked 288th, shows superior performance with the highest degree centrality of 0.0341, followed by the National University of Singapore, ranked 25th (0.0322), and Universiti Kebangsaan Malaysia, ranked 278th (0.0304). This position reflects an active and extensive network of collaborations, allowing these universities to take advantage of more global research opportunities than their counterparts.

Overall, the results of this analysis show that universities in Southeast Asia have a significant advantage over institutions in other regions. The average eigenvector centrality of universities in this region was recorded at 0.0101, with a maximum value of 0.1424, much higher than the average of universities outside the region, which only reached 0.0035. With a total of 391 institutions in the region, Southeast Asia is an important player in the global collaboration network.

Table 4. Metrics betweeness centrality, eigenvector centrality, degree centrality berdasarkan top 15 universitas.

No	Rank	Quartile	Node	Betweenness centrality	Eigenvector centrality	Degree centrality
1	288	Q1	Universiti Malaya	0.230555556	0.890972222	0.236805556
2	189	Q1	Universiti Sains Malaysia	0.027	0.941666667	0.209027778
3	Not Found	Not Found	Gunadarma University	0.179861111	0.031	0.140972222
4	25	Q1	National University of Singapore	0.170833333	0.79375	0.223611111
5	Not Found	Not Found	Cebu Technological University	0.163194444	0.106944444	0.14375
6	Not Found	Not Found	Cagayan State University	0.163194444	0.114583333	0.14375
7	Not Found	Not Found	Bataan Peninsula State University	0.160416667	0.120138889	0.139583333
8	Not Found	Not Found	University of Mindanao	0.160416667	0.141666667	0.134722222
9	410	Q1	Universiti Teknologi Malaysia	0.154861111	0.858333333	0.028
10	Not Found	Not Found	Universitas Multimedia Nusantara	0.154861111	0.269444444	0.143055556
11	278	Q1	Universiti Kebangsaan Malaysia	0.022	0.988888889	0.211111111
12	Not Found	Not Found	Lyceum of the Philippines University Manila	0.022	0.105555556	0.139583333
13	204	Q1	Universiti Putra Malaysia	0.140972222	0.890277778	0.197916667
14	Not Found	Not Found	Universiti Islam Sultan Sharif Ali	0.140972222	0.041	0.139583333
15	Not Found	Not Found	Mandalay University	0.140277778	0.152083333	0.136805556

Interestingly, there is a strong correlation between eigenvector centrality and degree centrality (0.8915), which suggests that universities with many direct connections also have a large influence on the network. For example, Universiti Kebangsaan Malaysia has an eigenvector centrality that is 32.5% higher than that of Brawijaya University, while Universiti Malaya has a degree centrality that is 47.6% higher than that of the same university.

Although there is a significant difference in scores among the top 15 universities, such as the eigenvector centrality difference of 0.0377 between the highest and lowest scores, universities such as Universiti Teknologi Malaysia with a ranking of 410 (0.1236), Universiti Teknologi MARA with a ranking of 707 (0.1179), and Universitas Airlangga with a ranking of 904 (0.1268) still play an important role in collaboration networks.

The National University of Singapore, despite having an eigenvector centrality (0.1143) that is 19.7% lower than Universiti Kebangsaan Malaysia, still has strong connectivity with a degree centrality of 0.0322. This shows that the university has many direct connections, even though its global influence is relatively lower than that of some other universities in the region.

5.1.3. The role of universities with high betweenness centrality

Based on the Table 4 that displays the values of betweenness centrality, eigenvector centrality, and degree centrality, Universiti Malaya, Universiti Sains Malaysia, and the National University of Singapore, which are ranked 25th, have high centrality values. Universiti Malaya with a ranking of 288, for example, has the highest betweenness centrality of 0.0332, indicating a significant role in bridging connections between institutions. Gunadarma University, Cebu Technological University, and Universiti Teknologi Malaysia also showed good performance, especially in direct connectivity, as represented by degree centrality.

To provide a clearer picture of the relationship between betweenness and degree centrality, the following scatter plot visualizes the distribution of institutions based on both metrics. This plot shows how universities with high centrality scores tend to have high degree centrality, as shown by Universiti Malaya, Universiti Sains Malaysia, and the National University of Singapore.

The analysis of betweenness centrality reveals the strategic role of universities as liaisons in international collaboration networks, with Universiti Malaya leading the way (0.0332), followed by Universiti Sains Malaysia (0.0270) and Gunadarma University (0.0259). The National University of Singapore recorded a score of 0.0246, indicating its significant role in connecting institutions. Cebu Technological University and Cagayan State University share a score of 0.0235, highlighting their equal role in facilitating collaboration, while Multimedia Nusantara University (0.0223) shows a connecting contribution despite its smaller global influence see Figure 2.

The average betweenness centrality of universities in Southeast Asia reached 0.0014, almost five times higher than that of other regions (0.0003), with a regional maximum of 0.0332. The correlation between betweenness and degree centrality (0.9273) shows that universities that act as liaisons also have many direct connections. For example, Universiti Malaya, ranked 288th, recorded the highest degree centrality

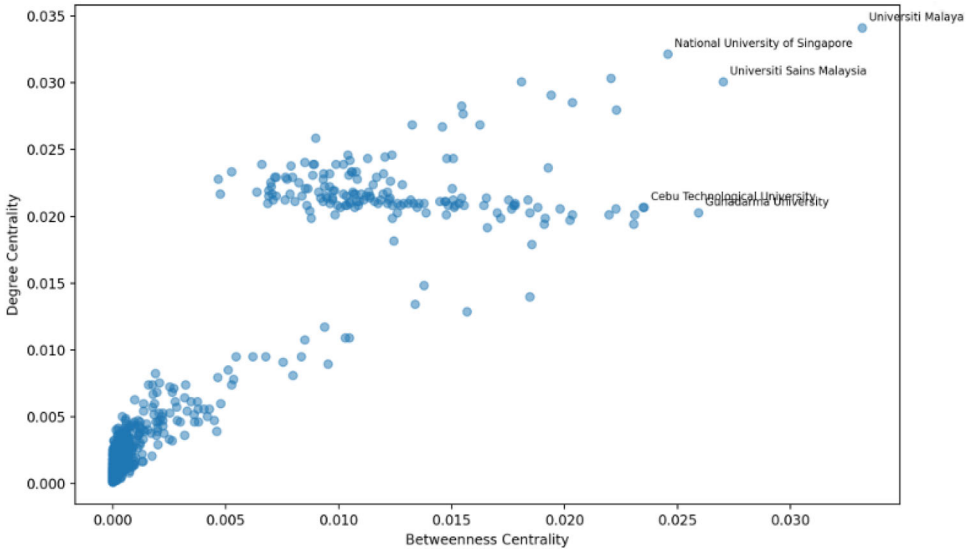

Figure 2. Relationship Betweenness and Degree Centrality.

Table 5. Closeness centrality, betweenness centrality, eigenvector centrality, degree centrality based on top 15 universities.

