Sustainable Development Goals Interlinkages for Saudi Arabia

Setting up the Integrated Sustainable Development Network for the Common Country Analysis for KSA

Background Paper, Draft, February 2021, Aljaz Kuncic[1]

1. Background and Introduction

The challenges of sustainable development as captured by the 17 SDGs, 169 targets and 232 indicators, are plentiful and vary depending on the country context. It is clear however that for developing planning geared at reaching the SDGs, the interlinkages between SDGs will be crucial for the achievements of goals, as will learning from successful experience of others, especially in light of the global economic transformation on account of COVID-19 and the drop in oil prices, especially affecting major oil-exporters such as KSA.

The literature on the linkages between specific areas in the Agenda 2030 or specific SDG goals – the SDG developmental network - is gaining momentum both in academia as well as in the sphere of international organizations. Jungcurt (2016) provides a good overview of several pieces on these topics, or specifically for linkages between SDGs, while other examples would be Nilsson et al. (2016a) and Nilsson et al. (2016b), Le Blanc (2015), Zhou and Moinuddin (2017), and Kuncic (2018). On the other hand, the literature on nearest neighbor matching is often found on topics of program evaluation such as Heckman, Ichimura and Todd (1998), Lechner (1999), Dehejia and Wahba (2002), and Smith & Todd (2005), but also and directly linked to the use in this paper, to identify similar countries and identify their positive practices such as in Abu-Ismail et al. (2015).

In line with this literature but going a step further, this paper will build on the interlinkages approach and the nearest neighbor matching approach, and presents a framework of development planning more suitable to todays' circumstances of COVID-19 and oil price shocks, need for resilience, and to the holistic nature of the 2030 Agenda, applying it to the case of KSA and its Vision 2030.

This paper is structured in the following way: section 1 provides the background and the introduction, section 2 describes data and methodology, section 3 summarizes the nearest neighbours available for KSA, section 4 shows and analyzes the SDG Developmental network of KSA, section 5 does the same for an identified nearest neighbour (UAE) and provides some quick comparisons, and section 6 concludes and suggests ways forward for more in depth research.

2. Data and Methodology:

We rely on the data based on Sachs et al. (2020), which was supplemented with intra and extrapolation, and where SDG scores were calculated.[2]

In the **first step**, we have already identified nearest neighbors for KSA 10 years ago (in 2010) in terms of developmental as measured by the SDG Index. Out of the nearest neighbours, we identified the ones who have progressed the most in the last 10 years, and were also the most resilient to external shocks in light

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[2] See Hamilton, A. and Kuncic, A. (2021): Macroeconomic SDG forecasts for KSA, Background paper for KSA CCA

of the COVID-19 crisis. We know these successful nearest neighbours have by and large been implementing good policies in the last 10 years, were resilient to external shocks (and thus did relatively well in the face of COVID-19), and that they were, 10 years ago, the most similar to KSA. Thus, we would be interested to examine interlinkages between developmental variables of those successful and resilient nearest neighbors and learn from that combination. For that, we need to construct a developmental network, so that on its basis we would able to draw lessons from their developmental experiences and resilience to external shocks, and inform policy makers in KSA.

In the **second step**, we set up the needed developmental networks. The Developmental network is based on the interlinkages within the 2030 Agenda, which are examined at the SDG level. It shows the integrated nature of SDGs, as it tells us what the connections between SDG look like, and it implies how a policy intervention in one particular SDG relates to other SDGs. In that vein, the developmental network shows us what the leavers of development are, which are the policy interventions that can improve the entire 2030 Agenda the most, or in other words, it implies where we can get the biggest bang for out buck. In this step, we determine what the nearest neighbour's and KSA's developmental network looked like 2000-2020[3] based on the linkages between SDG scores. We end up with 2 developmental networks, one that led to high human development across the board and has shown high resilience in light of COVID-19 (the nearest successful neighbors) and one for KSA. As per Kuncic (2018), for each of the countries, we aim for "identification of 3 characteristics of such a network:

1) **Mapping the network:** identification of the most central (salient) connections, Goals, Targets and Indicators (the ones that are connected to the rest of the network the most, the levers of development, most suitable for quick and effective interventions)
2) **Determining the nature of interlinkages:** identification of positive and negative connections within the Goals, Targets and Indicators (to be aware as a policy maker where the trade-offs are and where policies can reinforce each other, as well as well different interventions might counter act one another)
3) **Uncovering tightly knit subgroups**: identification of communities within the network – subparts of network which are more connected to each other (as those SDGs, targets and indicators are the ones which should be addressed as a set at once)"

