

Exploring the Complex Adaptive Behaviour of Asian Countries in Innovation amidst Global Gender Gap: Implications to the Sustainable Development Goals

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With the ambiguous link between innovation and gender, this paper explored Asian countries' complex adaptive behaviour in innovation amidst the global gender gap. Data sets from the Global Innovation Index 2019 the Global Gender Gap Report 2020 to represent innovation productivity and gender equality accordingly. Applying descriptive-analytic research, approaches like data mining, factor analysis, clustering, and complex adaptive systems were used. Factor analysis results revealed features of gender parity in innovation. Based on synergy count, there are more prevalent dissimilarities in innovation and gender equality characteristics among Asian. Highly innovative countries lead in synergy counts, while less innovative countries lag in it. However, moderately innovative countries have irregular results. Based on the clustering, Asian countries innovation appeared to behave in a non-linear upward trend amidst the global gender gap. Their complex adaptive behaviours show random, albeit cycles with downward and upward shifts that vary in amplitude. These characteristics indicated that countries can still innovate as long as they adapt within their contexts. With multi-dimensionality of innovation, a holistic approach to productivity is necessary. Embracing gender equality will be a good source of innovation and sustainable development follows.

Keywords: Complex Adaptive System, Gender Equality, Innovation, Sustainable Development

Introduction

The concept of innovation and gender has recently gained a growing interest among researchers. Innovation, as a producer of new things and driver of economic boom and sustainability (Gaylo, 2018), is said to rarely adopt gender perspective either in innovation processes, studies, or policies (European Research Area and Innovation Committee, 2019). The same observations were also cited by other authors that most studies on innovation have less emphasis on the actors of innovation (Agnete Alsos, Ljunggren, & Hytti, 2013), the profile of the participants of the innovation process, and the places where these innovations happened (Fagerberg, Mowery, & Nelson, 2005). Further, Sarah Kaplan, a Professor from the University of Toronto, suggests that there will be progress when gender diversity is treated as an innovation problem. These realities may place innovation as a gender-biased phenomenon.

The United Nations, in 2015, emphasized the holistic approach in achieving sustainable development which places gender equality as one of the priorities. With that, the 2030 Agenda for Sustainable Development envisions the world with fair distribution and access to innovation. It is not just for the world's lowliest and least developed countries, but also for women in every country. Also, the International Development Innovation Alliance (IDIA), a group involving the Rockefeller Foundation with other development organizations, conveyed that gender equality and innovation must advance together to attain sustainable development (Trivedi & Sakha, 2019).

With the vague link of women and innovation, some studies have already started documenting gender differences in innovation. Nahlinder (2010) showed that men and women have different methods when they innovate where women are sometimes hampered with low self-confidence and family-related issues. A study on the impact of gender diversity on innovation performance by Turner (2009) in research and development suggested a gender balance on teams to increase innovation outputs because it was found that women are over-represented in some domains and are not contributory to the innovation performance. Roscoe (2016) added that there is increasing evidence that bigger gender equality leads to better innovation in the business sector. Thus, the interaction of innovation and gender among countries need to be looked into to uncover emerging features.

In this paper, the interaction of Asian countries' innovation performance concerning their gender gap was studied. Asia has driven a boom of innovation in recent years and is considered the next global innovation hotspot (Yu, 2019). Since innovation and gender equality are complex and dynamic processes (International Development Innovation Alliance, 2018), their interaction can be explained using a non-linear approach. Nowadays, a complex adaptive system is one of the non-linear approaches used by researchers.

A complex adaptive system (CAS) is composed of agents that evolve and adapt over time (Gaylo, Tantoy & Añar, 2019). CAS concentrates upon interactions, on relations between the

agents and their effects upon the whole, making their synergy an important aspect of the complex system (Lucas, 2006). Thus, the CAS approach was used to explore the system considering how agents' interaction, in terms of countries' innovation performance and gender equality, generates patterns or behaviour. It may result in an understanding on how some of those behaviours emerge as dominant over others and how other behaviours may be eradicated or lessened (Human Systems Dynamic Institute, 2016).

