CURRENCY MARKET INTERDEPENDENCE AND COVID-19

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PIER Research Exchange
January 2021

Motivations / Literature Review

- Asset Relationships / Market Structure
  - Currency markets:
    - Jang, Lee, and Chang (2011), Keskin et al. (2011), Wen and Wang (2020)
  - Equity markets:
    - Lee and Nobi (2018), Tumminello et al. (2010), Zhang et al. (2020)
  - Others:
    - Safe haven assets: Hossfeld and MacDonald (2015)
    - Public Debt network: Matesanz and Ortega (2015)
    - Cryptocurrencies: Goodell and Goutte (2020)
- Techniques and methods to measure asset relationships or structure
  - Minimum spanning tree (MST)
    - Mantegna (1999), Kruskal (1956), Ward (1963)
  - Others:
    - Hierarchical clustering: Sokal and Michener (1958), Almeida et al. (2007)
    - Variance decomposition: Diebold and Yilmaz (2014)

Research Questions / Contributions

- How do we measure asset relationships?
  - More than pairwise correlation
  - Non-parametric
- Given measured relationships/structures, what are their financial implications?
  - How do assets co-move during varying market conditions?
  - Are there possibly safe-haven assets?

- This paper
  - Applies Minimum Spanning Tree (MST) and Hierarchical Clustering (HC) techniques to quantify asset relationships and investigate their structures and changes.
  - Reports empirical evidence and financial implications by testing with public daily currency data (2015-2020).
    - Currency market becomes more connected during difficult market conditions
    - Changes of regional currency relationships
    - A handful of assets behave similar to safe-haven assets at times.

Outline

- Motivations/Literature Review
- Data
  - Summary Statistics
  - Time Windows of Study
    - Related to COVID-19 situations
- Methodology
  - Definitions
  - Tree construction techniques: MST, HC
- Results
  - Correlation heatmaps
  - MSTs, HTs
- Implications/Conclusions

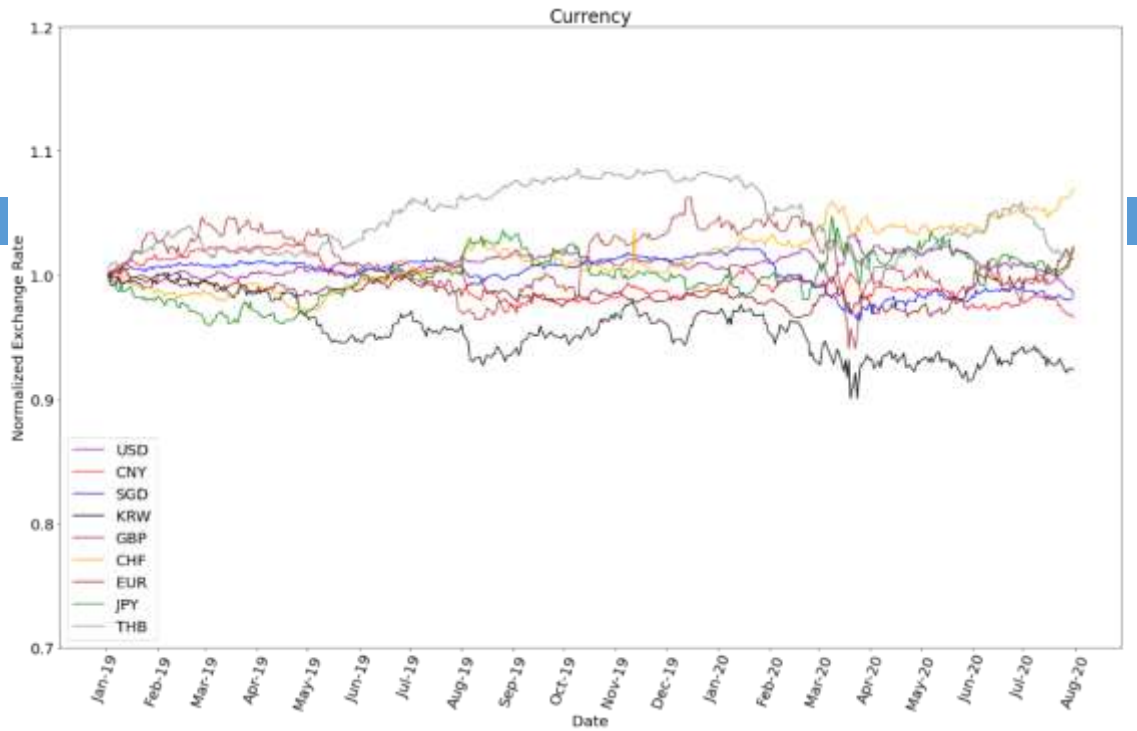
Data

- Public daily exchange rates from imf.org and investing.com
- Period: January 2019 – July 2020
- *SDR* as numeraire
- 30 assets (24 currencies, 5 cryptocurrencies, and gold spot)
  - APAC: Japanese Yen (JPY), Chinese Yuan (CNY), Singapore Dollar (SGD), Thai Baht (THB), Indian Rupee (INR), Indonesian Rupiah (IDR), Philippine Peso (PHP), Vietnamese Dong (VND), Australian Dollar (AUD), New Zealand Dollar (NZD), Korean Won (KRW), and Hong Kong Dollar (HKD)
  - Europe: Euro (EUR), Swiss Franc (CHF), UK Pound (GBP), Swedish Krona (SEK), Turkish Lira (TRY), Norwegian Krone (NOK), and Russian Ruble (RUB)
  - N. America: US Dollar (USD) and Canadian Dollar (CAD)
  - Latin America: Brazilian Real (BRL), Argentine Peso (ARS), and Venezuelan Bolivar (VEF)
  - Cryptocurrencies: Bitcoin (BTC), Litecoin (LTC), Ethereum (ETH), Ripple (XRP), and Monero (XMR)
  - Gold (XAU)

Data and Summary Statistics

Summary Statistics of Daily Returns of Selected Currencies during Jan 2019 to July 2020

