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Analysing Malaysian Technology Sector during COVID-19: A Minimum Spanning Tree Approach

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ABSTRACT

This paper examines the structural changes of the companies listed in the technology sector in Bursa Malaysia during the COVID-19 pandemic. The closing price of each stock is used as the basis for calculating the cross-correlation between the companies' returns. Minimum spanning trees are employed to analyse the relationships and visualize the correlation changes for each period. Additionally, degree centrality is utilized to analyse the network's structure further. This study covers the period from 2020 to 2021 and involves 39 companies within the technology sector. The findings reveal significant fluctuations in the companies' correlations each year. Moreover, the most influential companies vary according to the period, demonstrating position changes. The fact that Inari Amertron (INAR), Revenue Group (REVE), and My EG Services (MYEG) consistently become leading players in different years shows how strong and influential they are in the technology sector. This suggests that these companies have the ability to shape market trends and possibly even control the direction of the industry. The results provide valuable insights for investors and policymakers, aiding in visualizing company relationships and facilitating strategic portfolio optimization.

1. Introduction

The COVID-19 pandemic has had a profound impact on the technology sector, particularly in the context of the financial market. One significant effect has been the acceleration of digital transformation across industries, as mentioned in [1]. As businesses faced lockdowns and social distancing measures, they rapidly adopted technology solutions to enable remote work [2] and online operations [3]. The COVID 19 pandemic had an impact, on the technology sector leading to an increased demand for cloud computing, cybersecurity measures, collaboration tools and e-

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commerce platforms. Organizations had to adapt to the prioritize productivity. This surge in transformation brought both opportunities and challenges for technology companies. They had to innovate and cater to evolving business needs while also addressing concerns about scalability, security and seamless integration of solutions. Additionally, remote work tools and communication technologies experienced a rise in demand due to the pandemic, as in the previous study [4]. With restrictions on gatherings and the shift towards work models companies heavily relied on video conferencing software, project management tools and virtual collaboration platforms. Platforms like Zoom, Microsoft Teams and Slack played a role in facilitating communication among employees by enabling meetings, project coordination and maintaining team cohesion. This increased demand also emphasized the importance of data privacy and security as organizations faced challenges, in protecting information within a remote work environment.

In addition, the closure of educational institutions necessitated the rapid transition to online education and e-learning platforms mentioned in [5-8]. As traditional classroom settings became inaccessible, educational systems faced the challenge of ensuring uninterrupted learning experiences for students [9,10]. This required the implementation of technology infrastructure, virtual learning management systems, and interactive educational content. Consequently, educators and students heavily relied on video conferencing tools, online collaboration platforms, and e-learning software to facilitate remote teaching and learning. The technology sector played a crucial role in developing and providing the necessary tools and support systems, thus enabling the continuation of education on a large scale.

The impact of the technology sector on the financial market during the COVID-19 pandemic was characterized by notable positive and negative consequences [11,12]. The surge in remote work, digital transformation, and e-commerce led to a significant increase in demand for the technology sector's products and services. This heightened demand translated into robust growth and market capitalization for companies within the technology sector. However, the technology sector also encountered challenges in meeting the escalated demand due to disruptions in the global supply chain. Concurrently, the financial market experienced elevated levels of volatility and instability in response to the pandemic, as discussed by [13,14]. Uncertainty in the market was exacerbated because of the effects these shifts had on the valuation and stock prices of technology businesses. In the technology industry as a whole, the effects of market volatility were felt differently across various sub-industries. Certain segments, such as video conferencing platforms, remote work tools, and e-commerce enterprises, experienced unprecedented development and outperformed other sectors during this period. Despite the sector's resilience in driving digital transformation and acting as a catalyst for change, it was not immune to the disruptions caused by the pandemic in the broader financial market. The stock prices of technology companies were influenced by the volatile market conditions, which further emphasized the interplay between the technology sector and the financial market during the COVID-19 pandemic.