Framework of the Study

The paper considers Asian countries' behavior in innovation concerning to the global gender gap as non-linear and complex. With this, the study is anchored on the complex adaptive system approach. Complex adaptive system is a group of agents who interact in independent ways to produce system-wide patterns, such that those patterns that emerge influence the behaviour of the agents (Dooley, 1997). The agents, in the context of this study, are the 36 Asian countries' innovation performance and gender equality indices. Complex adaptive behaviours in innovation with respect to global gender gap among Asian countries will be uncovered.

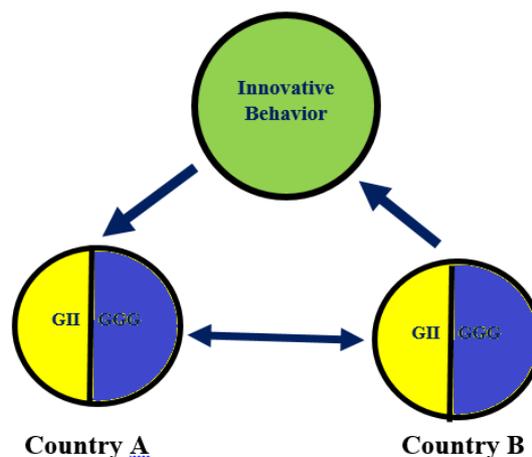


Figure 1. Schematic Diagram of Complex Adaptive Behaviors in Innovation

Using countries as agents in figure 1, they interact with one another in terms of the global Innovation Index (GII) and the Global Gender Gap (GGG). This interaction results in clustering of countries according to innovation performance and gender disparity. Ideally, countries with similar attributes are expected to cluster. However, due to the dynamic interactions of countries, it will lead to a different grouping or emergent behavior.

Methodology

The study is descriptive-analytical. Data from the Global Innovation Index (GII) 2019 and Global Gender Gap (GGG) Report 2020 were used in the study. Global Innovation Index 2019 provides details on the innovation performance of countries worldwide with eighty indicators including politics, education, and business (Cornell University, INSEAD, & WIPO, 2019). Further, Global Gender Gap Report 2020 provides a scale on the progress of countries towards gender parity on the following dimensions: educational attainment, economic participation and opportunity, political empowerment, and health and survival (World Economic Forum, 2020). The progress towards gender parity implies the percentage of gender equality in a country.

Factor analysis was used to determine the features described by the agents or variables. These features were used as inputs to calculate the synergies. Resulting features are mathematical representations or patterns of the variables' combined effects. Also, synergies imply feature connections among other countries. Positive synergies, blue in colour, imply feature similarities. Negative synergies, red in colour, imply dissimilarities in the feature. In calculating the synergy, an application from Northwestern Mindanao State College of Science and Technology (NMSCST) was utilized. A histogram was used to cluster countries based on their synergy counts. With the aid of the scatterplots, the complex adaptive behaviour of Asian countries in innovation became clear amidst the gender gap.

Results and Discussions

Table 1 shows the result of the factor analysis performed to extract the feature from the original data sets. Tabular values indicate that there are two features extracted. The two features reflect Gender Parity in Innovation. The first feature accounted for 70% variance and has a positive weight (load) for both innovation performance and gender gap. Hence, the first feature space has high gender parity in innovation and considers gender equality as a useful mechanism to increase innovation performance and vice versa. On the other hand, the second feature has only accounted for 30% variance, and there are an opposing sign of weight between innovation, and gender equality. Thus, the second feature space has low gender parity in innovation and it shows instances of producing innovation amidst low gender equality.

Table 1. Principal Component Factor Analysis Results

Variable	Factor 1	Factor 2
Innovation Performance	0.837	0.548
Gender Equality	0.837	-0.548
Variance	0.700	0.300

Using these features, the synergies were computed for pairs of countries using an application from the Northwestern Mindanao State College of Science and Technology (NMSCST). The results of the synergies taken in the analysis are shown in figure 1.