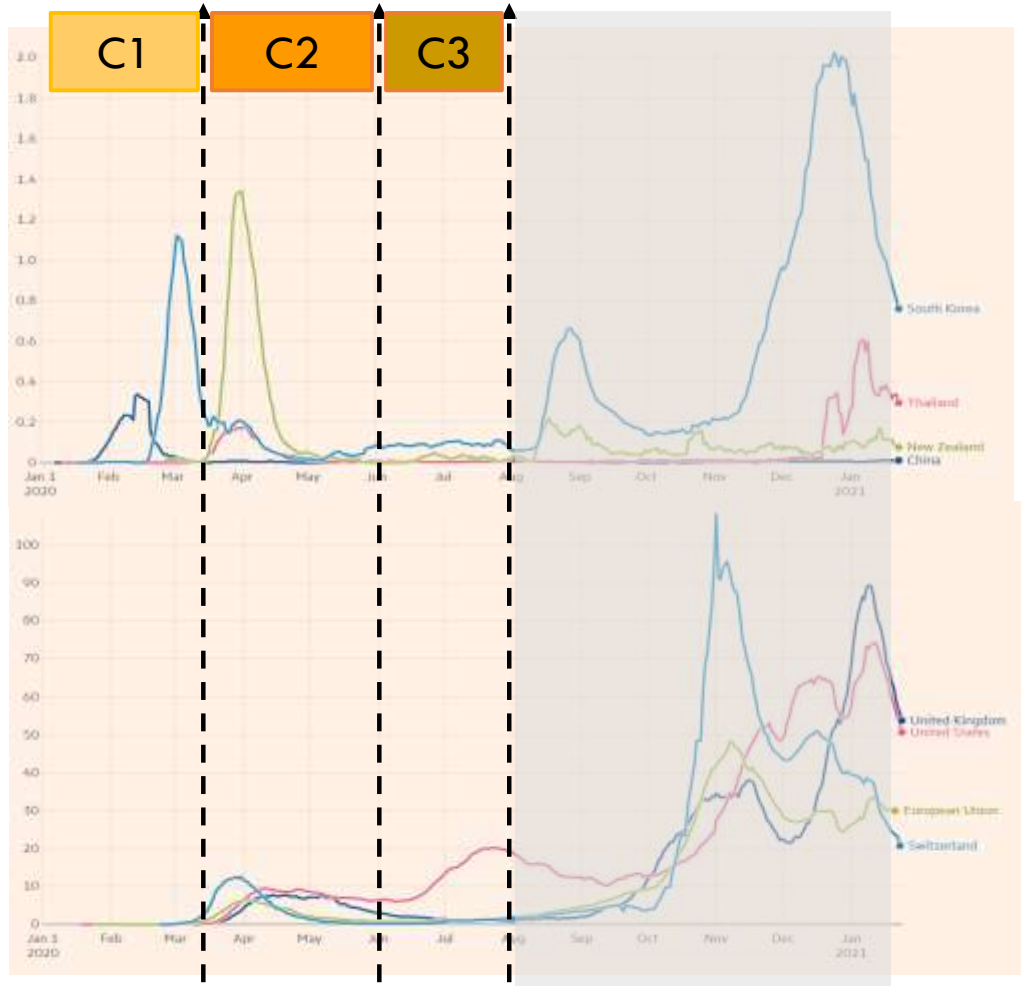
	USD	EUR	CHF	GBP	JPY	CNY	SGD	THB	XAU	BTC
Mean (%)	0.00	0.01	0.02	0.01	0.00	-0.01	0.00	0.01	0.11	0.38
SD (%)	0.19	0.26	0.34	0.49	0.45	0.24	0.21	0.29	0.92	4.83
Skewness	0.45	0.29	1.09	0.13	1.32	-0.66	0.10	-0.32	0.00	-0.89
Kurtosis	8.27	4.39	30.02	5.76	13.56	7.51	6.56	5.09	5.37	16.86
Max (%)	1.26	0.94	3.24	2.38	3.51	0.84	1.12	1.03	3.94	20.43
p95 (%)	0.27	0.44	0.43	0.75	0.70	0.40	0.29	0.41	1.61	8.76
Median (%)	0.00	-0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.11	0.09
p5 (%)	-0.34	-0.42	-0.43	-0.80	-0.64	-0.38	-0.35	-0.43	-1.37	-5.89
Min (%)	-0.65	-0.95	-2.60	-1.99	-1.74	-1.48	-0.87	-1.15	-3.74	-39.77
Correlation with USD	1.00	-0.60**	-0.36**	-0.51**	-0.04	0.38**	0.16**	0.24**	0.07	0.12
(p-value)	-	(0.00)	(0.00)	(0.00)	(0.40)	(0.00)	(0.00)	(0.00)	(0.17)	(0.01)
Autocorrelation at lag s, ρ_s										
ρ_1	0.05	-0.09	-0.17**	0.07	-0.05	0.02	-0.32**	0.02	0.03	-0.13**
(p-value)	(0.30)	(0.06)	(0.00)	(0.15)	(0.25)	(0.66)	(0.00)	(0.70)	(0.46)	(0.01)
ρ_2	0.15**	-0.01	-0.01**	0.12**	-0.12**	0.06	0.14**	0.06	0.02	0.07**
(p-value)	(0.01)	(0.19)	(0.00)	(0.01)	(0.03)	(0.48)	(0.00)	(0.50)	(0.69)	(0.01)
ρ_5	-0.11**	0.10**	-0.02**	0.00**	-0.04**	0.00	0.08**	0.04	-0.07	-0.01
(p-value)	(0.00)	(0.03)	(0.02)	(0.02)	(0.00)	(0.88)	(0.00)	(0.82)	(0.29)	(0.07)



Time Windows of Study

Period	Time Window
2019 **Before COVID-19 outbreak**	January 2 – December 30, 2019
C1 **Onset of COVID-19**	January 2 – March 10, 2020
C2 **COVID-19 Pandemic**	March 11 – May 31, 2020 **WHO announces COVID-19 pandemic on March 11.*
C3 **First Lockdown Eased**	June 1 – July 31, 2020

7-day Rolling Average of New COVID Cases (per 100K population) in Selected Countries during Jan 2020 – Jan 2021