In the **third step**, comparing the two developmental networks allows us to identify the differences between a successful and resilient developmental network and the actual developmental network for KSA, which yields direct suggestions for policy interventions and identifies areas where policy changes are needed, taking into account the fact that we are comparing two similar developmental framework (one for closest successful neighbours 10 years ago and one for KSA), that we are focusing on the interconnected nature of the SDG agenda, with its synergies and trade-offs, resilience to external shocks in light of COVID-19, and that because we operate with the SDG networks, we are in line with the international push to look at planning for human development through the SDG lens and to Build Back Better after the pandemic. The value added of this approach lies in its direct and country specific policy implications – identifying areas needing policy interventions and the types of such interventions, based on similar situations in the recent past that produced good results both in terms of wide ranging developmental achievements as well as in terms of resilience to external shocks. By comparing both developmental networks, we can identify areas in line with the 3 developmental network characteristics above, that are suitable "for a longer-term policy intervention:

[3] Expanding the time period as a long time dimension is crucial here.

1) Transition to relying on other parts of the 2030 Agenda as your economic, social and environmental engine: this could imply a transition from an economy based on heavy industry and pollutant energies, to one based on a knowledge economy and renewables
2) Reforming linkages amongst the parts of the 2030 Agenda: as traditional economic development model includes tradeoffs between economic growth and environment, the move towards a more sustainable development would include the economic, social and environmental dimension to be positively related and to reinforce one another
3) With a long-term vision of development, the synergies between parts of the 2030 Agenda can be targeted strategically, so as to increase the multiplication effect of a policy which touches upon several interconnected issues"[4]

Nearest neighbour matching methodology is used for the identification of nearest neighbours[5], while social network analysis is be used for constructing developmental networks and utilizing its tools for comparison (looking at centralities of SDGs, identifying communities of tightly knit goals, etc.; see De Nooy et al., 2018 for more details on Social Network Analysis).

3. Nearest neighbors

We rely on the data based on Sachs et al. (2020), which was supplemented with intra and extrapolation, and where SDG scores were calculated. With the SDG Index replicated sub-scores, the nearest neighbor algorithm ranks each country in relation to KSA. To calculate the nearest neighbor match, first, the absolute value of each of the 17 SDG scores for the Kingdom of Saudi Arabia (KSA) in 2020 is subtracted from each other countries 17 SDG scores from 2010. The reason for taking the difference between the KSA's 2020 score and other country's 2010 score is to provide a better forecast when interpolating the matched country's annual growth rate on the KSA's forecasted 2030 SDR score. Then by each country, all 17 SDG score differences are summed. Lastly, the sums are sorted in ascending order; the lower the sum, the closer a given country in 2010 matches KSA in 2020, which gives us a good decade of possible dynamics for KSA from now until 2030 on each SDG. Out of all the nearest neighbours, which are the top 15% of best matches (29 countries), the top 5 performers and bottom 5 performers from 2010 to 2020 are shown in Table 1 below.[6]

Table 1: Top 5 and bottom 5 nearest neighbours and their cumulative average yearly SDG growth rates

Top 5 Performers:	**Annual Growth Rate:**	**Nearest Neighbor Ranking**	**SDR 2020 Score:**	**Bottom 5 Performers:**	**Annual Growth Rate:**	**Nearest Neighbor Ranking**	**SDR 2020 Score:**
United Arab Emirates	1.20%	12	70.3	Lebanon	0.05%	10	66.7
Morocco	0.65%	15	71.3	Qatar	0.03%	3	64.7
Maldives	0.55%	11	67.6	Kuwait	0.02%	26	63.1
Croatia	0.51%	8	78.4	Jordan	-0.07%	16	68.1
Kazakhstan	0.44%	20	71.1	Libya[7]	-0.12%	4	59.5