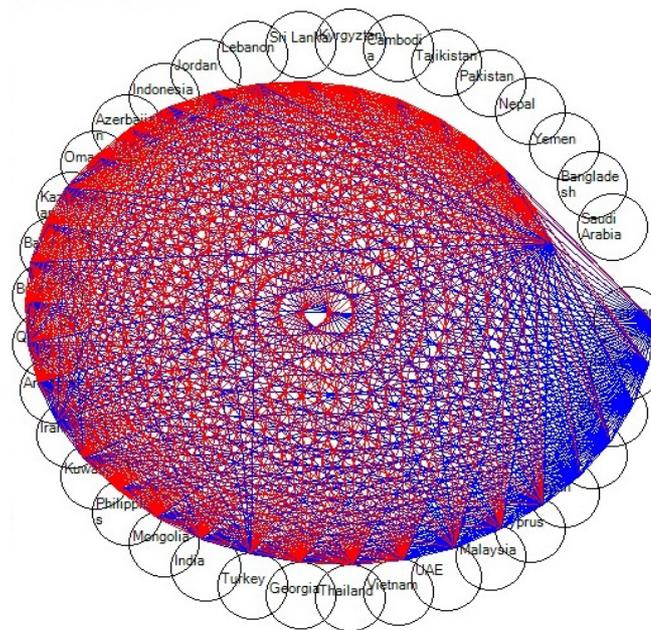


Figure 1. Synergy Results of Paired Countries

A causal scrutiny of figure 1 shows that there are more prevalent dissimilarities (red) among Asian countries in terms of innovation productivity and gender equality than their similarities (blue). The synergy pairs reflect the diverse characteristics of countries in generating innovations and handling gender equality. The divergence signifies the complexity in understanding the interaction of the said variables from one Asian country to another. To have a clearer picture, the result of synergies is shown in Table 2.

Based on table 2, China, Japan, and South Korea, which are considered highly innovative countries, had the highest number synergy. This result is connected to Yu's (2019) assertion that these three countries are powerhouses in innovation. Victoria Kwakwa, World Bank's Vice President for East and Pacific Region, stated that countries like South Korea serve as an anchor of collaboration in the region for innovation (World Bank, 2020). She noted that Korea's global leadership in innovation would be gradually significant for supporting developing countries, especially in Asia.

Table 2. Summary table of Synergy

Country	Synergy	GII	GGG	Country	Synergy	GII	GGG
Armenia	10	33.98	0.684	Kyrgyzstan	4	28.38	0.689
Azerbaijan	4	30.21	0.687	Lebanon	12	28.54	0.599
Bahrain	12	31.10	0.629	Malaysia	22	42.68	0.677
Bangladesh	2	23.31	0.726	Mongolia	10	36.29	0.706
Brunie Darussalam	7	32.35	0.686	Nepal	2	24.85	0.680
Cambodia	3	26.59	0.694	Oman	19	30.98	0.602
China	32	54.82	0.676	Pakistan	5	25.36	0.626
Cyprus	24	48.34	0.692	Philippines	4	36.18	0.781
Georgia	10	36.98	0.708	Qatar	18	33.86	0.629
India	13	36.58	0.668	Saudi Arabia	6	32.93	0.599
Indonesia	4	29.72	0.700	Singapore	31	58.37	0.724
Iran	26	34.43	0.584	Sri Lanka	12	28.45	0.599
Israel	31	57.43	0.718	Tajikistan	7	26.43	0.626
Japan	33	54.68	0.652	Thailand	12	38.63	0.708
Jordan	11	29.61	0.623	Turkey	22	36.95	0.635
Kazakhstan	4	31.03	0.710	UAE	24	42.17	0.655
South Korea	33	56.55	0.672	Vietnam	12	38.84	0.700
Kuwait	13	34.55	0.650	Yemen	6	14.49	0.494

The less innovative countries like Nepal, Bangladesh, and Cambodia (Gaylo, 2018) are at the bottom of the synergy count. Looking at the gender equality progress of countries with high synergy and low synergy, they do not differ greatly. However, moderately innovative countries differ in behavior as to gender equality and synergy count. For example, the case of two moderately innovative countries, the Philippines and Iran vary. The Philippines, with high gender equality among Asian countries, has low synergy count. On the other hand, Iran, has low gender equality compared to the rest of Asian countries, but its synergy result is high. This irregular behavior has to be uncovered.

To discover the complex adaptive behavior of Asian countries in innovation amidst the global gender gap, the countries were clustered based on their synergy count. A histogram was utilized to easily group the countries. With the aid of the histogram in figure 2, two clusters were derived. Cluster 1 is considered the group with a low synergy count, ranging from 13 and below, where 24 countries belong. Cluster 2 has a high synergy count, ranging from 18 and above, with 12 countries in the group. To fully explain the different clusters, scatterplots were presented to supplement the discussion. The scatterplot of the features in countries belonging to cluster 1 is shown in figure 3 and figure 4 for cluster 2.