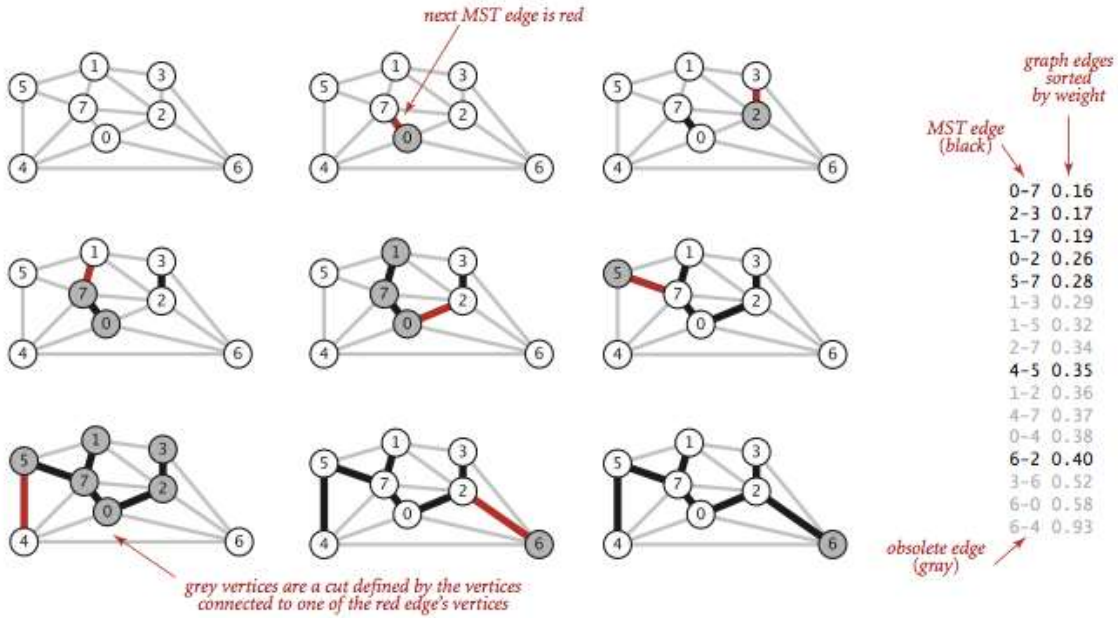
Source: Financial Times / COVID Tracking Project, JHU

Methodology: How to Determine Asset Trees

- **Definitions**
  - Assets ⇒ Nodes (or vertices)
  - Distances between assets ⇒ Links (or edges)
  - Mantegna (1999): $d_{ij} = \sqrt{2\left(1 - \rho_{R_i,R_j}\right)}$

1 Minimum Spanning Tree (MST)

- Kruskal's algorithm (1956)
  1) Sort all links (edges) from smallest to largest distances.
  2) Start with link with smallest distance.
  3) Add the next smallest link from the remaining links unless a cycle is formed.
  4) Repeat 3) until all nodes are connected.
- Other algorithms: Prim (1959)



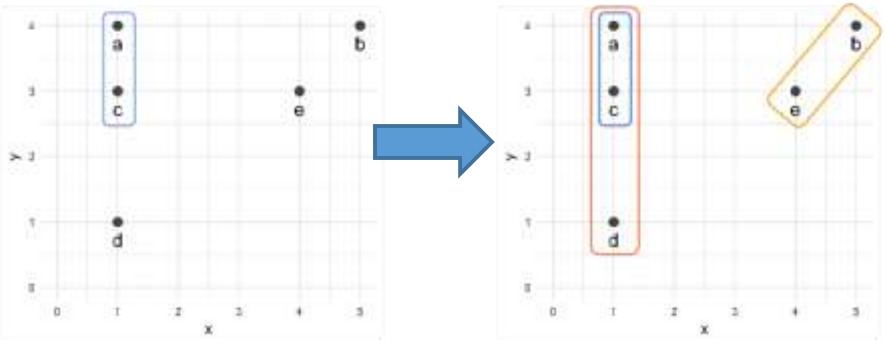
Source: Sedgewick and Wayne (2018)

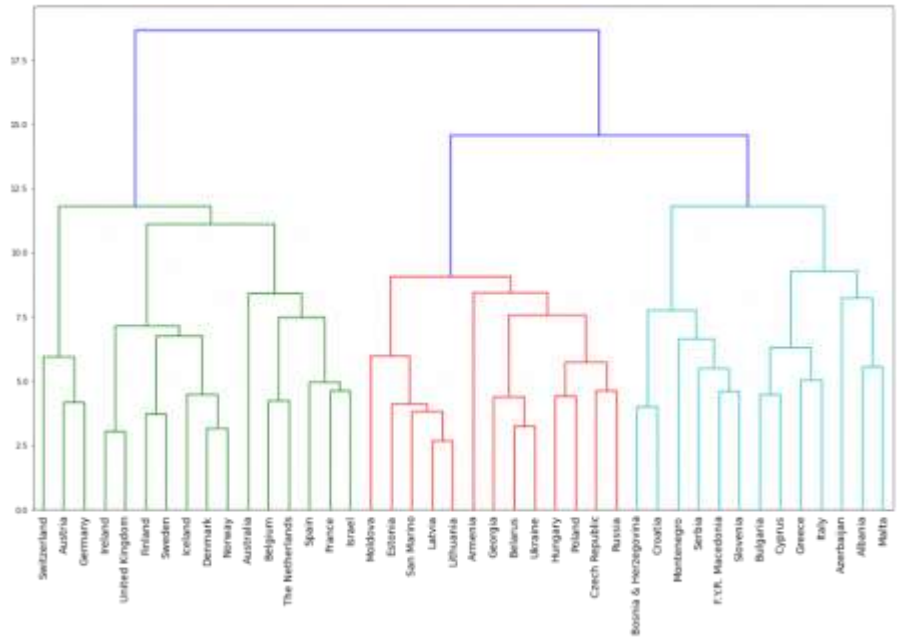
Methodology: How to Determine Asset Trees