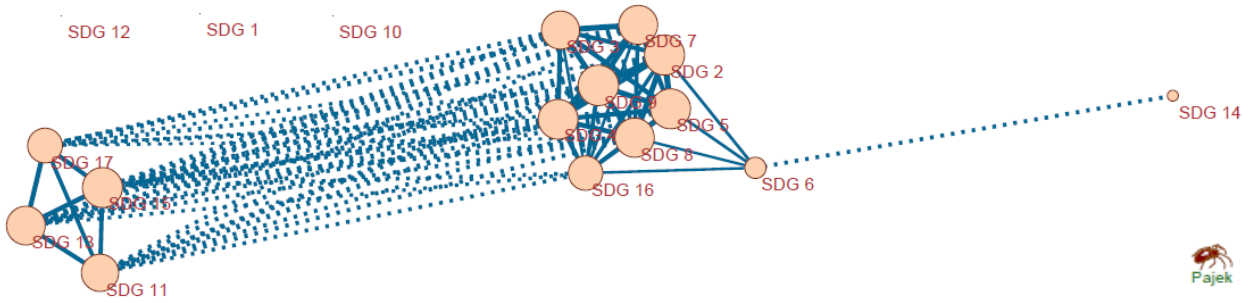
[4] Kuncic (2018)
[5] Hamilton, A. and Kuncic, A. (2021): Macroeconomics SDG forecasts for KSA, Background paper for KSA CCA
[6] Hamilton, A. and Kuncic, A. (2021): Macroeconomic SDG forecasts for KSA, Background paper for KSA CCA
[7] The 2020 Sustainable Development Report did not calculate the score for Libya; however, we used the raw data provided to generate a score.

4. SDG Developmental network of KSA

We use historical data on all the SDG scores available for KSA (SDG 1, SDG 10 and SDG 12 are not available). Table 1 in Appendix A shows the Pearson correlation matrix for KSA, where only the correlations significant at the level of 5 percent are reported, and the period 2000 – 2021 (21 years) is taken into account.

The correlations between SDG score are the linkages, represented as a network where the nodes are the SDGs, and where the size of the node implies the node's importance in the network (centrality measured with weighted degree, with absolute values of connections) and where a larger size implies more and stronger connections, the pattern of the linkage tells us whether the linkage is positive or negative (full line, dotted line), and the thickness of the linkage shows the strength of the correlation. Figure 1 shows the SDG Network for KSA, using the Kamada-Kawai algorithm, which simulates the network as a physical system with the edges behaving like springs, and nodes as charged particles.

Figure 1: SDG Network for KSA, 2000-2021



We can see that the three missing SDGs (1, 10 and 12) are unconnected to the network. In terms of its characteristics, the Density of the network (with no loops allowed), which is the number of lines, expressed as a proportion of the maximum possible number of lines, is 0.515, with a total number of connections at 70. The average number of linkages each SDG has (Average degree) is 8.234. Moreover, we can see that SDG 14 is the most remote from the network, having only one connection to SDG 6, and we can also see that the rest are clustered into two groups, which are predominantly positively connected within, and negatively between.

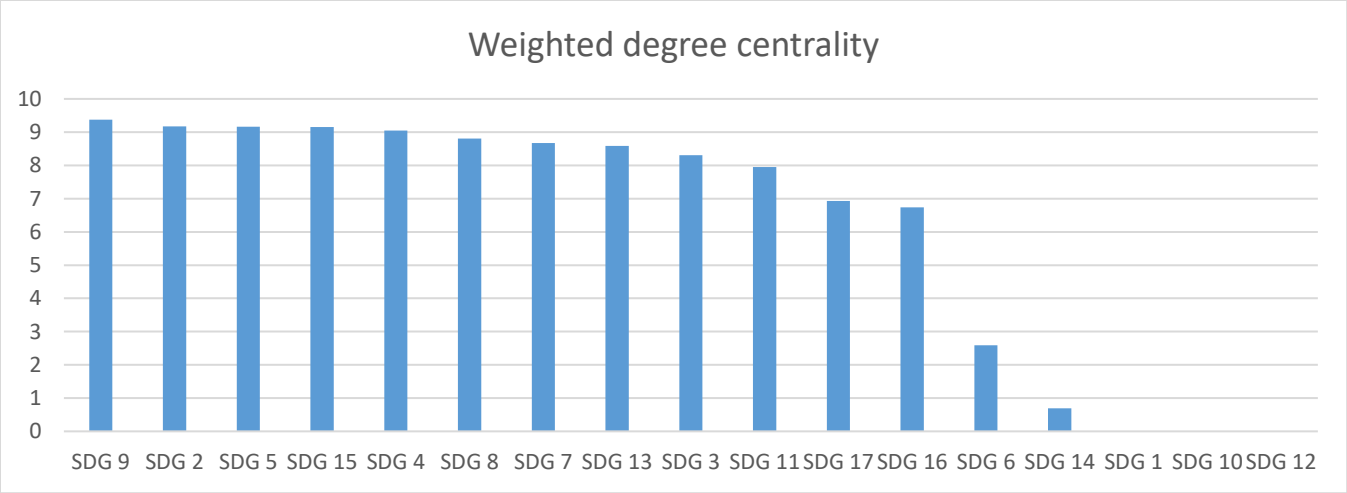
Additionally, the relative importance or centrality of each SDG is reflected by its size, where we can see that SDG 9 is the most central goal, followed by SDG 2, 5, 15, etc, with SDG 14, 6, 16 and 17 being the least central goals in the network. We can also examine the strongest positive and negative connections in our network, which we do in Table 1 below, where the strongest positive links are mainly between SDG 2 and others, SDG 5 and others, and SDG 9 and others, while the strongest negative links are mainly between SDG 15 and others, and SDG 4 and others.