No	Rank	Quartile	Node	Country	Closeness centrality	Degree centrality	Eigenvector centrality
1	288	Q1	University of Malaya	Other	2.995138889	0.236805556	0.890972222
2	278	Q1	The National University of Malaysia	Malaysia	2.94375	0.211111111	0.988888889
3	189	Q1	Universiti Sains Malaysia	Malaysia	2.934027778	0.209027778	0.941666667
4	204	Q1	Universiti Putra Malaysia	Malaysia	2.891666667	0.197916667	0.890277778
5	410	Q1	Universiti Teknologi Malaysia	Malaysia	0.288888889	0.028	0.858333333
6	25	Q1	National University of Singapore	Singapore	2.852777778	0.223611111	0.79375
7	354	Q1	University of Indonesia	Indonesia	2.85	0.192361111	0.893055556
8	904	Q1	Universitas Airlangga	Other	2.834722222	0.185416667	0.880555556
9	707	Q1	MARA University of Technology	Other	2.832638889	0.186805556	0.81875
10	62	Q1	The University of Queensland	Other	2.822222222	0.08125	0.594444444
11	44	Q1	UNSW Sydney	Other	2.816666667	0.075694444	0.528472222
12	Not Found	Not Found	CNRS National Research Centre	France	2.808333333	0.075694444	0.45625
13	389	Q1	Chulalongkorn University	Other	2.802083333	0.209027778	0.599305556
14	29	Q1	University of Melbourne	Other	2.793055556	0.075	0.081
15	677	Q1	International Islamic University Malaysia	Malaysia	2.761805556	0.196527778	0.597916667

(0.0341), followed by Universiti Sains Malaysia at 189th (0.0301), and the National University of Singapore at 25th (0.0322).

The National University of Malaysia, despite having the highest eigenvector centrality (0.1424), only occupies the 11th position in betweenness centrality (0.0220), showing a greater influence than its role as a link. In contrast, Philippine universities, such as Cebu Technological University, Cagayan State University, Bataan Peninsula State University, and the University of Mindanao, dominated the liaison role, with each recording a score above 0.0231.

5.1.4. Openness to international collaboration based on closeness centrality

Universities with high closeness centrality scores can reach other institutions more quickly in a collaborative network. This reflects the level of openness to international collaboration, which is an important indicator of the internationalization process.

Based on the previous Table 5, Universiti Malaya, Universiti Kebangsaan Malaysia, and Universiti Sains Malaysia stand out in terms of closeness centrality and degree centrality, reflecting high direct connectivity and the efficiency of access to other universities in the network. The following scatter plot visualizes the relationship between closeness centrality and degree centrality, showing a pattern of positive correlation between them. The University of Malaya was at the top, demonstrating the optimal combination of direct connectivity and access efficiency. Other universities, such as Universiti Kebangsaan Malaysia, Universiti Sains Malaysia, and University of Indonesia, occupy strategic positions that reflect their

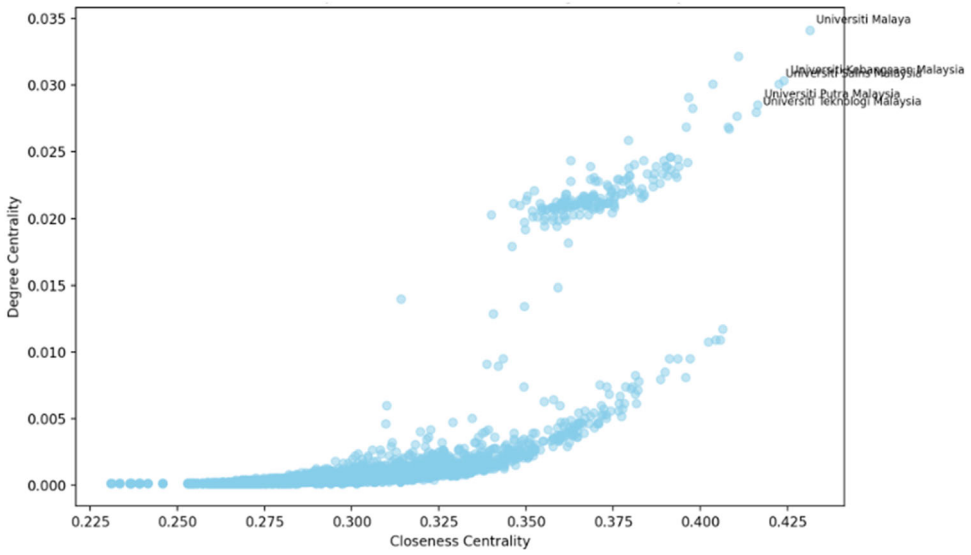

Figure 3. Relationship closeness and degree centrality.

significant role in the collaboration network. This visualization provides additional context for understanding the relative position of universities in Southeast Asia and globally in international collaboration networks.

The analysis of closeness centrality shows an interesting pattern in the openness of international collaboration among higher-education institutions. Universiti Malaya ranked 288th led the way with the highest closeness centrality score of 0.4313, followed by degree centrality of 0.0341, reflecting efficiency and strategic connectivity in global collaboration networks. Universiti Kebangsaan Malaysia, ranked 278, is in second place with a centrality closeness of 0.4239 and the highest eigenvector centrality value in the network, 0.1424. Universiti Sains Malaysia ranked 189th with a closeness centrality of 0.4225 and a degree centrality of 0.0301, reaffirming its role as one of the leading institutions in the region see Figure 3.

From a regional perspective, Malaysia showed the strongest performance, with an average closeness centrality of 0.3217 and a maximum value of 0.4239. Other ASEAN countries also showed significant variations. Brunei, despite having only three institutions, recorded a high average closeness centrality of 0.3398, while Singapore achieved a maximum closeness centrality value of 0.4108 with an average of 0.2945. Indonesia, with the largest number of institutions (92), recorded a maximum closeness centrality value of 0.4104, demonstrating its important role in regional collaborations.

The geographical distribution shows that Malaysian universities dominate the top five in terms of closeness centrality, with all scores being above 0.4160. The National University of Singapore also recorded a high closeness centrality score of 0.4108, indicating a strong combination of direct connectivity and network efficiency. The University of Indonesia recorded a value of 0.4104, with an eigenvector centrality of 0.1286, reflecting significant connectivity at the global level.

Among other ASEAN countries, Vietnam, with 65 institutions, recorded a maximum closeness centrality score of 0.3794, whereas Thailand recorded a maximum value of 0.3669 from 42 institutions. In contrast, Cambodia and Myanmar showed lower values, with average centrality closeness of 0.2579 and 0.2680, respectively, reflecting limitations in global collaboration networks.

Non-ASEAN institutions also have a significant presence in this network. The University of Queensland, ranked 62nd, recorded a closeness centrality of 0.4064, while UNSW Sydney, ranked 44th, reached 0.4056, demonstrating strong connectivity in the international networks. The CNRS of France also recorded a closeness centrality value of 0.4044, confirming the global interconnectedness of this institution.

Correlation analysis shows that institutions with high closeness centrality tend to have a high degree of centrality. For example, Universiti Malaya, ranked 288th, has a closeness centrality of 0.4313 and degree centrality of 0.0341, while Chulalongkorn University, ranked 389th, has a closeness centrality of

Table 6. Degree centrality, eigenvector centrality, and betweenness centrality Metrics based on top 15 Southeast Asian universities.

No	Rank	Quartile	Node	Degree centrality	Eigenvector centrality	Betweenness centrality
1	288	1	University of Malaya	0.236805556	0.890972222	0.230555556
2	25	1	National University of Singapore	0.223611111	0.79375	0.170833333
3	278	1	The National University of Malaysia	0.211111111	0.988888889	0.022
4	189	1	Universiti Sains Malaysia	0.209027778	0.941666667	0.027
5	389	1	Chulalongkorn University	0.209027778	0.599305556	0.125694444
6	78	1	Nanyang Technological University	0.202083333	0.623611111	0.134722222
7	204	1	Universiti Putra Malaysia	0.197916667	0.890277778	0.140972222
8	677	1	International Islamic University Malaysia	0.196527778	0.597916667	0.106944444
9	410	1	Universiti Teknologi Malaysia	0.028	0.858333333	0.154861111
10	354	1	University of Indonesia	0.192361111	0.893055556	0.107638889
11	707	1	MARA University of Technology	0.186805556	0.81875	0.1125
12	625	1	Mahidol University	0.186805556	0.63125	0.091666667
13	904	1	Universitas Airlangga	0.185416667	0.880555556	0.101388889
14	1996	1	Vietnam National University, Hanoi	0.179861111	0.36875	0.009
15	1305	1	Prince of Songkla University	0.170833333	0.624305556	0.072222222

Table 7. Network concentration Metrics.