Despite extensive research exploring the impact of the COVID-19 pandemic on the financial market, as discussed in [15-17] and the technology sector globally mentioned in [18,19], there remains a significant gap in the literature regarding the interrelationships and network dynamics among technology sector companies listed in Bursa Malaysia during this critical period. Therefore, the objective of this study is to address this gap by providing a comprehensive overview of the condition of technology sector companies listed in Bursa Malaysia. Specifically, we aim to examine the relationships between these companies and analyse the changes in these relationships during the crucial period spanning from 2019 to 2021, influenced by the COVID-19 pandemic. To achieve this, we employ network analysis techniques, constructing a network representation using the minimum spanning tree (MST) algorithm, as previously studied in [20]. By doing so, we seek to visualize and uncover the unique patterns and structural changes that emerged within the technology sector companies, offering novel insights into their dynamics during this unprecedented time in the Malaysian context.

The paper has the following structure: Section 2 discusses the data, Section 3 describes the methodologies, Section 4 discuss the result and Section 6 concludes the study.

2. Data

This paper applies 43 companies in technology sector as listed on Bursa Malaysia. Owing to the absence of data caused by both missing and unavailable data sources, the study was constrained to a sample of only 39 companies, as indicated in Table 1. The closing price of each stock is extracted from the financial database, Eikon Datastream. The period chosen for this paper is the most crucial part of the pandemic, which runs from 2019 to 2021. This study compares the network year by year to see how it has changed.

Table 1
List of companies in technology sector according to Bursa Malaysia

No	Ric	Company Name	No	Ric	Company Name
1	ARBB	ARB	21	JHMC	JHM Consolidated
2	AWAN	Awanbiru Technology	22	KESM	Kesm Industries
3	CNSH	Censof Holdings	23	KYAC	Key Asic
4	CUSC	Cuscapi	24	MITE	MI Technovation
5	DATA	Dataprep Holdings	25	MMST	MMS Ventures
6	DIGS	Digistar	26	MNGA	Mesiniaga
7	DNEX	Dagang Nexchange	27	MPIM	Malaysian Pacific Industries
8	DOVT	D&O Green Technologies	28	MYEG	My EG Services
9	DSON	Datasonic Group	29	NVTE	Notion Vtec
10	EDSB	Edaran	30	OMES	Omesti
11	ELSR	Elsoft Research	31	PMAS	Pentamaster Corporation
12	EXFM	Excel Force Music	32	REVE	Revenue Group
13	FRKN	Frontken Corporation	33	THET	Theta Edge
14	GHLS	GHL Systems	34	TRIV	Trive Property Group
15	GNIC	Globetronics Technology	35	TURY	Turiya
16	HEIT	Heitech Padu	36	UNSM	Unisem (M)
17	HONG	Hong Seng Consolidated	37	VSTE	Vstecs
18	INAR	Inari Amertron	38	VTRX	Vitrox Corporation
19	INDU	Industronics	39	WLOW	Willowglen Music
20	JCYI	JCY International			

3. Methodology

This subsection elaborates the procedure to build the minimum spanning tree and the computation of betweenness centrality. All computational and analytical processes are conducted within the Rstudio environment.

3.1 Minimum Spanning Tree

The procedures to construct the financial network using minimum spanning tree is based on seminal works of Mantegna [21]. To begin, the logarithmic return is calculated based on the adjusted closing price of each stock., $k_i(t)$ as in Eq. (1).

$$k_i(t) = ln\frac{c_i(t)}{c_i(t-1)} \quad (1)$$

where $c_i(t)$ is the price of stock *i* at time t.