Table 2: Strongest links in the SDG Network for KSA, 2000-2021

TOP 10				BOTTOM 10			
Rank	Line	Value	Line-Id	Rank	Line	Value	Line-Id
1	2-5	0.982	SDG 2-SDG 5	1	9-15	-0.981	SDG 9-SDG 15
2	3-7	0.950	SDG 3-SDG 7	2	2-15	-0.917	SDG 2-SDG 15
3	4-9	0.920	SDG 4-SDG 9	3	7-13	-0.907	SDG 7-SDG 13
4	2-8	0.915	SDG 2-SDG 8	4	5-15	-0.903	SDG 5-SDG 15
5	2-9	0.909	SDG 2-SDG 9	5	4-11	-0.895	SDG 4-SDG 11
6	5-9	0.905	SDG 5-SDG 9	6	4-15	-0.881	SDG 4-SDG 15
7	5-8	0.894	SDG 5-SDG 8	7	8-15	-0.878	SDG 8-SDG 15
8	8-9	0.877	SDG 8-SDG 9	8	4-13	-0.867	SDG 4-SDG 13
9	7-9	0.872	SDG 7-SDG 9	9	7-17	-0.860	SDG 7-SDG 17
10	3-9	0.852	SDG 3-SDG 9	10	9-13	-0.841	SDG 9-SDG 13

To determine what the most powerful levers for policy makers are to target SDGs within their existing developmental network, we examine the centrality of each SDG by using a measure called weighted degree, which is a correlation (value of connection) weighted number of all nodes connected to a particular node (for this calculation, the absolute value of negative correlations is taken). The results are shown in Figure 2 below, which as the network itself, shows that the most central SDGs are SDG 9, 2, 5, 15, 4, trailed very closely by SDGs 8, 7, 13, and 11, while SDGs 17 and 16 are less central, and SDG 6 and SDG 14 the least with quite low values.