Method	Value
Total number of institutions	7.15
Top 10% of institutions (715 institutions)	Controls 75.69% of all connections
Gini Coefficient (degree centrality)	5.392361111

Table 8. Degree centrality distribution Statistics.

Statistics	Degree centrality
Count	7.15
Mean	0.0009
Standard Deviation (std)	0.0034
Minimum	0.0001
25% Quartile	0.0001
Median (50%)	0.0001
75% Quartile	0.0004
Maximum	0.236805556

0.4035 and degree centrality of 0.0301. This data indicate that openness to international collaboration is influenced not only by the number of direct connections but also by the strategic position of institutions in the global network.

Overall, Malaysian universities showed excellence in international collaboration, while institutions from other ASEAN countries showed significant variation. This pattern reflects a combination of institutional policies, research capacity, and internationalization strategies implemented by each university, which together shape their level of interconnectedness and influence in the global network of collaboration.

5.1.5. Dominance of certain universities in collaboration

Degree centrality analysis shows that some universities have a much higher number of collaborations. This indicates the dominance of certain universities in the collaboration network, which reflects differences in research capacity and resources (Table 6).

The first table provides an overview of the overall concentration of the network, which is highly concentrated. With the top 10% of institutions controlling 75.69% of all connections, most of the influence was concentrated in a small number of institutions. To deepen the analysis, the second table presents the degree centrality distribution statistics, which provide details about the distribution of connectivity values among all the institutions in the network (Table 7).

From the second table, we can understand the distribution of degree centrality, starting from a very low minimum value to a maximum of 0.0341. This data shows inequality in connectivity distribution, with only a few institutions having high connectivity. The next table highlights the top 15 universities by degree centrality, which play an important role in bridging connections and supporting global collaboration. This table provides a specific overview of the institutions that dominate the global collaboration networks (Table 8).

The results of the analysis of the inter-university collaboration network show that dominance in the international collaboration network is concentrated in a small number of institutions. Of the 7,150 institutions, the top 10% (715 institutions) controlled 75.69% of all connections in the network. A Gini coefficient of 0.7765 confirms a very high distribution inequality, with most institutions having far fewer connections than dominant institutions.

The top five universities based on degree centrality are University of Malaya with a ranking of 288 (0.0341), National University of Singapore with a ranking of 25 (0.0322), Universiti Kebangsaan Malaysia ranked 278 (0.0304), Universiti Sains Malaysia ranked 189 (0.0301), and Chulalongkorn University ranked 389 (0.0301). These universities not only dominate direct connectivity but also play a significant role as a link in the network, as demonstrated by their betweenness centrality.

The degree centrality distribution pattern showed a minimum value of 0.0001 and a maximum of 0.0341, with an average of only 0.0009 and a standard deviation of 0.0034. As many as 75% of institutions have a degree centrality value below 0.0004, reflecting that the majority of institutions have very few connections in the network. This pattern further clarifies the inequality that occurs when only a handful of institutions have broad access to a global collaborative network.

Malaysia and Singapore dominate this network geographically. Malaysia has several universities in the top 15, including Universiti Malaya, Universiti Kebangsaan Malaysia, Universiti Sains Malaysia, and Universiti Putra Malaysia (UPM). Singapore shows strong dominance through the National University of Singapore with a ranking of 25 (degree centrality of 0.0322) and Nanyang Technological University with a ranking of 78 (0.0291). Thailand also made a significant contribution through Chulalongkorn University with a ranking of 389 (degree centrality of 0.0301) and Mahidol University with a ranking of 625 (0.0269).

Other regional distributions showed large discrepancies. For example, Indonesian institutions, although numbering 92, have a maximum degree centrality value of 0.0277, far below that of Malaysian and Singaporean universities. Vietnam, with 65 institutions, has a maximum degree centrality score of only 0.0259, whereas institutions in smaller countries, such as Laos and Cambodia, have an average degree centrality lower than 0.0004.

From a structural perspective, the high concentration of connections creates a dependence on a small number of dominant institutions. For example, universities in the top 10% show an average connection value of over 0.0100, whereas the other 90% are well below that number. Institutions such as the University of Malaya and the National University of Singapore not only have extensive connections but also forge collaborations, especially with their fellow dominant institutions.

This pattern suggests that the current system of collaboration networks has the characteristic of 'rich-get-richer', where institutions that already have many connections tend to continue expanding their influence. However, the majority of institutions with very low connectivity face the challenge of engaging in global networks.

5.1.6. Gaps in collaboration networks

While there are highly connected universities, the analysis also shows gaps in collaborative networks. Some universities have very limited connections, indicating the need for strategies to increase their participation in international collaborations (Table 9).

Based on the analysis of the gaps in the collaboration network presented in the previous table, there is a significant difference in the level of connectivity between the universities. To illustrate the distribution of these connections more thoroughly, the Table 10 presents network inequality statistics based on degree centrality, including mean values, standard deviations, and important percentiles, such as 25%, 50%, and 75%. These data provide deeper insights into the distribution of connectivity across the network while confirming the inequalities that have been identified .

The following table presents the five universities with the highest degree centrality in the global collaboration network: Universiti Malaya with a rank of 288 leads the way with a degree centrality value of 0.0341, followed by the National University of Singapore with a rank of 25 (0.0322) and Universiti Kebangsaan Malaysia with a rank of 278 (0.0304). Universiti Sains Malaysia ranked 189th and Chulalongkorn University ranked 389th had the same degree centrality value (0.0301). This position reflects their strategic role as connectivity hubs in international collaboration networks.

Table 9. Comparison of degree centrality, eigenvector centrality, and betweenness centrality with gap to mean analysis.

No	Rank	Quartile	Node	Degree centrality	Eigenvector centrality	Betweenness centrality	Gap_to_mean
1	25	1	National University of Singapore	0.223611111	0.793055556	0.170833333	34.32.00
2	278	1	The National University of Malaysia	0.211111111	0.988888889	0.152777778	32.38.00
3	189	1	Universiti Sains Malaysia	0.209027778	0.941666667	0.1875	32.08.00
4	389	1	Chulalongkorn University	0.209027778	0.599305556	0.125694444	32.08.00
5	78	1	Nanyang Technological University	0.202083333	0.623611111	0.134722222	31.04.00
6	204	1	Universiti Putra Malaysia	0.197916667	0.890277778	0.140972222	30.44.00
7	677	1	International Islamic University Malaysia	0.196527778	0.597916667	0.106944444	30.14.00
8	410	1	Universiti Teknologi Malaysia	0.19375	0.858333333	0.154861111	29.84
9	354	1	University of Indonesia	0.192361111	0.893055556	0.107638889	29.55.00
10	707	1	MARA University of Technology	0.186805556	0.81875	0.1125	28.65
11	625	1	Mahidol University	0.186805556	0.63125	0.091666667	28.65
12	904	1	Universitas Airlangga	0.185416667	0.880555556	0.101388889	28.50.00
13	1996	1	Vietnam National University, Hanoi	0.179861111	0.36875	0.0090	27.61

Table 10. Network gap statistics.