2 Hierarchical Clustering

- Sokal and Michener (1958)
- Agglomerative algorithm (bottom-up)
  1) Each node (asset) is a cluster (group).
  2) Calculate the distance between nodes or the clusters.
  3) Group two nearest nodes (or clusters) and replace them as a new cluster.
  4) Repeat 2) - 3) until there is no node left.
- Average linkage

	a,c	b	d	e
a,c	0			
b	?	0		
d	?	25	0	
e	?	2	13	0

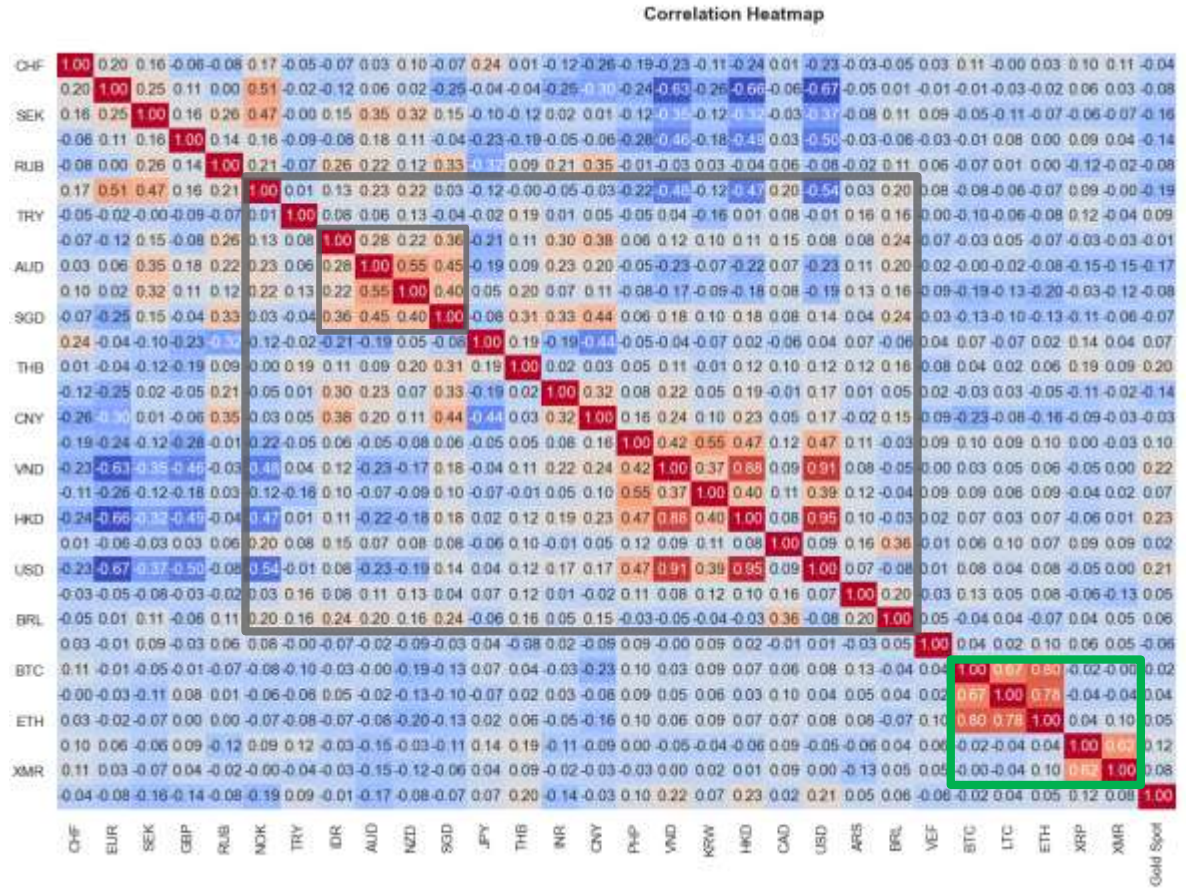




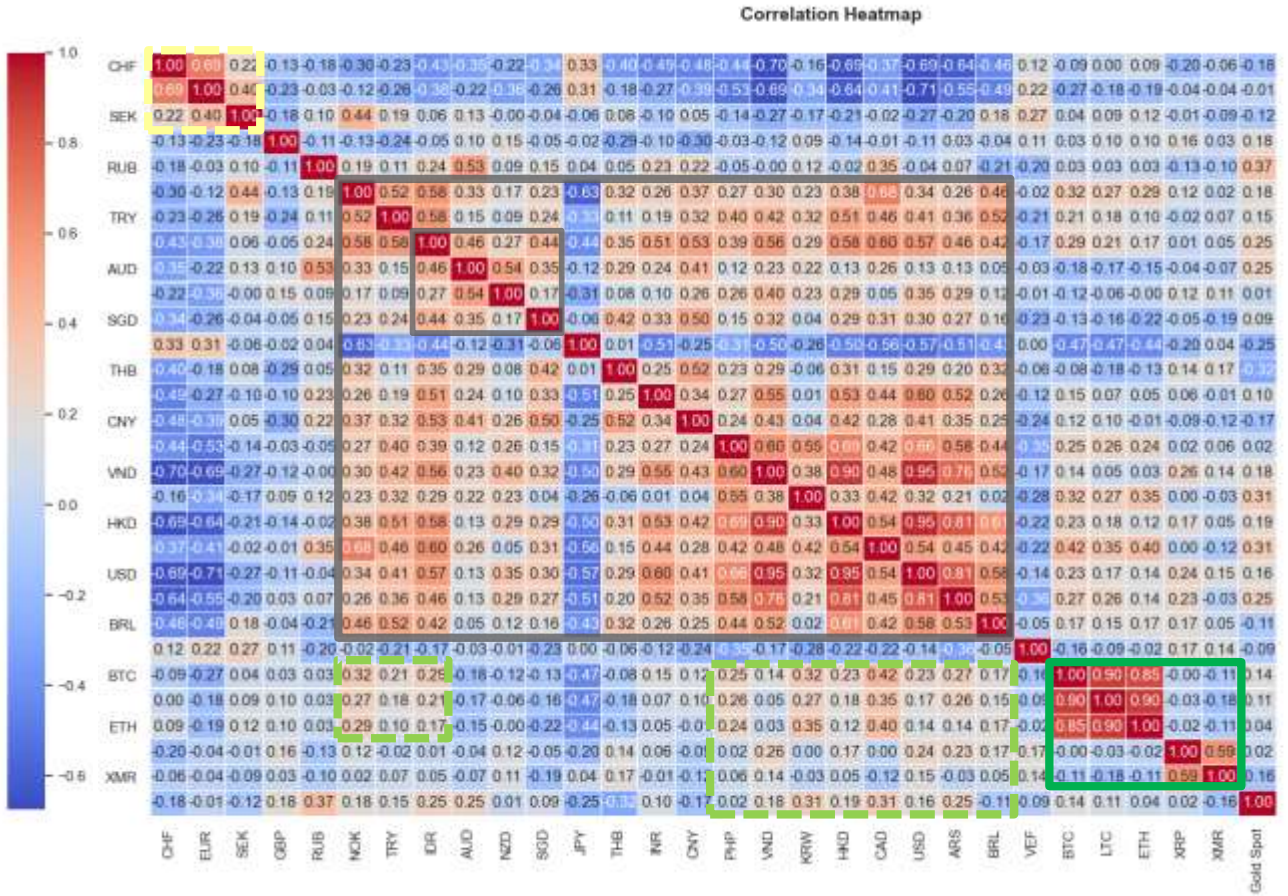
Source: Pipis (2020) / Sanchez and Marzban (2020)