In the second step, the logarithmic return is converted into the Pearson correlation coefficient so that the interconnectivity of the stocks can be evaluated. This transformation can be seen in the Eq. (2). The findings will lead to the formation of 39×39 correlation matrix.

$$p_{ij} = \frac{\langle m_i m_j \rangle - \langle m_i \rangle \langle m_j \rangle}{\sqrt{(\langle m_i^2 \rangle - \langle m_i \rangle^2)\left(\langle m_j^2 \rangle - \langle m_j \rangle^2\right)}} \quad (2)$$

where *i* and *j* are stocks and $\langle m_i \rangle$ is the average of return of stock *i*.

The third step is to convert the correlation matrix into a Euclidean distance matrix using Eq. (3).

$$d_{ij} = \sqrt{1 - 2p_{ij}} \quad (3)$$

where p_{ij} is a distance between stock *i* and stock *j*.

The construction of the correlation network is based on Kruskal's algorithm, utilizing a minimum spanning tree approach. The network incorporates nodes representing stocks and edges depicting correlations between two stocks. The distances are arranged in ascending order from smallest to largest values. Subsequently, the shortest distance between two stocks is chosen as the initial connection to build the network. Links are incrementally added while ensuring that all stocks are included without forming any loops. As stated by Kruskal, the resulting correlation network should consist of N-1 links with the minimum total weight.

3.2 Betweenness Centrality

The betweenness centrality metric was employed to assess the importance of individual stocks within the network. A mediator was introduced to facilitate the analysis of information flow within the network, thereby enabling the determination of the stock's prominence from the previous study [22]. Eq. (4) presents the calculation for the betweenness centrality $C_B(i)$:

$$C_B(i) = \sum_{j<k} \frac{r_{jk}(i)}{r_{jk}} \quad (4)$$

where $r_{jk}(i)$ represented the sum of the shortest distance from *j* to *k* that passed through *i*, while r_{jk} was the sum of shortest distance from *j* to *k*, where $j \neq i$and $k \neq i$.

4. Result and Discussion

4.1 Descriptive Analysis

The descriptive analysis of closing prices for the 39 companies for three years is presented in Table 2. The mean closing price ranges from 0.057 to 21.945, with a standard deviation varying from 0.031 to 14.440. The minimum and maximum closing prices range from 0.014 to 51.000, respectively. The skewness values range from -0.467 to 2.008, indicating varying degrees of asymmetry in the distribution of closing prices. The kurtosis values range from 1.381 to 7.886, indicating different levels of peakiness or flatness in the distributions. These descriptive statistics provide a comprehensive overview of the closing price characteristics for each company, facilitating further analysis and interpretation.

There are highlight points that can be obtain from the analysis. MPIM stands out with a remarkably higher mean closing price of 21.945 compared to other companies, indicating a potentially lucrative investment opportunity. Additionally, MPIM exhibits a high standard deviation of 14.440, suggesting greater volatility in its closing prices. On the lower end, DIGS has the lowest minimum closing price of 0.014, making it an attractive option for investors seeking lower entry points. Conversely, MPIM demonstrates the highest maximum closing price of 51.000, indicating the possibility of substantial growth. In terms of distribution, INAR displays the highest positive skewness value of 2.008, implying an upward price movement trend. Furthermore, INDU stands out with the highest kurtosis value of 7.886, suggesting a highly peaked distribution and potential price volatility. These outstanding points provide valuable insights into the characteristics and investment prospects within each category of the closing prices for the examined companies.

Table 2
Descriptive analysis of the closing prices for each company over a three-year period