Statistics	Degree centrality
Count	7150
Mean	0.0009374092
Standard Deviation (std)	0.003394072
Minimum	0.0001398797
25% Quartile	0.0001398797
50% Quartile	0.0001398797
75% Quartile	0.0004196391
90% Quartile	0.0011190376
95% Quartile	0.0022380753
99% Quartile	0.021681354
Maximum	0.0341306476

Table 11. The most connected University.

No	Rank	Node	Degree centrality
1	288	University of Malaya	0.236805556
2	25	National University of Singapore	0.223611111
3	278	The National University of Malaysia	0.211111111
4	189	Universiti Sains Malaysia	0.209027778
5	389	Chulalongkorn University	0.209027778

Table 12. Isolated institutions.

No	Rank	Node	Degree centrality
1	871	University of Patras	0.0001
2	80	IBM Research	0.0001
3	Not Found	Guangzhou Institute of Geochemistry	0.0001
4	Not Found	Yale School of the Environment	0.0001
5	Not Found	University of Science & Technology of Fujairah	0.0001

In contrast, the following Table 11 displays the five universities with the lowest degree centrality, reflecting their limitations in establishing connections within the global collaboration network. Universities such as the University of Patras, IBM Research, Guangzhou Institute of Geochemistry, Yale School of the Environment, and the University of Science & Technology of Fujairah have a degree centrality value of 0.0001, indicating a very low level of connectivity within the network. This highlights the need for increased collaboration for these universities to engage more actively on a global scale (Table 12).

Connectivity ratio analysis shows a large gap between the most connected and most isolated universities, with a ratio of 244:1 between the University of Malaya (degree centrality 0.0341) and universities such as the University of Patras, IBM Research, and others (degree centrality of 0.0001). A total of 78.90% of institutions are isolated, reflecting the dominance of some of the leading universities in the global collaboration network.

5.2. Cliques

The second section discusses network click analysis. This analysis includes the size, variation, and patterns that appear among groups (Table 13).

This dataset shows 19 unique click sizes, with the number of members ranging from three to 21 per click. The average click size was approximately 12 members, which reflects the level of collaboration in the group, while a standard deviation of 5.63 indicates moderate variation, with some clicks being much larger or smaller than the average. The smallest click comprised three members, whereas the largest click comprised 21 members, indicating a wide range of collaboration scales. Based on the quartile, 25% of clicks have seven members or less, which represents a smaller group; the median size is 12, which means half of the clicks have 12 members or less; and 75% of clicks have 16 members or less, highlighting the rarity of larger collaborative groups.

5.2.1. Size and composition of largest cliques

The Click Size Distribution table illustrates the frequency of collaboration between universities based on the number of members in each click. Click with three universities dominated with 2,640 groups. This was followed by a click with four universities, which recorded 2,038 groups. Collaborations involving five universities were recorded as 1,577 groups. In contrast, larger clicks indicate a decreasing frequency, such as clicks the size of six universities with 1,302 groups. Clicks involving seven universities were recorded in 1,056 groups. Collaborations with 10 universities were identified in 732 groups, whereas clicks with more than 20 universities were very rare, with only seven groups recorded. This data reflects the dominance of collaboration within small groups, which shows higher similarities between universities in terms of their rankings or research orientation (Table 14 and Figure 14).

This click size distribution curve shows an interesting pattern in the collaboration between universities. From the graph, most of the collaborations occurred in relatively small groups, with the highest frequency of clicks with the size of three universities (2,640 groups) and four universities (2,038 groups). In contrast, the frequency began to drop drastically when the click size was greater than six universities.

Table 13. Summary Statistics for cliques.

Statistic	Click size	Frequency	Percentage (%)	Cumulative percentage (%)
Count	19	19	19	19
Mean	12	919.63	05.26	69.91
Standard Deviation	0.252083333	658.17.00	0.178472222	27.15.00
Minimum	3	7	00.04	15.11
25th Percentile	07.05	584.05.00	03.35	51.48.00
Median (50%)	12	815	0.2125	73.28.00
75th Percentile	16.05	1108.05.00	06.34	95.56.00
Maximum	21	2640	15.11	99.98

Table 14. Cliques distribution.

No	Size of cliques	Frequency
1	3	2640
2	4	2038
3	5	1577
4	6	1302
5	7	1056
6	8	765
7	9	663
8	10	732
9	11	949
10	12	1084
11	13	1133
12	14	986
13	15	815
14	16	707
15	17	506
16	18	334
17	19	144
18	20	35
19	21	7

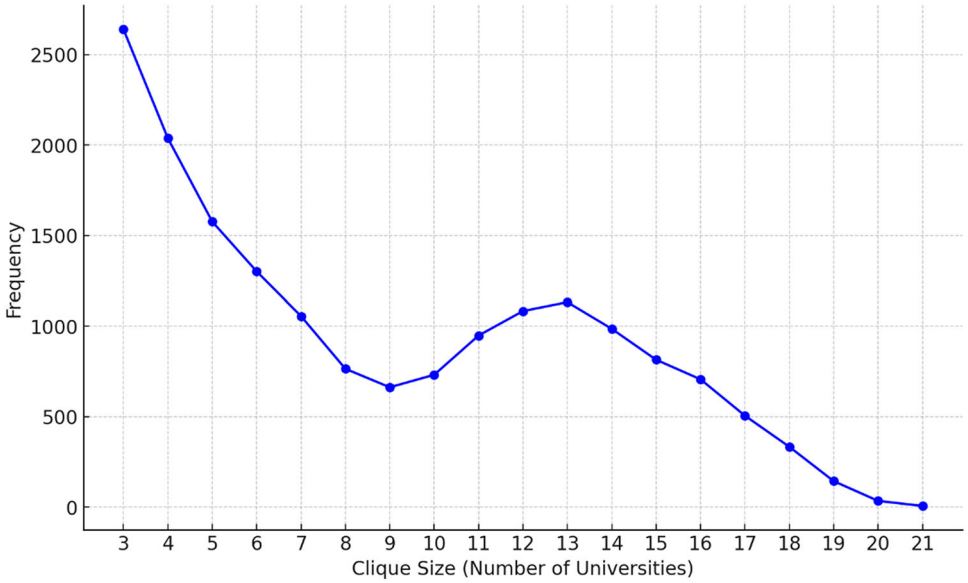

Figure 4. Curve of clique size distribution in university collaborations.

This shows that collaboration in larger groups, especially those involving more than ten universities, is rare. Statistically, these data did not show a normal distribution. Based on the statistical analysis, there were 19 categories of click size with an average frequency of 919.63 and a standard deviation of 658.17, which showed significant variation between click frequencies. The click frequency with a size of three universities recorded a maximum value of 2,640 groups, whereas clicks with a size of more than 20 universities were recorded in only seven groups. The median frequency was 815, with the 25th and 75th percentiles at 584.5 and 1,108.5 groups, respectively. In the click size range of 9–13 universities, the frequency of collaboration increased, with nine universities recording 663 groups, 10 universities 732 groups, 11 universities 949 groups, 12 universities 1,084 groups, and 13 universities 1,133 groups. Subsequently, there was a decrease in frequency, with 14 universities recording 986 groups. This indicates that the distribution peaks occur at smaller click sizes and then decline sharply, creating a left-skewed distribution with a long tail. This shows that most collaborations occur in small groups, and the frequency decreases as the click size increases. This distribution is asymmetrical, with most of the data centralized on the left side, while the right side (large groups) shows very low frequencies.