Correlation Heatmap Evolution

2019

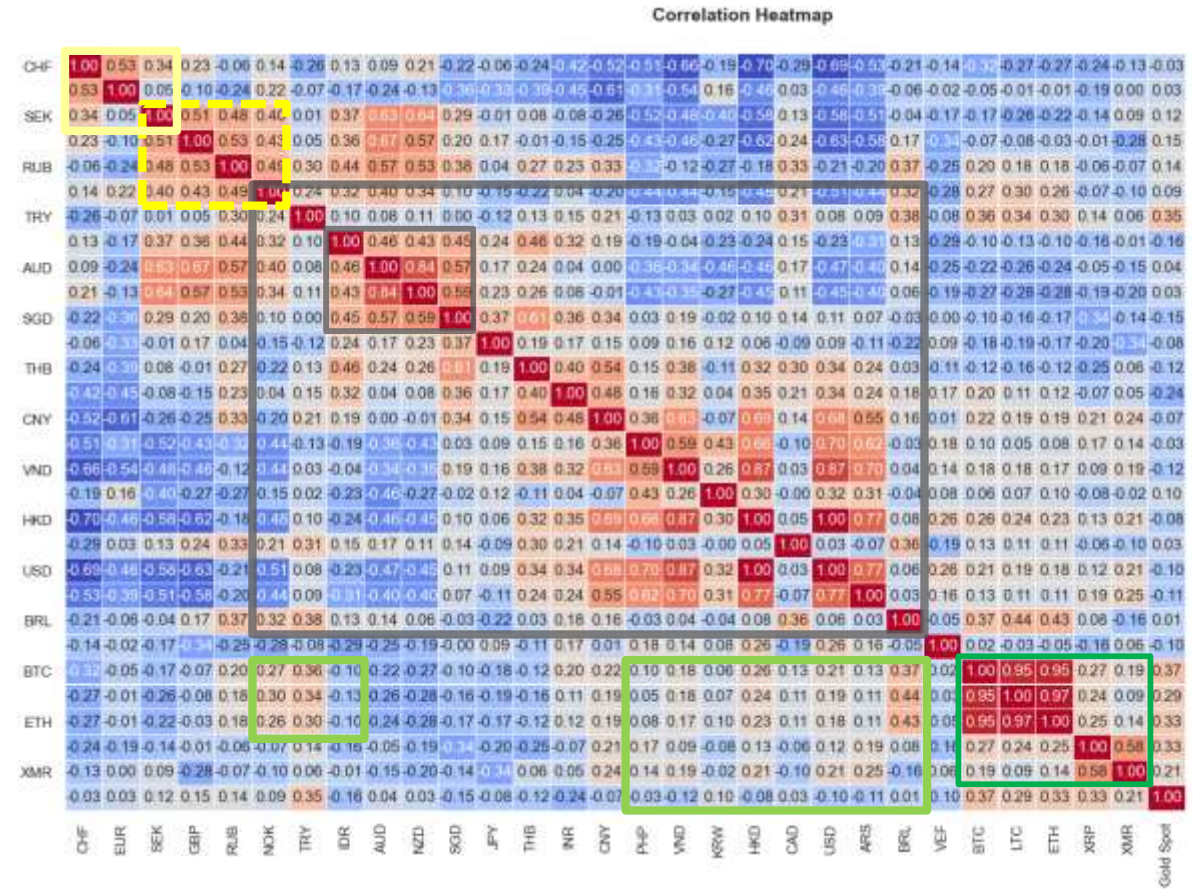


C1 - Onset of COVID-19

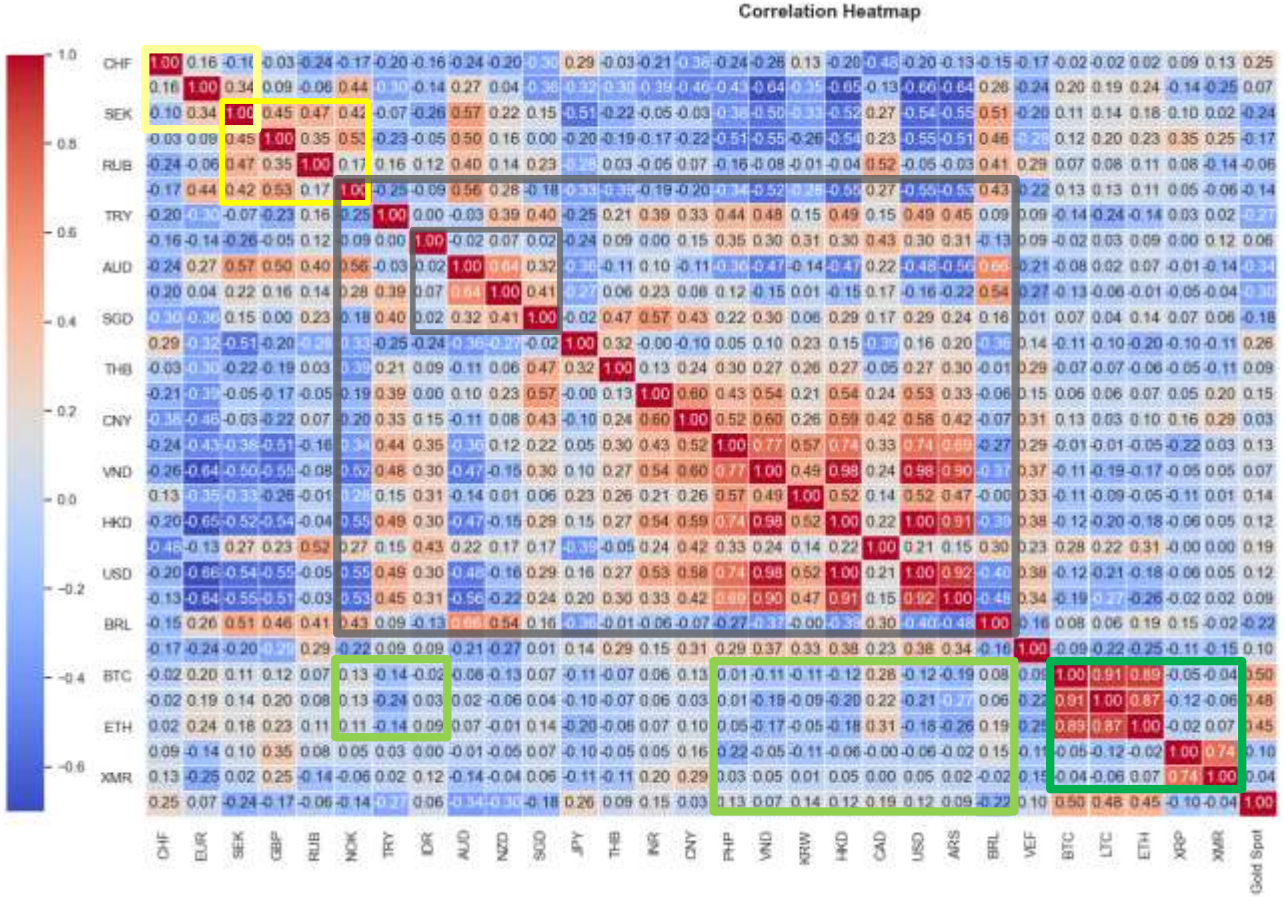


Correlation Heatmap Evolution

C2 – COVID-19 Pandemic



C3 – First Lockdown Eased