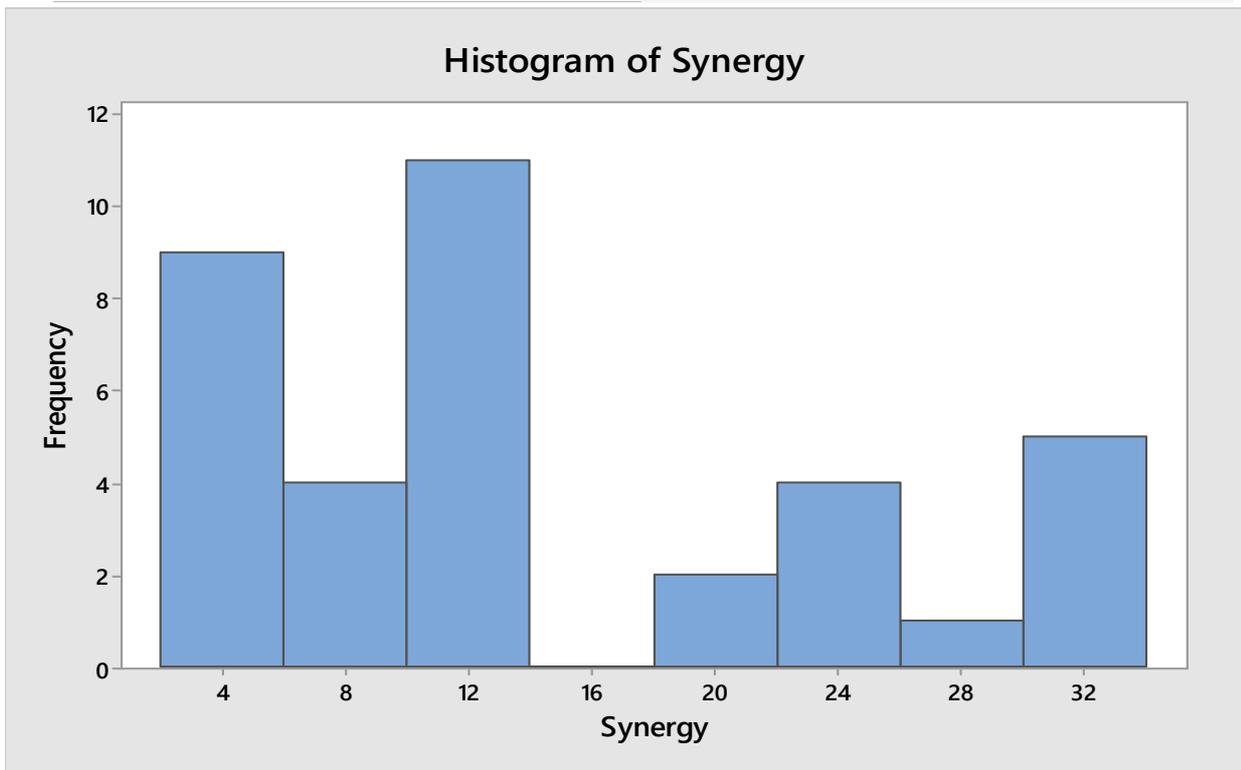


Figure 2. Histogram of Countries in terms of Synergy

Figure 3 presents the scatterplot of cluster 1. Armenia, Azerbaijan, Bahrain, Bangladesh, Brunei, Cambodia, Georgia, India, Indonesia, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Lebanon, Mongolia, Nepal, Pakistan, Philippines, Saudi, Sri Lanka, Tajikistan, Thailand, Vietnam, and Yemen belong to a high Asian countries with low synergy count, ranging from 2-13. Based on the figure, the cluster's complex adaptive behaviour in innovation concerning to gender equality appeared to be non-linear with a general upward trend. It has a random albeit cyclical nature with downward and slight upward shifts.