Continuing the analysis of the click size distribution curve, anomalies were detected in the click sizes of 13 and 9 universities. In the click size of 13 universities, there was an unusual frequency spike with 1,133 collaboration groups recorded, which is the highest number after the click size of 3–6 universities. This surge could indicate an uneven collaboration, with some larger groups of universities unexpectedly collaborating. Similarly, in the click size of nine universities, although the frequency of collaboration generally decreases after reaching a peak at click size 3 to 6, click size 9 shows a high frequency, namely 663 groups. Anomalies in both click sizes indicate a pattern of collaboration that does not fully follow the larger distribution trend and could indicate specific dynamics of cooperation between universities of that size.

Continuing the analysis of the click size distribution curve, although most of the collaborations occur in small groups, with the highest frequency in click size 3 (2,640 groups) and 4 (2, 038 groups) universities, there are also collaboration groups that involve more universities, especially in the click size of 21 universities. Although the frequency is relatively low, with only seven groups recorded in this category, the data still illustrate the advanced level of collaboration involving large and leading universities in the ASEAN region. This large group reflects broader international cooperation, despite the predominance of Indonesian universities, with few representatives from universities outside Indonesia, especially Malaysia. This shows that international collaboration in large clicks tends to be dominated by Indonesian universities, whereas universities from other countries are more limited in their involvement.

The following table presents the names of the universities involved in the click size of 21 universities, providing a clearer picture of the patterns and networks of collaboration formed in this study, with the

Table 15. University aggregate by clique size 21.

No	List of universities (click size 21)
1	University of Malaya, Sepuluh Nopember Institute of Technology, Universiti Kebangsaan Malaysia, Airlangga University, Universiti Teknologi Malaysia, Brawijaya University, State University of Malang, Sebelas Maret University, Diponegoro University, Bandung Institute of Technology, University of Indonesia, Gadjah Mada University, IPB University, Universiti Putra Malaysia, Maulana Malik Ibrahim State Islamic University Malang, University of Jember, Sunan Kalijaga State Islamic University, Yogyakarta, Bina Nusantara University, Syiah Kuala University, Hasanuddin University, Andalas University
2	University of Lampung, IPB University, Gadjah Mada University, Bandung Institute of Technology, Diponegoro University, Brawijaya University, Hasanuddin University, Syiah Kuala University, Sebelas Maret University, University of Indonesia, Sepuluh Nopember Institute of Technology, Andalas University, Airlangga University, Sunan Kalijaga State Islamic University, Yogyakarta, Jember University, Bina Nusantara University, Syarif Hidayatullah State Islamic University Jakarta, State University of Malang, Universiti Teknologi Malaysia, Universiti Kebangsaan Malaysia, Universiti Putra Malaysia
3	University of Lampung, IPB University, Gadjah Mada University, Bandung Institute of Technology, Diponegoro University, Brawijaya University, Hasanuddin University, Syiah Kuala University, Sebelas Maret University, University of Indonesia, Sepuluh Nopember Institute of Technology, Andalas University, Airlangga University, Sunan Kalijaga State Islamic University, Yogyakarta, Jember University, Bina Nusantara University, Syarif Hidayatullah State Islamic University Jakarta, State University of Malang, Universiti Teknologi Malaysia, Universiti Kebangsaan Malaysia, National Research and Innovation Agency
4	Universitas Lampung, IPB University, Universitas Gadjah Mada, Institut Teknologi Bandung, Universitas Diponegoro, Brawijaya University, Hasanuddin University, Universitas Syiah Kuala, Universitas Sebelas Maret, Universitas Indonesia, Institut Teknologi Sepuluh Nopember, Universitas Andalas, Universitas Airlangga, Universitas Islam Negeri Sunan Kalijaga, Yogyakarta, Universitas Islam Indonesia, Bina Nusantara University, Universitas Islam Negeri Syarif Hidayatullah Jakarta, Universitas Negeri Malang, Universiti Teknologi Malaysia, Universiti Kebangsaan Malaysia, Universiti Putra Malaysia
5	University of Lampung, IPB University, Gadjah Mada University, Bandung Institute of Technology, Diponegoro University, Brawijaya University, Hasanuddin University, Syiah Kuala University, Sebelas Maret University, University of Indonesia, Sepuluh Nopember Institute of Technology, Andalas University, Airlangga University, Sunan Kalijaga State Islamic University, Yogyakarta, Islamic University of Indonesia, Bina Nusantara University, Syarif Hidayatullah State Islamic University Jakarta, State University Malang, Universiti Teknologi Malaysia, Universiti Kebangsaan Malaysia, National Research and Innovation Agency
6	Syarif Hidayatullah State Islamic University Jakarta, University of Indonesia, Bandung Institute of Technology, Gadjah Mada University, Diponegoro University, IPB University, Andalas University, Hasanuddin University, Maulana Malik Ibrahim State Islamic University Malang, Sebelas Maret University, Sepuluh Nopember Institute of Technology, Brawijaya University, Jember University, Malang State University, Syiah Kuala University, Sunan Kalijaga State Islamic University, Yogyakarta, Bina Nusantara University, Universitas Airlangga, Universiti Teknologi Malaysia, Universiti Kebangsaan Malaysia, Universiti Putra Malaysia
7	Syarif Hidayatullah State Islamic University Jakarta, University of Indonesia, Bandung Institute of Technology, Gadjah Mada University, Diponegoro University, IPB University, Andalas University, Hasanuddin University, Maulana Malik Ibrahim State Islamic University Malang, Sebelas Maret University, Sepuluh Nopember Institute of Technology, Brawijaya University, Jember University, Malang State University, Syiah Kuala University, Sunan Kalijaga State Islamic University, Yogyakarta, Bina Nusantara University, Universitas Airlangga, Universiti Teknologi Malaysia, Universiti Kebangsaan Malaysia, National Research and Innovation Agency

dominance of collaboration between Indonesian universities and several universities from other ASEAN countries.

With a click size of 20 universities, there were 35 collaboration groups. Interestingly, four clicks of the total frequency came only from universities in Vietnam, which were not connected to other collaboration groups in the 31 frequencies that existed. Table 15 shows an example of clicks built in Vietnamese universities that tend to be inward. Most collaborations of this size involve universities from Indonesia, with several universities from other ASEAN countries, such as Universiti Kebangsaan Malaysia and Universiti Teknologi Malaysia, participating. This indicates a more isolated collaboration between universities in Vietnam, while other click groups involve universities from Indonesia and other ASEAN countries, with more dispersed frequencies.

5.2.2. Dominance of key universities

The universities that appear most frequently in the largest cliques are highlighted, showcasing their central role in fostering collaboration (Table 16).

Based on the analysis of collaboration intensity, Universiti Kebangsaan Malaysia and Universitas Airlangga stood out as the most dominant universities, appearing in 33.43% and 31.64% of the total clicks, respectively, followed by the University of Indonesia (27.26%), Sebelas Maret University (25.68%), and Universiti Sains Malaysia (25.55%). Of the 2,247 unique universities analyzed, only a small fraction frequently appeared in clicks, reflecting the concentration of the network on a specific institution. Indonesia and Malaysia dominate this list with eight and seven universities, respectively, indicating a strong pattern of regional collaboration in Southeast Asia. Universities such as Brawijaya University (23.60%) and Universiti Teknologi Malaysia (23.42%) also recorded significant contributions, while Institut Teknologi Sepuluh Nopember and Universiti Teknologi MARA accounted for 20.43% and 20.08% of the clicks, respectively. Universities with large contributions also showed a high average number of clicks,

Table 16. Intensity of collaboration for top 20 universities.