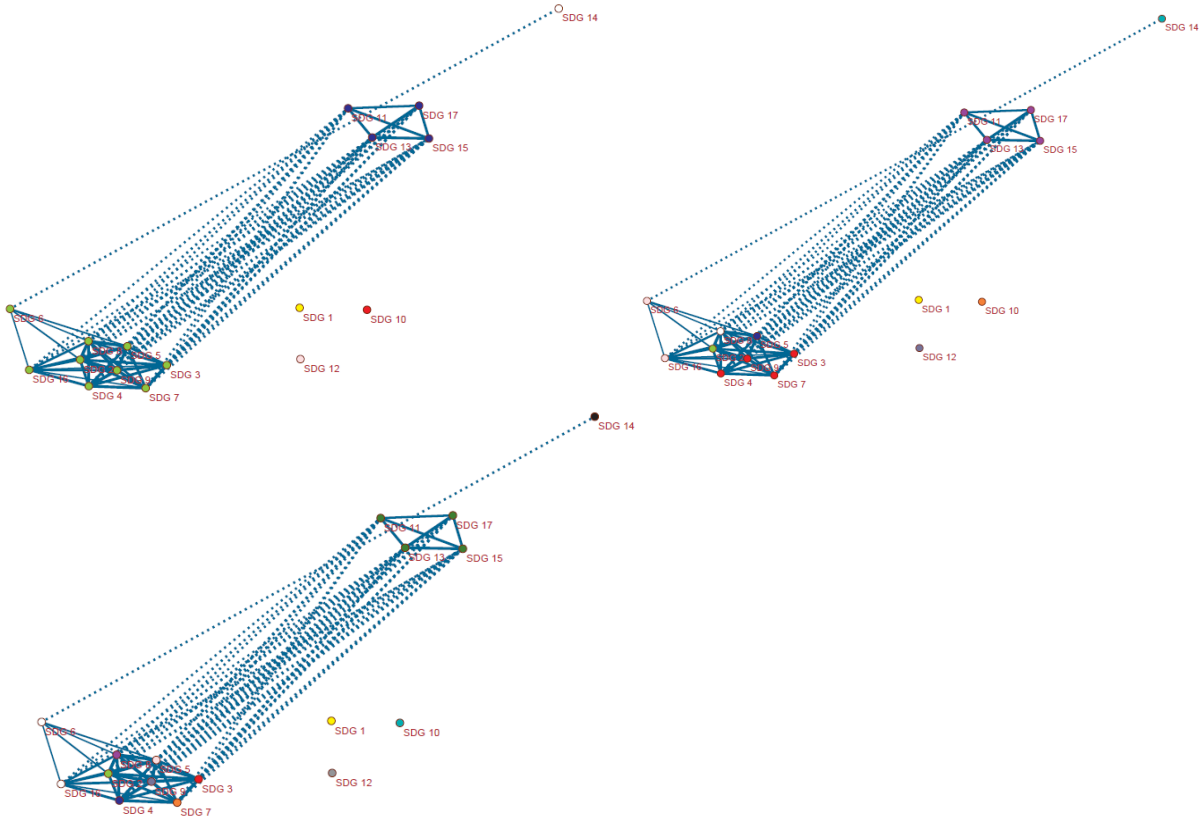
Figure 2: Centrality of SDGs in KSA



We want to explore beyond the mere centralities of SDGs and their groups based on positive and negative interlinkages. We employ community detection algorithm, which allows us to break the network apart into clusters where there are more lines inside each cluster than among clusters (with taking the values of lines into account). For a signed network (with both negative and positive values), we use the the Louvain method with gradually increasing the resolution parameter, with the higher parameter giving us more communities. Figure 3 below shows three such community solutions on the KSA SDG network, with a gradual increase in the resolution form 1.5 to 1.85 to 2. We see that the most interesting case of r=1.85, there are 7 meaningful clusters or nexuses identified by the community approach. The single SDG communities are the ones unconnected to the network, as well as SDG 14, 2, 6 and 5. Then we have the

three more interesting communities, which is the community of SDGs 6 and 16, the community of SDGs 3, 4, 7 and 9, and the community of SDGs 11, 13, 15 and 17.

Figure 3: Detecting communities in the SDG Network for KSA, r=1.5, r=1.85 and r=2



Zooming in on the communities in the SDG Network for KSA at r=1.85 in Figure 4, and shrinking the network to be able to see the communities better in Figure 5, tells us that in the most basic form, with SDG 14 always being on its own, we have two large communities that are predominantly positively connected within and negatively between, as mention before. The strongest negative connection is from the community with SDGs 3, 4, 7, and 9 to the community of SDGs 11, 13, 5 and 17, both of which have very strong internal linkages, as demonstrated by similarly thick loops (connections within).