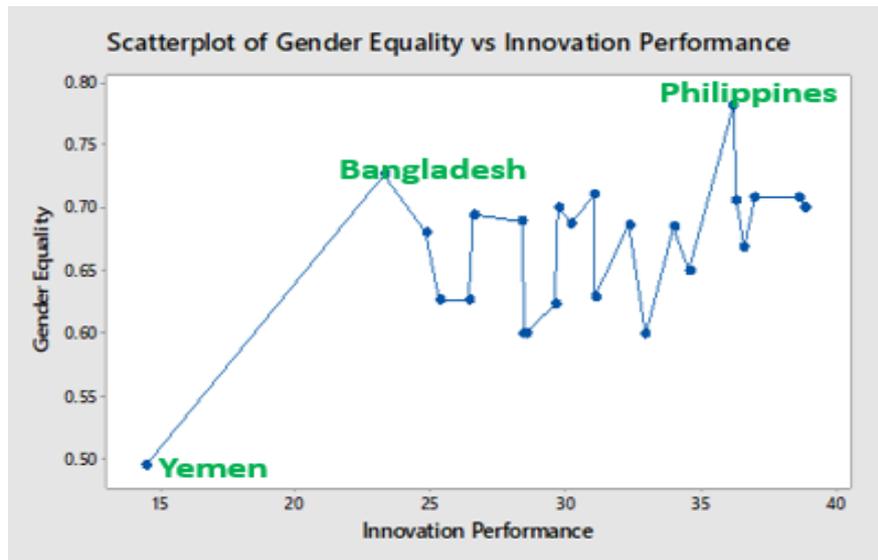


Figure 3. Cluster 1 Countries with Synergy Count Ranging from 2 – 13

The behavior of the second cluster of countries is shown in figure 4. China, Cyprus, Iran, Israel, Japan, Korea, Malaysia, Oman, Qatar, Singapore, Turkey, and UAE belong to the group of countries with high synergy count. In this cluster, the complex adaptive behavior of innovation with respect to gender equality appeared to also have non-linear and upward trend. Similarly, there are random albeit cycles with upward drifts. The amplitude (distance) varies in length with sudden jumps.

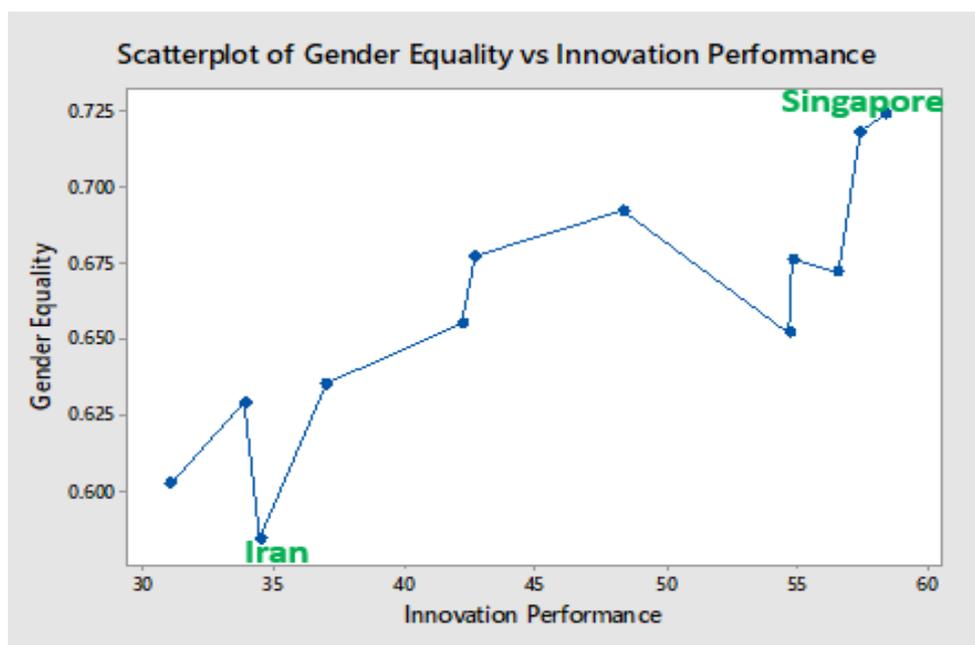


Figure 4. Cluster 2 Countries with Synergy Count Ranging from 18 – 33

Based on the two scatterplots, it is consistent that the complex adaptive behavior of Asian countries in innovation amidst the global gender gap appeared to have an upward trend and non-linear in nature. Their behaviors have random albeit cycles with downward and upward shifts that vary in amplitude. These results show that Asian countries strive, even with ups and downs, to be productive in their innovation amidst the gender gap. With many challenges in their economy, politics, education, business, culture, and other concerns, their innovation and gender equality are still considered to be crucial in their progress.