No	Rank	University	Frequency	Percentage (%)	Avg clique size
1	913	The National University of Malaysia	5841	33.43.00	12.11
2	904	Universitas Airlangga	5528	31.64	0.565277778
3	354	University of Indonesia	4763	27.26.00	12.55
4	733	Sebelas Maret University	4487	25.68	0.586111111
5	189	Universiti Sains Malaysia	4464	25.55.00	11.27
6	860	Brawijaya University	4123	1	14.05
7	410	Universiti Teknologi Malaysia	4093	23.42	12.41
8	1458	Sepuluh Nopember Institute of Technology	3569	20.43	13.45
9	707	MARA University of Technology	3508	20.08	12.34
10	552	Diponegoro University	3426	0.834027778	0.5875
11	1162	State University of Malang	3314	0.817361111	0.610416667
12	204	Universiti Putra Malaysia	3274	0.801388889	11.38
13	1097	Bandung Institute of Technology	3148	18.02	14.08
14	502	Gadjah Mada University	3106	0.7625	13.13
15	288	University of Malaya	3001	17.18	11.28
16	25	National University of Singapore	2373	13.58	0.318055556
17	566	Syiah Kuala University	2192	12.55	0.594444444
18	1004	Universiti Tun Hussein Onn Malaysia	2184	12.50	0.507638889
19	845	Yogyakarta State University	1848	10.58	13.55
20	811	Hasanuddin University	1818	10.40	14.06

such as Hasanuddin University (14.06), Bandung Institute of Technology (14.08), and Brawijaya University (14.05), affirming their role in building a wider network of collaborations.

The university's participation rate varied from a minimum of two clicks to a maximum of 5,841 clicks. A total of 75% of universities were involved in 15 clicks or fewer, indicating that only a small percentage of universities dominated the connections between groups. Top universities play an important role in connecting various research groups. This high variation in participation also indicates the existence of a hierarchical network structure, in which a small number of universities dominate the relationship between groups.

6. Discussions

The results of this study show the complexity of collaboration between universities in the ASEAN region. Based on eigenvector centrality, betweenness centrality, closeness centrality, degree centrality, and cliques, dynamic results were obtained. For example, Indonesia, which has the most universities based on university population compared to all universities in ASEAN, tends to have a lower impact on collaboration than Singapore and Malaysia, which have fewer universities. 'Not to mention the phenomenon of the rich-get-richer', which fundamentally forms a fragmented institutional collaboration landscape by showing that universities with high rankings have wider collaboration. A more detailed description of the results of this study is presented in the discussion section.

6.1. Rich-get-richer university

Based on the findings of this study, researchers have found that high-ranking universities tend to have a high level of collaboration. Highly ranked universities have a significant level of collaboration and demonstrate the characteristics of reputable institutions. Their profiles reflect their ability to build strong academic networks, produce high-quality publications and attract research partners from various international institutions. The example of the University of Malaya, which has the highest degree centrality (0.2368), shows a 'rich-get-richer' pattern by establishing connections with more than 75% of other ASEAN institutions. Out of a total of 7,150 institutions, the top 10% dominate, controlling 75.69% of all connections in the network. This shows that most connectivity and collaboration are concentrated in institutions that already have great influence (Tadjudin, 2000). This condition confirms the statement by Oldac and Yang (2023), who stated that Malaysia appears as a central actor in the region's scientific connectivity, even though Singapore produces the most publications. Both countries have high GDP income in ASEAN. Malaysia and Singapore show that high rankings and large GDP strengthen the capacity to build regional scientific networks. This is relevant to the research of Hou et al. (2021), who found that

not only does financial capacity support, but it also strengthens scientific connectivity in the global network.

An analysis of degree centrality in university networks reveals a 'Rich-Get-Richer' pattern, where elite universities such as Universiti Malaya, with a score 252 times above the average of 0.000937, as well as the National University of Singapore (0.2236) and Universiti Kebangsaan Malaysia (0.2111) dominate global academic networks. Meanwhile, the other 90% of institutions lag far behind, with degree centrality below 0.001, reflecting the gap between leading and less established universities. This dominance is reinforced by the resources, reputation, and networks of collaboration already built, creating a cycle in which elite universities are getting stronger, while others struggle to catch up (Behfar & Shekhtman, 2024)

An analysis of university networks revealed extreme inequalities in connectivity, with a Gini coefficient of 0.7765, confirming a very high concentration of connections in the dominant institutions. The largest clicks, involving 21 institutions, were dominated by universities such as Universiti Malaya and the University of Indonesia, which appeared in more than 35% of the large clicks, showing how already established universities tend to expand their influence through extensive multilateral collaborations. Meanwhile, institutions with the lowest connectivity, such as the University of Patras and the Guangzhou Institute of Geochemistry, recorded a degree centrality of only 0.0001, almost no connectivity in the network. This data not only reflects the growing dominance of elite universities but also isolates less established institutions, creating a 'Rich-Get-Richer' cycle that widens the gap. Even in previous research, Cho (2020) said that systemic inequality in the global academic ecosystem shows the dominance of developed countries. Is this an ideal picture of global academic collaboration, or is it a failure of the system to create an inclusive ecosystem? Without efforts to promote equitable connectivity, this inequality will continue to exacerbate the fragmentation of the academic world.

Institutions from Malaysia and Singapore dominate the 'rich-get-richer' pattern, with the average degree centrality of Malaysian universities reaching 0.3217 and Singaporean universities 0.4108. Universities from Indonesia, such as the University of Indonesia (0.1923) and Airlangga University (0.1854), also show significant participation. In contrast, universities in Myanmar and Laos recorded average scores below 0.0004, indicating limited connectivity. As many as 78.90% of institutions have low connectivity, with a degree centrality of less than 0.0004. This indicates that new or lesser-known institutions face major obstacles in entering a collaborative network that is already dominated by big players. Institutions with a high degree centrality, such as the University of Malaya, also recorded an eigenvector centrality of 0.8909, indicating that they not only have many direct connections but also have a great influence on the network as a whole. The correlation between degree centrality and eigenvector centrality reached 0.8915, confirming that direct connectivity often strengthens strategic positions in the network.

6.2. The paradox of university quantity with the quality of university networks

Indonesia has 92 universities, the highest number of institutions in ASEAN, but it is inferior in network influence compared to Singapore, which has only three universities. The University of Indonesia's (UI) *eigenvector centrality* of 0.8931, an indicator that measures the quality of connections with influential actors, is lower than that of the National University of Singapore (NUS) (0.7938), even though Singapore has 30 times fewer universities. This phenomenon reinforces the theory of preferential attachment (Barabási & Albert, 1999), where institutions with a global reputation (such as NUS) attract more collaboration owing to the cumulative effect of the initial advantage. On the other hand, *the degree centrality* UI (0.1924) is lower than that of NUS (0.2236) indicating that the quantity of institutions does not guarantee connectivity (Borgatti & Everett, 2000, 2006) World-class institutions tend to form elite clusters that make them more likely to cooperate with institutions that have a high ranking or developed countries (Hazelkorn, 2017).