No	Company	Mean	SD	Min	Max	Skewness	Kurtosis
1	ARBB	0.278	0.068	0.094	0.535	0.099	3.567
2	AWAN	0.557	0.264	0.098	1.240	0.620	2.290
3	CNSH	0.210	0.117	0.040	0.515	0.946	2.510
4	CUSC	0.181	0.060	0.050	0.320	0.114	2.104
5	DATA	0.519	0.590	0.070	3.790	1.900	7.011
6	DIGS	0.057	0.018	0.014	0.168	0.708	4.630
7	DNEX	0.396	0.248	0.080	0.980	0.899	2.084
8	DOVT	2.110	1.951	0.450	6.030	0.888	2.041
9	DSON	0.488	0.147	0.202	0.835	-0.078	2.659
10	EDSB	0.510	0.194	0.160	1.170	1.205	3.781
11	ELSR	0.810	0.157	0.390	1.220	0.030	2.249
12	EXFM	0.508	0.085	0.265	0.735	0.089	3.142
13	FRKN	1.981	1.049	0.423	4.060	0.322	1.775
14	GHLS	1.389	0.384	0.733	2.120	0.191	1.483
15	GNIC	2.194	0.432	1.350	3.280	0.512	2.393
16	HEIT	1.139	0.276	0.425	1.780	-0.081	2.659
17	HONG	0.648	0.898	0.022	3.840	1.946	5.894
18	INAR	2.352	0.867	1.040	4.250	0.524	1.821
19	INDU	0.152	0.095	0.030	0.665	2.008	7.886
20	JCYI	0.337	0.161	0.135	0.795	1.121	3.487
21	JHMC	1.543	0.427	0.525	2.590	0.004	2.309
22	KESM	9.909	2.490	5.130	17.500	0.786	3.057
23	KYAC	0.095	0.031	0.020	0.210	0.312	3.654
24	MITE	2.799	1.208	0.973	5.200	0.029	1.501
25	MMST	0.816	0.182	0.335	1.370	0.537	2.930
26	MNGA	1.331	0.240	0.550	1.980	-0.467	3.008
27	MPIM	21.945	14.440	8.400	51.000	0.683	1.778
28	MYEG	0.768	0.175	0.397	1.120	0.173	1.954
29	NVTE	0.644	0.260	0.283	1.920	0.995	4.367
30	OMES	0.437	0.068	0.317	0.692	0.433	2.917
31	PMAS	3.837	1.530	1.031	6.730	-0.083	1.656
32	REVE	1.307	0.424	0.672	2.380	0.465	2.183
33	THET	0.569	0.265	0.180	2.190	1.582	7.068
34	TRIV	0.166	0.084	0.030	0.452	0.322	2.286
35	TURY	0.183	0.080	0.060	0.420	0.467	2.050

36	UNSM	2.273	1.323	0.780	4.590	0.505	1.486
37	VSTE	0.886	0.355	0.367	1.470	0.186	1.380
38	VTRX	5.882	2.355	2.880	11.080	0.478	1.770
39	WLOW	0.452	0.045	0.315	0.615	0.722	4.075

4.2 Minimum Spanning Tree

Figures 1 to 3 depict the minimum spanning tree (MST) of the technology sector in Bursa Malaysia during the COVID-19 pandemic, specifically for the years 2019, 2020, and 2021, respectively. In these figures, the nodes within the MST represent individual stocks, while the edges or links connecting the nodes signify the distances calculated based on the correlation between each pair of stocks. The structural composition of the minimum spanning tree (MST) varies across different years, reflecting distinct connections and patterns during each period. Specifically, in the year 2020, companies exhibited a tendency to cluster and establish connections with other companies, indicating a higher level of interdependence within the network compared to 2019. However, in 2021, the companies displayed a dispersed arrangement throughout the network, lacking significant clustering.