The complexity of the interaction between innovation and gender equality is documented in some countries like Yemen, Singapore, Philippines, Iran and Bangladesh. Yemen, considered as the poorest country in the Middle East, with the lowest gender equality progress in the dataset, is shown to be the least innovative one. On the other hand, Singapore, a high-income economy, has the third-highest gender equality score in the data set and is the most innovative Asian country. Singapore's performance in innovation is in line with Ritter-Hayasi's et al. (2019) claim that developed countries with balance between two genders is often found to have a positive effect in their innovation. Also, Hess (2019) cited that a research by Accenture found that innovation is six times higher at organizations with the equal workplace cultures compared to those organizations with the least equal ones. In this context, gender equality matters in innovation productivity, but the discrepancy in income and economy has to be considered.

The Philippines and Bangladesh rank first and second in the data set in terms of gender equality; however, they perform in moderate and less in innovation accordingly. Bangladesh ranked second lowest in the dataset in terms of innovation, even with the second-highest gender equality. In this scenario, high gender equality does not necessarily translate to higher innovation performance. Iran is another case, where it has the second lowest gender equality progress in the dataset but it is highly connected to many Asian countries, with average innovation productivity.

Implications to Sustainable Development Goals

United Nations suggests that gender equality is not only a fundamental human right, but a necessary foundation for a peaceful, prosperous and sustainable world. Despite progress in the advancement of gender equality, there are still reports of violence against women more so in this global pandemic. Placing women as collaborators of men in the innovation arena will provide an avenue for them to grow. Nanterme, former chairman and chief executive officer of Accenture, believes that the future workforce is an equal one where companies are the most inclusive and diverse.

As innovation adapts to the global gender gap, the goal of achieving gender equality and empowering women may come as a reality. Acknowledging the complexity and irregularity of the innovation behaviour of Asian countries amidst gender gap, is the key to develop policies

that will bring productivity within the interplay of innovation and gender-related issues. It can be gleaned from the tables and graphs that much has to be done in achieving gender-balance workforce. However, it can start in the innovation system. Little by little, there will be progress, which is rooted on the non-linear upward trend of Asian countries' innovation behaviour with respect to gender gap.

Conclusions and Recommendations

With gender gap in Asian countries, their innovation system showed complex adaptive behaviours. Asian countries' gender parity features in innovation provided two faces, one is high and the other one is low. Even in the lens of both high and low synergy clusters, Asian countries behave in a non-linear upward trend in innovation with respect to gender equality. The patterns of behaviour have random albeit cycles with downward and upward shifts that vary in amplitude.

Even with the complexities and irregularities in the innovation behaviour of Asian countries with respect to gender equality, in general, countries with high synergy counts innovate more when compared to countries with less synergy counts. Highly innovative Asian countries connect more to other Asian countries as compared to the less innovative ones. It is due to the fact that the highly innovative countries have much to share to those which less in innovation, and also with other highly innovative ones. With this, less innovative countries can learn from their practices. More interactions from other countries bring more innovations. If a hub for innovation networks among Asian countries can create more gender balance workforce, the more it will be instrumental in attaining gender equality from the 2030 Sustainable Development Goals.

Despite the presence of gender gap, countries can still innovate as long as they adapt within their contexts. Innovation productivity is a multi-dimensional construct and gender equality is just one of its dimensions. Holistic approach to innovation is the key for more productivity, and may consider gender equality to boost their performance.

With these results, policy makers may develop procedures that considers innovation as a multi-faceted construct, and may be translated in other fields like in education, to provide additional input to the emerging field of innovation in education. If acted accordingly, Asian countries can make better informed decisions and choices for future wise actions. Embracing diversity in gender will be a source of innovation, then sustainable development follows.

Limitations

The study has limitations. First, there are only 36 countries in Asia considered in the paper. The profile of other countries innovation and gender gap were not included due to lack of data.



Secondly, the data under study are limited and are coming from the Global Gender Gap Report 2020 and Global Innovation Index 2019. Lastly, it is delimited to understand the complex adaptive behaviour of Asian countries in innovation despite global gender gap.

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