Based on a study, Pratama et al. (2024) found that the rectors of public universities in Indonesia lack work experience or education abroad, which may affect the orientation of institutional collaboration. For example, the *degree centrality of* Universitas Airlangga (0.1854) is lower than that of Nanyang Technological University (0.2021), even though Indonesia has 31 times more universities. This finding is

in line with the theory of human capital (Becker, 2009), which argues that global leadership capacity is a determinant of network integration. Even in the Indonesian context, Pratama et al. (2024) argued that the leadership of rectors of higher education in Indonesia tends to create a pattern of academic inbreeding. The Rector is usually an alumnus of the university. Rectors with strong international networks, such as at NUS, tend to have the potential to build many cross-border collaborations (Hazelkorn, 2015). Of course, the causal relationship between the rector's background and collaboration patterns still requires further research (Pratama et al., 2024)

Indonesia has problems with its higher education internationalization program. Rosser (2019) stated that Indonesia has great ambitions in the internationalization of education but ends up being mediocre. Indonesia's internationalization policy, which has existed since 2006, does not focus on improving the academic ecosystem but on the quantity of outputs (Rosser, 2019), so it is not surprising that many universities in Indonesia have academic integrity problems. Indonesian lecturers are trapped by predatory journals because of the demands of research administration, fulfillment of promotion requirements, or the desire to obtain publication incentives (Ampuni et al., 2020; Macháček & Srholec, 2022). Not to mention that administrative jobs for lecturers in Indonesia are very high with low wages (Afridah et al., 2025; Astuty et al., 2025), so that the time and capacity to carry out academic activities are limited. Indonesian scholars who are alumni of foreign universities are trapped in bureaucratic and institutional complexity (Sutrisno, 2019), and instead of improving the higher education ecosystem, existing policies actually increase the burden on higher education in a globally competitive Indonesia (Rosser, 2023).

The low average *centrality closeness* of Indonesia (0.2825) compared to Singapore (0.4108) indicates the inefficiency of access to the global network (Freeman, 2002) Burt's (2021*)* Burt (2021) theory suggests collaboration strategies with *brokers* such as NUS or the University of Malaya, for example, through a global competency-based lecturer exchange program to reduce dependence on *preferential attachment*. Brunei Darusalam, despite having only 3 universities, recorded an average *closeness centrality* of 0.3398, higher than Indonesia. This success was triggered by a hyper-specialization strategy, in which Universiti Brunei Darussalam (UBD) focused on partnering with high-ranking universities.

6.3. Gap of university collaboration

The universe of global research collaboration in ASEAN presents a paradox: a handful of universities shine as bright stars while thousands of others grapple in the dark. Data from 7,150 institutions show that *degree centrality*—a measure of direct connections in a network—is only 0.000937 on average, with a standard deviation of 0.0034, revealing extreme inequality. Half of institutions (50%) are trapped below 0.0001, while the elite 1%, such as the University of Malaya (0.2368), enjoy *a degree centrality* 250 times above average. This phenomenon is not just a coincidence; it reflects *scale-free networks* (Barabási & Albert, 1999) where The University of Malaya attracts the majority of connections as a hub, while small institutions are marginalized. Attraction reflects Merton (2016) Matthew Effect. Merton explained that strong institutions are growing, while weak institutions are falling behind.

At the regional level, inequality has become more pronounced. Malaysia, with an average *degree centrality* of 0.3217, and Indonesia (0.2844), showed solid collaboration capacity. Countries such as Myanmar and Laos—with an average below 0.0004—are only spectators on the global research stage. On the other hand, Singapore shot up with 0.4108, beating even global partners such as France's CNRS (0.4044). Singapore's success is inseparable from its status as a global city (Olds & Yeung, 2004), which combines aggressive education policies, advanced infrastructure, and openness to cross-disciplinary collaboration. This gap also emphasizes the concept of *Core-Peripheral* (Wallerstein, 2011) Singapore and Malaysia as the *core* dominant, while Laos and Myanmar are trapped as *peripheries*.

Compared to global giants, ASEAN universities are still limping. The University of Indonesia (0.1923), for example, is far behind the University of Queensland (0.4064). This gap is not just about resources but refers to the concept of academic dependency (Altbach, 1998). This explains why the Global South often relies on Global North partners for publication, funding, and legitimacy. World System Theory can be used to clarify the root of the problem: the global knowledge hierarchy dominated by developed countries creates a Frankish structural inequality. While Singapore may be an exception, most ASEAN

countries, such as the Philippines and Cambodia, still struggle to penetrate the *inner circle* of elite research collaboration.

The fact that 75% of ASEAN universities have *degree centrality* below 0.0004—and only 10% reach above 0.010—indicates a rigid hierarchy. Institutions such as the University of Malaya dominate structural holes (Burt, 1992) and are strategically positioned as intergroup linkages, allowing them access to resources and wider collaboration. However, small universities in Laos and Myanmar lack social capital (Bourdieu & Wacquant, 2013), such as reputation, alumni networks, or access to international journals, to compete. ASEAN research collaboration is not only uneven but also tends to strengthen the status quo: the elite are getting stronger, while the weak are becoming more alienated.

Addressing this gap requires multidimensional intervention. First, referring to the opinion Granovetter (1973), who said that it is necessary to strengthen fellow *weak ties*. This can be achieved through cross-university collaboration—for example, between the University of Yangon (Myanmar) and the National University of Laos. This option can create alternative paths that reduce reliance on large hubs. Second, Tawil and Locatelli (2015) stated that capacity building programs must focus on peripheral countries, such as Cambodia. This action aims to strengthen the research infrastructure and training of researchers. Third, South-South Cooperation (Liverani et al., 2023), such as ASEAN's collaboration with Africa or Latin America, can be a strategy to reduce dependence on Global North partners.

The university collaboration gap in ASEAN reflects structured inequality. Unequal *data degree centrality*, variation between countries, and elite dominance are not random phenomena but the result of complex historical, economic, and political dynamics. Social theories—from *world systems* to *cultural capital*—provide a lens through which to understand the root causes of problems and devise solutions. The challenge now is to transform the collaborative network from pyramid elitism (Hughes, 2021) to an inclusive higher education network (Ortiz Colón et al., 2018) that allows every university, large or small, to have the opportunity to contribute to the advancement of global knowledge.

6.4. Openess to collaboration

One of the measures used in this study is the closeness centrality. This concept was developed by Freeman (1978) to measure the efficiency of an actor in reaching all actors in the network. If the value is higher or closer to the absolute value of one, then the actor has the reach of all actors in the network through the shortest rut. Based on this research, the University of Malaya recorded the highest closeness centrality (0.4313), indicating its strategic position as a core institution that is able to facilitate the flow of knowledge across institutions. This fact explains the concept of core-periphery introduced by Borgatti and Everett (2000) University of Malaya as a core actor that plays the role of the dominant link. However, small universities are marginalized (periphery) because of limited connections.

Malaysia has an average closeness centrality of 0.3217, outperforming other ASEAN countries, including Singapore (0.2945) and Indonesia (0.2844). Malaysia's high closeness value can be a result of its education policy in international research collaboration, thus strengthening its position as a *core* in the core-periphery model (Kumar & Jan, 2013; Mydin et al., 2021). The Malaysian government, through the Malaysia Education Blueprint 2015–2025 firmly targets an increase in international publications and strategic partnerships (Suo, 2023). In contrast to Indonesia, which has 92 institutions, this study shows fragmentation due to resource inequality (Rosser, 2023). Only the University of Indonesia achieved a high centrality closeness (0.4104). This phenomenon reflects the Matthew effect (Merton, 1968), in which already dominant institutions increasingly gain access to collaboration, thereby widening the gap with small universities. Marginson (2006) states that universities in developing countries often limit globally reputable collaborations (Marginson, 2022; Marginson & Xu, 2021).