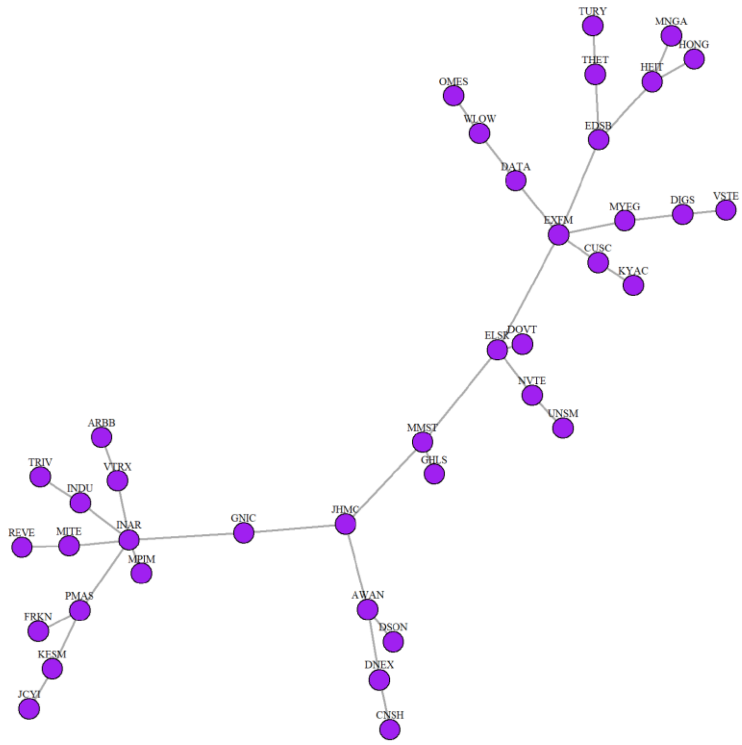

Fig. 1. Minimum spanning tree for the year of 2019

Examining the dominant players within the MST for each year provides further insights. In 2019, INAR, EXFM, and EDSB emerged as the dominant companies in the market, showcasing their substantial influence within the network. In contrast, for the year 2020, the network was dominated by REVE, MMST, and FRKN, highlighting their prominent positions and potential impact on the overall market dynamics. Lastly, in 2021, INAR, REVE, and MYEG were identified as the dominant entities driving market dynamics. These findings underscore the dynamic nature of the MST and the changing roles of companies within the technology sector of Bursa Malaysia. The observed shifts in clustering and dominant players across the years provide valuable insights into the evolving market dynamics and interconnections among the companies during the COVID-19 pandemic.

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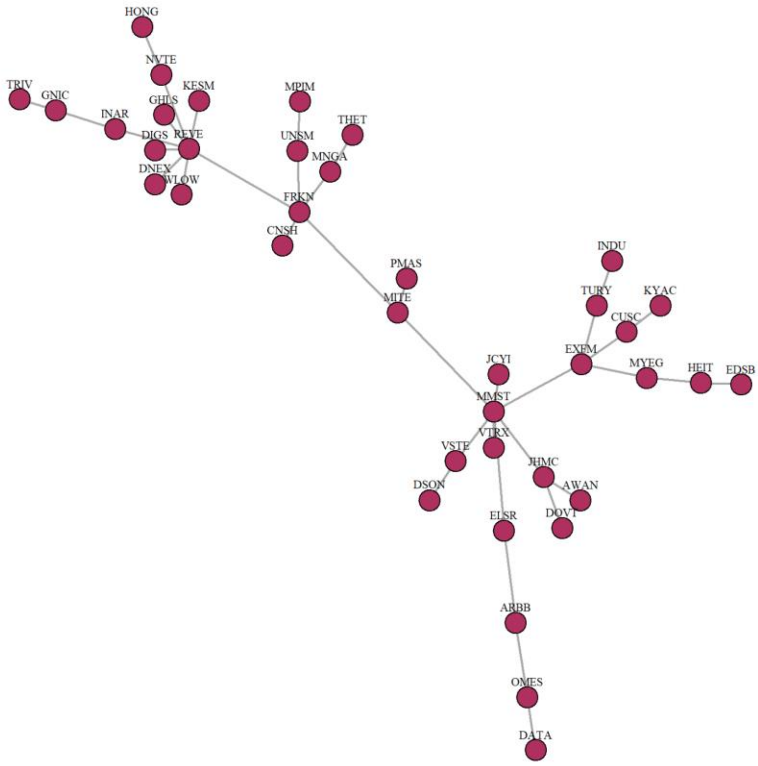