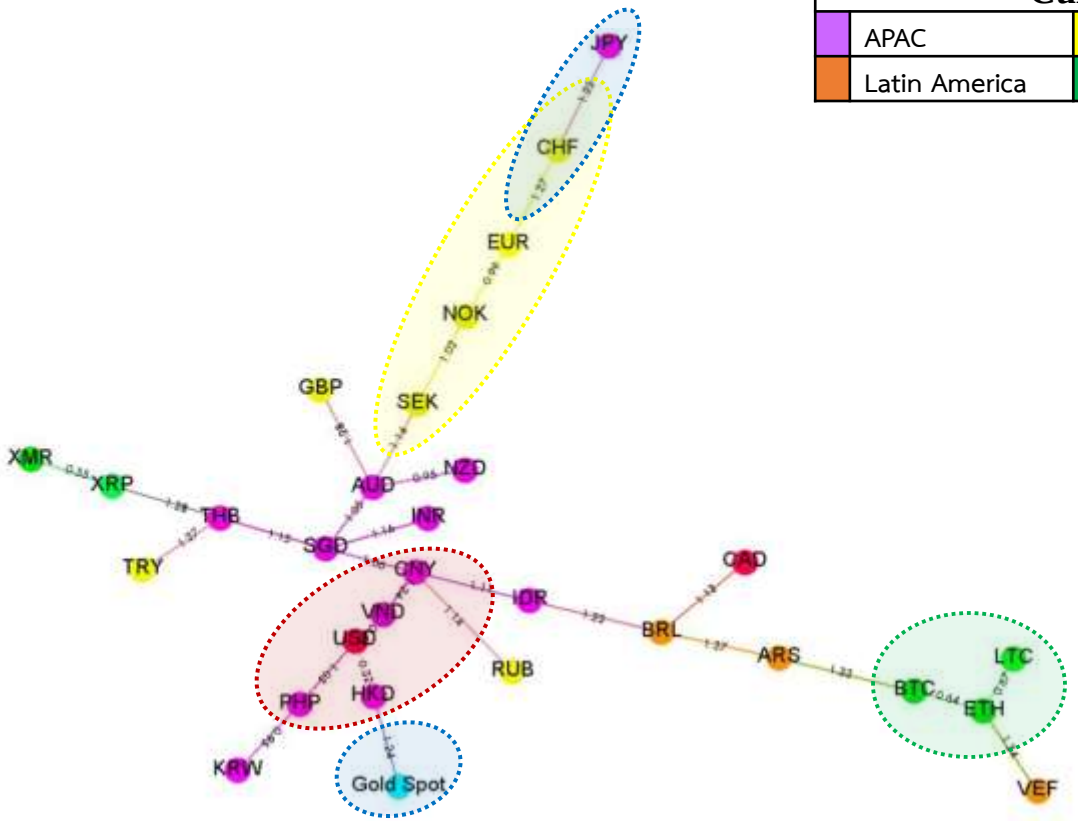


Results: Minimum Spanning Tree (MST) Evolution

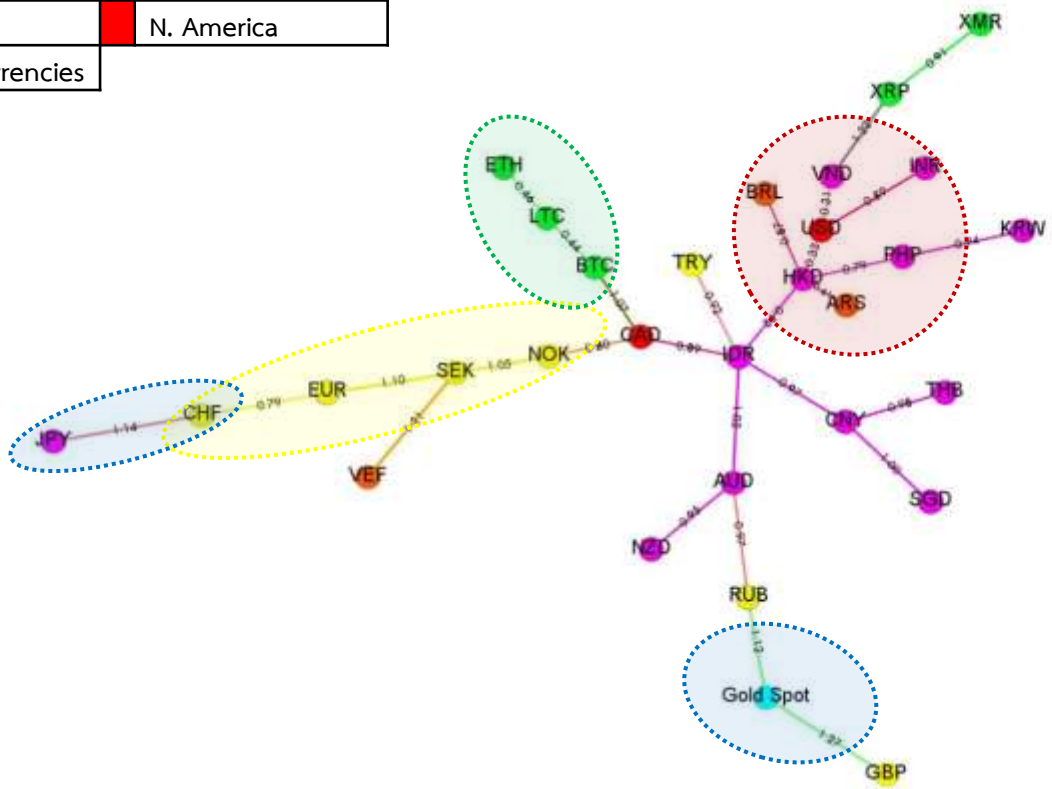
2019

C1 - Onset of COVID-19

Currency (Node) Colors		
APAC	Europe	N. America