Figure 4: Zooming in on the communities in the SDG Network for KSA at r=1.85

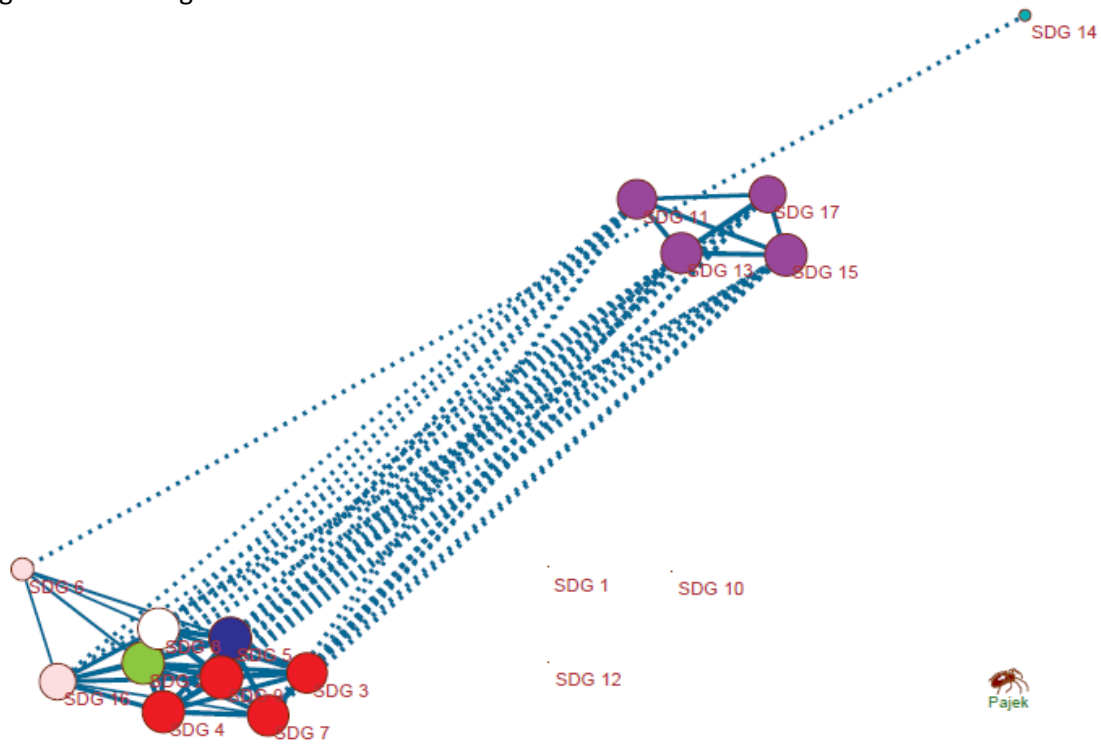
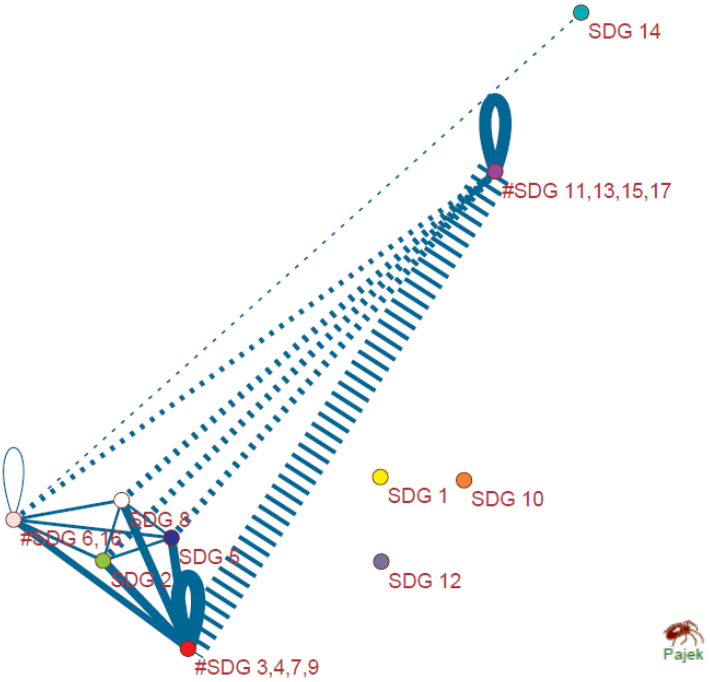


Figure 5: Shrinking of SDG Network with communities for KSA at r=1.85



5. Developmental networks of nearest neighbors and comparison to KSA for policy intervention identification

As an example, we take UAE, who have had an average annual growth 2010-2020 of 1.2%, and are the best performing nearest neighbor to KSA, while also sharing geographical and cultural proximity. We again use historical data on all the SDG scores available for UAE (SDG 1, SDG 10, SDG 11 and SDG 12 are not available). Table 1 in Appendix A shows the Pearson correlation matrix for UAE, where only the correlations significant at the level of 5 percent are reported, and the period 2000 – 2021 (21 years) is taken into account.

Figure 6 shows the SDG developmental network for UAE, already with the size of the nodes proportional to weighted centrality and with communities identified at r=X, Figure 7 shows that same network shrunk, and Figure 8 shows the weighted centralities of all SDGs.