Fig. 2. Minimum spanning tree for the year of 2020

This network structure can be further understood by analysing the descriptive statistics of the companies' stock prices over a three-year duration. Notably, companies sharing edges could exhibit similar trends in their stock price behaviour, potentially leading to clusters of interconnected entities with analogous descriptive characteristics. If we consider the network constructed for year of 2019, we can see that AWAN, DSON, DNEX and CNSH are connected within the network. Examining their descriptive statistics, we notice that these companies exhibit relatively similar means and standard deviation. This alignment in mean and standard deviation values hints at correlated stock price trends. The network connection between these companies might indicate that they tend to move together, forming a cluster within the network due to their similar descriptive characteristics.

Surprisingly, despite MPIM having a relatively high mean closing price of 21.945 and a substantial standard deviation of 14.440, the company doesn't exhibit an extensive network connectivity and isn't positioned centrally within the network. This observation raises intriguing insights into the intricate relationships between stock behaviour and network architecture. However, it's worth noting that MPIM shares a correlation with INAR. This correlation suggests that while MPIM might not be extensively connected within the network, it could still have the potential to influence the stock price of INAR due to their correlated behaviour. This intricate interplay underscores the nuanced nature of network dynamics, where influence and connectivity are not solely determined by descriptive statistics, but can also be influenced by specific correlations and contextual factors.

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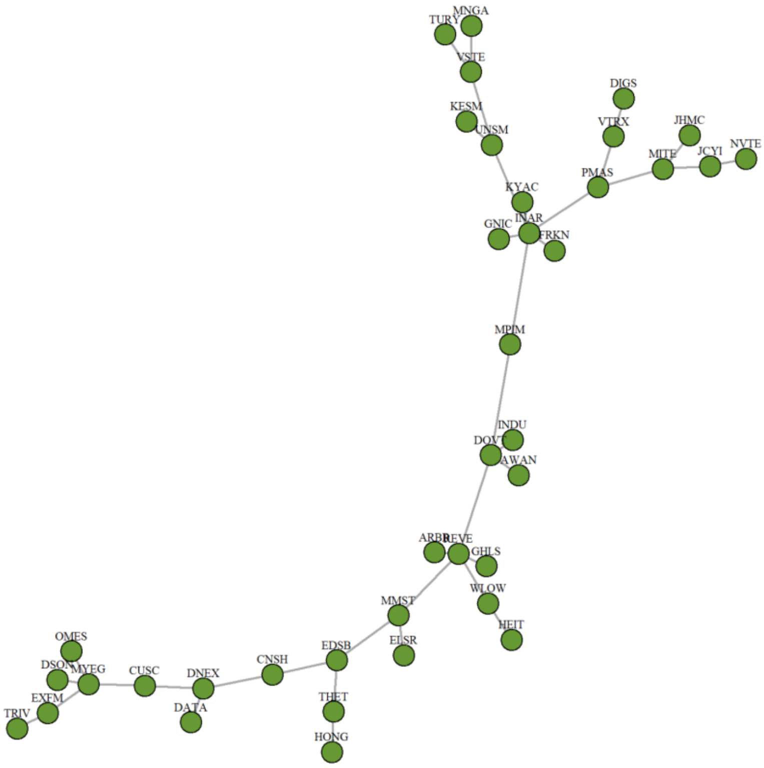

Fig. 3. Minimum spanning tree for the year of 2021

4.3 Betweenness Centrality

The betweenness centrality results for the technology sector in Bursa Malaysia reveal important insights into the influential companies within the network as depicted in Table 3. In 2019, JHMC emerged as the most central company, exhibiting a high betweenness centrality score of 0.582. Following closely behind were ELSR and EXFM, with betweenness centrality scores of 0.579 and 0.576, respectively. These findings indicate that these companies held crucial positions in facilitating the flow of information within the network during that year.