Latin America	Cryptocurrencies	



Total Distance = 30.81
Average Distance = 1.03

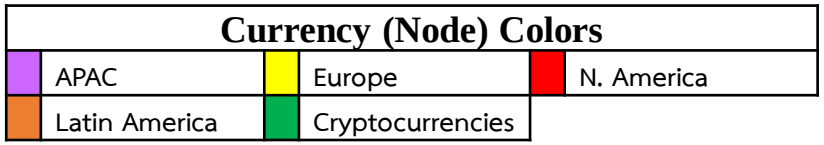


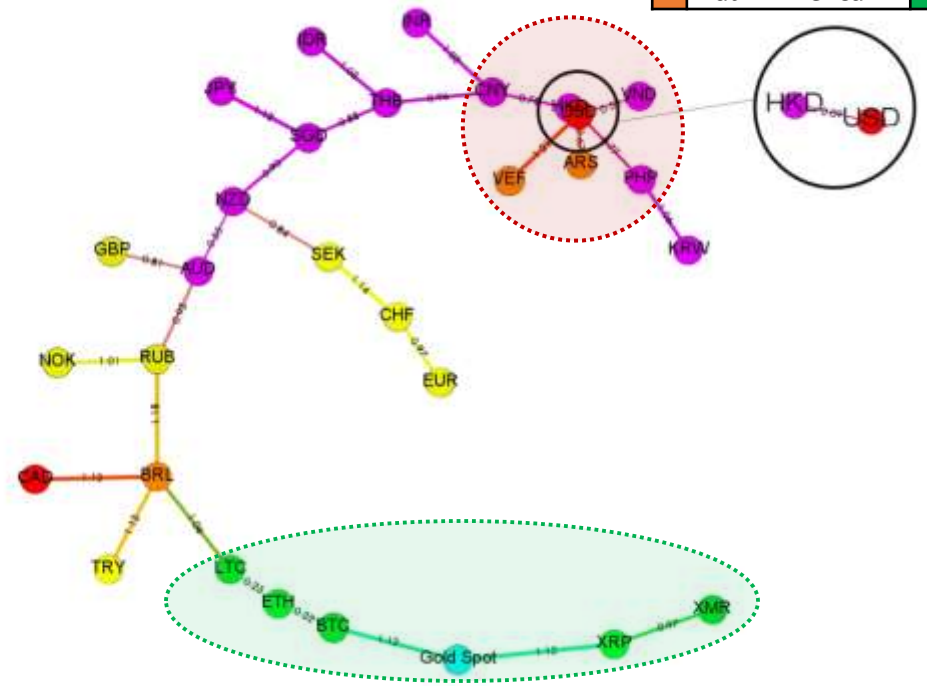
Total Distance = 26.06
Average Distance = 0.87