Figure 6: Communities in the SDG Network for UAE at r=1.2

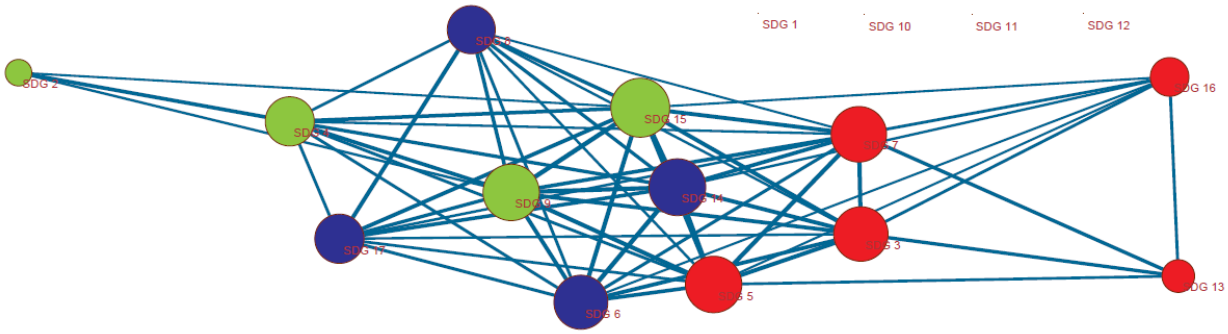


Figure 7: Shrinking of SDG Network with communities for UAE at r=1.2

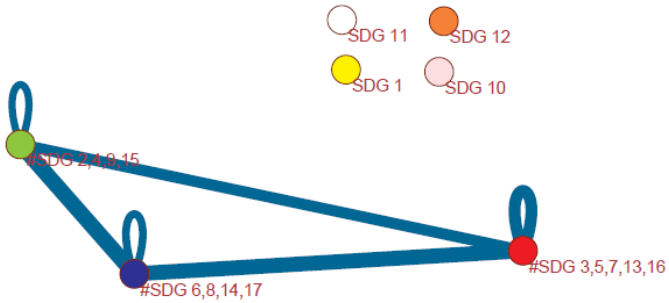
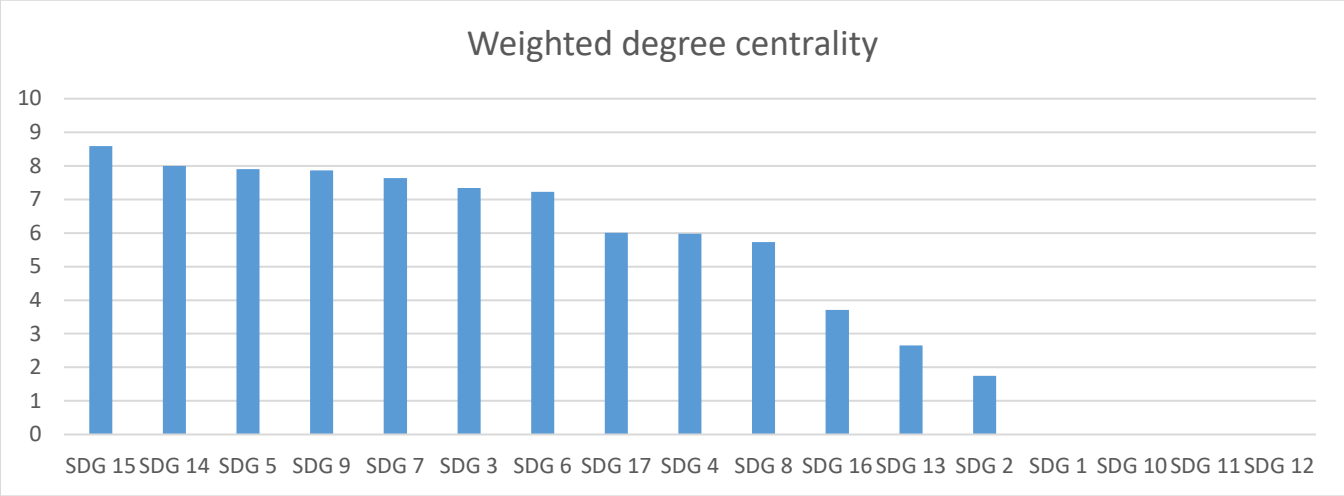


Figure 8: Centrality of SDGs in UAE



There are several important differences between the developmental network of KSA and UAE, as one of its nearest neighbours.

First and perhaps the most glaring one is, that as opposed to KSA, where there is a clear and strong trade-off in the form of negative linkages between more environmental SDGs and the more classic socio-economic SDGs, UAE seemed to have overcome that, even more so, it seems to have a developmental model where environmental, economic and social progress go hand in hand. In fact, in UAE, there are no negative spillovers/interlinkages, which is surprising in itself (and should be additionally checked to make sure it is not a construct of the data alone).