An interesting fact is shown by a small but rich country like Brunei Darusalam. The country has only three institutions but an average closeness of 0.3398. This challenges the common assumption that the number of institutions is directly proportional to the network's influence. The universities in the country show preferential attachment. The number of institutions or countries is small but can be related to global actors with a wide network. For example, Universiti Brunei Darussalam (UBD) is actively partnering with Oxford University and the National University of Singapore (NUS) to make it easier to reach other networks.

Non-ASEAN institutions, such as the University of Queensland (0.4064) and the French CNRS (0.4044), show that connectivity is not limited to geography. The connection between institutions of developed countries and universities of ASEAN countries can be seen from two perspectives: as a form of inclusivity of relations or as efforts to maintain excellence. According to world system theory (Wallerstein, 2011)(Wallerstein, 2011), actors from developed countries (Global North) maintain dominance in global knowledge networks, including ASEAN countries. This dominance is supported by superior financial resources and research infrastructure, allowing them to act as structural holes to connect regional clusters (Burt, 2021) However, ASEAN universities such as the University of Indonesia and the University of Malaya remain competitive as *semi-periphery* because they have higher closeness in the ASEAN context.

The positive correlation between the closeness centrality and degree centrality of the University of Malaya, which has a closeness of 0.4313 and a centrality degree of 0.0341, confirms Freeman's statement that actors with many high degrees tend to have efficient access to the entire network. Conversely, universities with low degree centrality are trapped in *the periphery*, reinforcing structural inequality. This pattern reproduces inequality through a preferential attachment mechanism that allows selective actors to collaborate, such as Darusalam universities.

6.5. Collaboration bridging

The University of Malaya has *the highest betweenness centrality* in ASEAN (0.0332) which shows its role as a structural broker that bridges institutional clusters (Burt, 2021) This value shows the ability of the University of Malaya to control the flow of knowledge between networks which in the context of this research is related to cross-border research collaboration. The second position is occupied by Universiti Sains Malaysia (0.0270), which acts as a liaison between local universities and East Asian partners (e.g. China and Japan), while Indonesia's Gunadarma University (0.0259) connects regional institutions with non-ASEAN actors (Borgatti & Everett, 2000). In contrast, the National University of Singapore (0.0246) has a lower liaison role despite its extensive direct connections, as its collaborations tend to be centered on top global university partners, such as the Ivy League, rather than bridging regional gaps (Hazelkorn, 2017).

Based on the existing betweenness data, the researchers found the potential for fragmentation in existing networks. Relying on core-periphery (Borgatti & Everett, 2000, 2006) supported by data from the University of Malaya and Universiti Sains Malaysia as *the core* dominates the flow of resources, while institutions such as universities in Laos/Cambodia tend to be close to zero, they are trapped in the *periphery* due to the lack of strategic connections. The analysis shows that universities in the Philippines, such as Cebu Technological University and Cagayan State University, recorded a betweenness centrality of 0.0235, confirming their contribution as regional linkers. In contrast, Indonesian universities show limited betweenness, indicating that their role is more limited in the global context.

The correlation between betweenness and degree centrality was 0.9273, indicating that universities with a liaison role also tend to have many direct connections. For example, the University of Malaya has the highest degree centrality (0.0341) and the highest betweenness centrality (0.0332), indicating its dominant position in the network. These data emphasize the importance of direct connections in building influence as a link.

6.6. The university's strategic position in the collaboration network

Universiti Kebangsaan Malaysia leads the way with an eigenvector centrality of 0.9888 and a degree centrality of 0.2111, which shows a significant influence on collaboration networks. Universiti Sains Malaysia followed with an eigenvector value of 0.9416 and a degree centrality of 0.2090, demonstrating a strong direct correlation. The University of Indonesia, as the main representative of Indonesia, recorded an eigenvector centrality of 0.8930 and degree centrality of 0.1923, strengthening its position as a leading institution in ASEAN. The University of Malaya, despite having an eigenvector centrality of 0.8909, has the highest degree centrality at 0.2368, indicating a more intense direct connection than other universities in the region.

Indonesia stands out with several prominent universities on the list, including Gadjah Mada University (eigenvector 0.7812), Airlangga University (0.8805), and Bandung Institute of Technology (0.7354). Malaysia also has many excellent universities, such as Universiti Putra Malaysia (eigenvector 0.8902) and Universiti Teknologi Malaysia (0.8583). Universities in Singapore, such as the National University of Singapore, recorded an eigenvector centrality of 0.7937, indicating extensive connections in the region. Thailand, despite having 42 institutions, only places Chulalongkorn University as a leading university, with an eigenvector centrality of 0.5993.

Although ASEAN universities have great influence, some global partners, such as the University of Queensland, recorded a closeness centrality of 0.4064, while France's CNRS had 0.4044. Universities outside the region scored high, despite having limited involvement in the number of institutions. For example, France has only six institutions but remains a strategically collaborative partner in this network. These data confirm that the strategic role depends not only on the number of institutions but also on the quality of connections.

The correlation between the eigenvector and degree centrality showed a strong positive pattern, with a correlation of 0.8915. For example, Universiti Kebangsaan Malaysia has 32.5% higher eigenvector centrality than Universitas Brawijaya, and Universiti Malaya has 47.6% higher degree centrality than the same university. This correlation indicates that institutions with many direct connections tend to have a significant influence on the network, reinforcing their position as a collaboration hub.

7. Conclusions

Based on this study, the researcher concluded that there is a dominance of leading universities that highlight the phenomenon of homophily 'rich-get-richer.' Highly ranked institutions, such as the National University of Singapore (NUS) and University of Malaya, have extensive networks. 10% of universities can reach 75.69% of connections. This indicates that only a few universities can reach the others. The abundance of resources, high ranking, and global reputation are among the factors that make this happen. In contrast to universities with low rankings, they tend to reach fewer networks. Even universities from countries with fewer resources, such as Laos and Cambodia, tend to be isolated from the network. The inequality of resources and university rankings determines the homophily of collaboration among universities.

The number of universities is not always directly proportional to their ability to capitalize on networks. For example, Indonesia has the most universities in ASEAN but still has fewer networks than Malaysia and Singapore. Even when compared to three universities from Singapore, the strength of the network of universities in Indonesia is still far behind. Malaysian universities tend to have even network strength, so they reach almost the entire network. However, Vietnamese universities prefer internal collaboration within the country, which hinders their potential involvement in global collaboration. The hierarchical network structure is further compounded by the fact that only 10% of the universities in the region have a degree centrality of more than 0.010, while the remaining 75% have a very low degree centrality.

Universities in Malaysia and Singapore stand out for their openness and collaboration efficiency, as reflected by their high closeness centrality. Institutions such as Universiti Malaya, Universiti Sains Malaysia, and Gunadarma University in Indonesia also play an important role as 'connectors' in the network, linking various parties to strengthen the regional research ecosystem. Universiti Kebangsaan Malaysia, Universiti Sains Malaysia, and the University of Indonesia were the most influential institutions based on eigenvector measures and degree centrality. To address these inequalities, a more inclusive strategy is needed to empower marginalized universities, such as those in Cambodia and Laos, and to encourage universities in Vietnam to be more active in international collaboration.

Author contibutions

a. Bayu Indra Pratama: Conceptualization, Data Curation, Formal Analysis, Funding acquisition, investigation, Methodology, Project administration, Resource, Supervision, Validation, Visualization, Writing – Original Draft and Review & Editing.

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Data availibility statement

Data supporting the findings of this study are available from the corresponding author upon reasonable requests. Access to the data may be provided for research purposes, subject to compliance with the institutional and ethical guidelines.

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