Moving to the year 2020, MMST took the lead with a significantly higher betweenness centrality score of 0.703, highlighting its increased influence and pivotal role in information flow. FRKN and MITE also demonstrated noteworthy betweenness centrality scores of 0.590 and 0.536, respectively. These results suggest that during 2020, MMST, FRKN, and MITE occupied central positions in the network, serving as key intermediaries for information dissemination among the companies.

Shifting our focus to 2021, the betweenness centrality analysis reveals that REVE claimed the top position with a betweenness centrality score of 0.599. Following closely behind were INAR and DOVT, with scores of 0.596 and 0.563, respectively. These findings indicate that REVE, INAR, and DOVT played vital roles in facilitating information flow within the network during the analysed period. The fluctuation of centrality scores, from year to year can be attributed to factors. These factors include changes in market dynamics shifts in industry trends and alterations in the landscape. Companies with centrality play a crucial role as connectors between other companies, in the network influencing the flow of information and influence. This dynamic interplay reflects the ever-changing nature of business relationships and the adaptive strategies that companies employ to navigate evolving market conditions. It is noteworthy that the companies with high betweenness centrality scores in 2021 differed from those in the previous years, suggesting a dynamic shift in the influence and significance of different companies over time. This shift underscores the importance of staying attuned to these changes to make informed business decisions and strategic partnerships.

Overall, the betweenness centrality analysis provides valuable insights into the prominence and influence of companies within the technology sector in Bursa Malaysia. The identified central companies in each year highlight their crucial positions in facilitating information flow and their potential impact on the network's dynamics and overall market behaviour.

Table 3
The top 10 value of betweenness centrality according to the year

No	Company	2019	No	Company	2020	No	Company	2021
1	JHMC	0.582	1	MMST	0.703	1	REVE	0.599
2	ELSR	0.579	2	FRKN	0.590	2	INAR	0.596
3	EXFM	0.576	3	MITE	0.536	3	DOVT	0.563
4	MMST	0.539	4	REVE	0.457	4	MPIM	0.501
5	INAR	0.488	5	EXFM	0.331	5	MMST	0.479
6	GNIC	0.444	6	ELSR	0.149	6	EDSB	0.448
7	EDSB	0.243	7	JHMC	0.104	7	CNSH	0.341
8	AWAN	0.152	8	ARBB	0.102	8	DNEX	0.317
9	PMAS	0.152	9	INAR	0.102	9	PMAS	0.284
10	HEIT	0.104	10	MYEG	0.102	10	CUSC	0.235

5. Conclusion

In conclusion, the analysis of the minimum spanning tree (MST) and betweenness centrality results offers compelling insights into the dynamics and influential players within the technology sector of Bursa Malaysia during the COVID-19 pandemic for the years 2019, 2020, and 2021.The MST analysis revealed distinct changes in the network's structural composition, reflecting shifting connections and patterns over time. The clustering effect observed in 2020, where companies tended to cluster together and establish stronger connections, suggests a higher level of interdependence and potential collaboration within the network. Conversely, the dispersed arrangement of companies in 2021 indicates a reduced clustering effect and potentially more fragmented network structure. Furthermore, the identification of dominant players within each year's MST reinforces the significance of certain companies in driving market dynamics. The consistent emergence of INAR, REVE, and MYEG as dominant entities in different years highlights their resilience and influence within the technology sector. These findings indicate that these companies possess the capabilities to shape market trends and potentially dictate the sector's trajectory. The betweenness centrality analysis provides further conviction by pinpointing companies with crucial positions in facilitating information flow within the network. The changing companies with high betweenness centrality score each year underscore the dynamic nature of influence and the ever-shifting landscape within the technology sector. Overall, these findings convincingly demonstrate the evolving nature of the technology sector in Bursa Malaysia during the COVID-19 pandemic. The observed patterns, clustering dynamics, and changing dominant players highlight the intricate web of interactions and interdependencies among companies. Stakeholders such as investors, policymakers, and market participants can leverage these insights to make informed decisions and navigate the changing market landscape effectively.

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