Second, UAE SDG network is much more connected than the one of KSA, which is already visible by comparing the two graphs in terms of distance between SDGs, but also in terms of identifying communities, where UAE has a non-classical grouping of SDGs, which are practically equally distributed in three communities, whereas KSA has several singletons as communities and the network itself is much more divided.

Third, the centralities of SDGs in the two countries are different, with KSA having a more classical SDG 9 in the first place, while UAE has three other SDGs (15, 14, 5), two of them environmental and one on women, before their SDG 9, meaning more important as a lever of development.

6. Conclusion and way forward

This paper presents, summarizes and illustrates the use of network analysis to plot a developmental network for a country using their SDG scores, and shows how nearest neighbour matching can be used to present alternative (but reachable) and better developmental networks.

In going forward, more research should go into the following, which would allow us to arrive at policy recommendations:

- comparing KSA's 2000-2010 developmental network to its 2011-2020 one to see whether things have changed

- constructing a future developmental network for KSA, illustrating what KSA's developmental network would ideally look like, and comparing it to the present/existing developmental network, for identification of needed policy changes[8]
- going more into depth for other nearest neighbors and examining their developmental networks (one by one as well as an amalgamation of them all as a network, treating it as a panel), search for communalities, which can inform the policies needed to improve the developmental network of KSA
- once the future developmental network for KSA is determined, and the lessons from the best developmental networks from KSA's nearest neighbours are identified, case studies should go into the depth of the exact policies that are needed to move from the existing developmental network KSA has, to a better one

[8] See Kuncic (2019)

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Appendix A:

Table 1: Pairwise Pearson correlation coefficients for KSA

	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9	SDG 10	SDG 11	SDG 12	SDG 13	SDG 14	SDG 15	SDG 16	SDG 17
SDG 1																	
SDG 2		1.00															
SDG 3		0.76	1.00														
SDG 4		0.79	0.77	1.00													
SDG 5		0.98	0.80	0.80	1.00												
SDG 6		0.50			0.50	1.00											
SDG 7		0.76	0.95	0.83	0.78		1.00										
SDG 8		0.92	0.68	0.83	0.89	0.45	0.66	1.00									
SDG 9		0.91	0.85	0.92	0.91		0.87	0.88	1.00								
SDG 10																	
SDG 11		-0.68	-0.66	-0.89	-0.69		-0.73	-0.72	-0.77		1.00						
SDG 12																	
SDG 13		-0.74	-0.81	-0.87	-0.73		-0.91	-0.70	-0.84		0.74		1.00				
SDG 14						-0.69								1.00			
SDG 15		-0.92	-0.82	-0.88	-0.90		-0.84	-0.88	-0.98		0.73		0.81		1.00		
SDG 16		0.64	0.46	0.76	0.64	0.45	0.49	0.67	0.71		-0.66		-0.61		-0.66	1.00	
SDG 17		-0.58	-0.74	-0.71	-0.55		-0.86	-0.53	-0.74		0.66		0.82		0.74		1.00

Table 2: Pairwise Pearson correlation coefficients for UAE

	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9	SDG 10	SDG 11	SDG 12	SDG 13	SDG 14	SDG 15	SDG 16	SDG 17
SDG 1	.																
SDG 2		1.00															
SDG 3			1.00														
SDG 4		0.78		1.00													
SDG 5			0.84	0.62	1.00												
SDG 6			0.81	0.62	0.77	1.00											
SDG 7			0.87	0.50	0.90	0.66	1.00										
SDG 8			0.51	0.58	0.53	0.62	0.45	1.00									
SDG 9		0.51	0.80	0.79	0.87	0.82	0.77	0.76	1.00								
SDG 10										.							
SDG 11											1.00						
SDG 12												.					
SDG 13			0.71		0.58		0.73						1.00				
SDG 14			0.83	0.72	0.87	0.94	0.79	0.70	0.90					1.00			
SDG 15		0.45	0.84	0.77	0.88	0.89	0.83	0.75	0.94					0.98	1.00		
SDG 16			0.61		0.45	0.46	0.60						0.62	0.51	0.45	1.00	
SDG 17			0.51	0.61	0.58	0.65	0.53	0.85	0.71					0.76	0.81		1.00