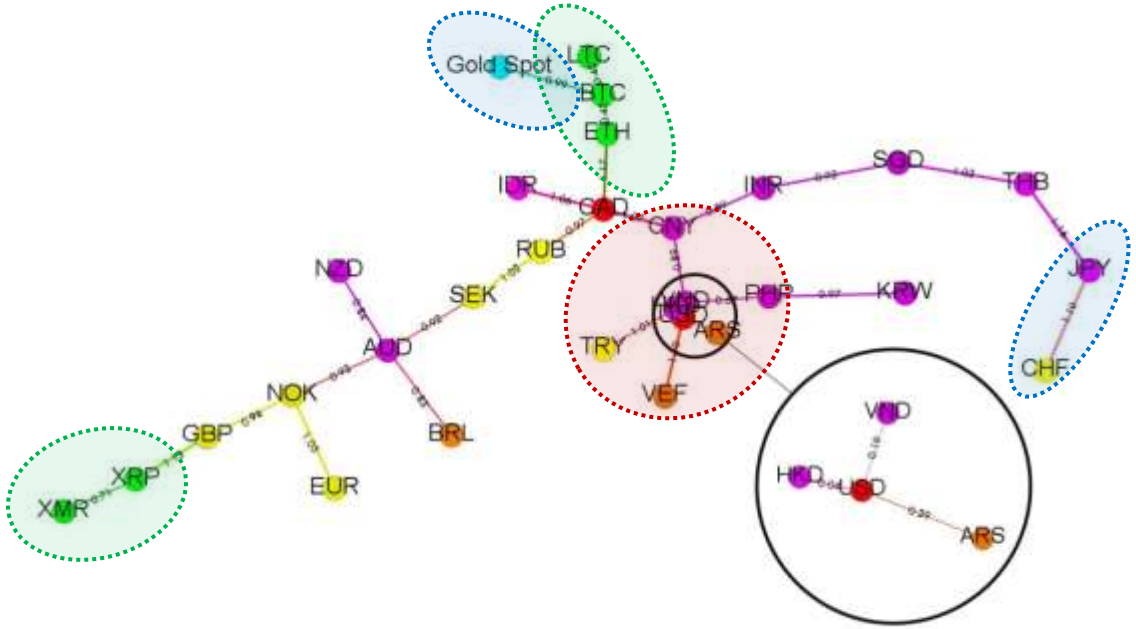
Results: Minimum Spanning Tree (MST) Evolution

C2 – COVID-19 Pandemic

C3 – First Lockdown Eased





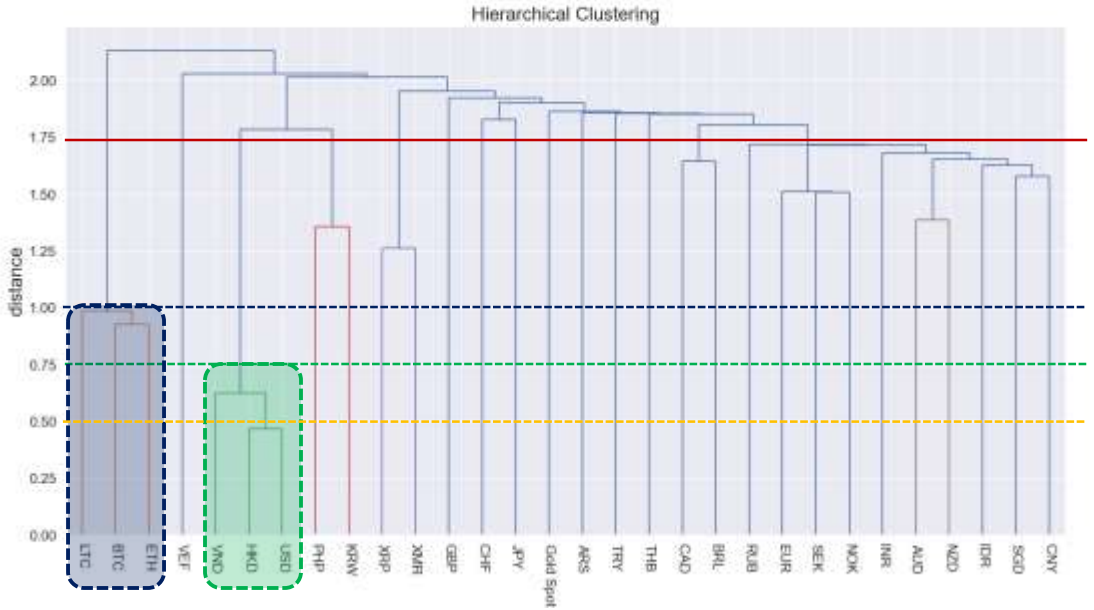


Total Distance = 25.51
Average Distance = 0.85

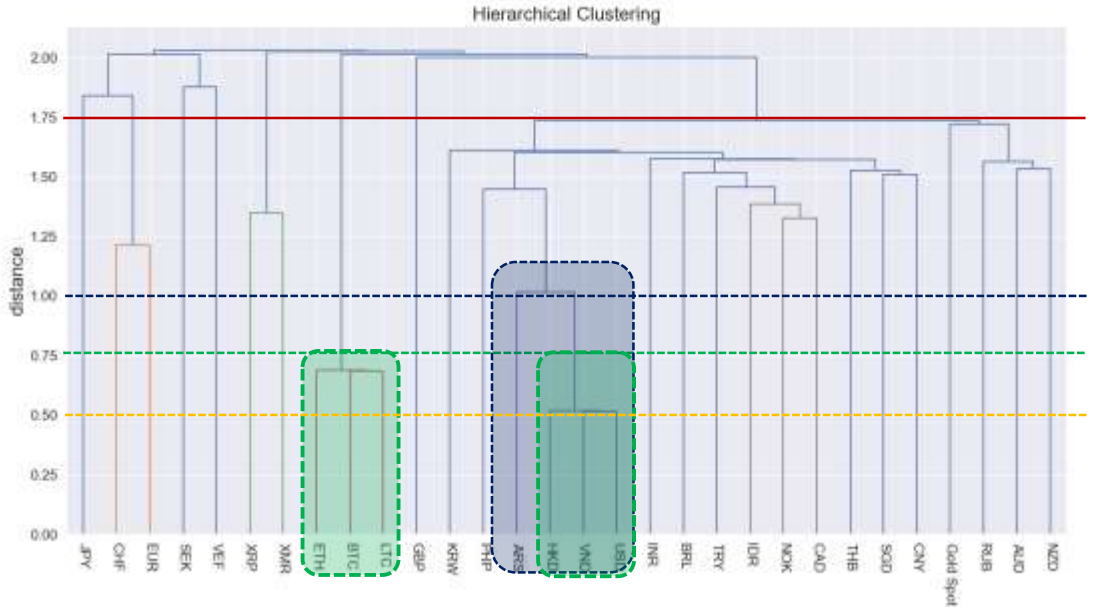
Total Distance = 25.09
Average Distance = 0.84

Results: Hierarchical Cluster Evolution

2019

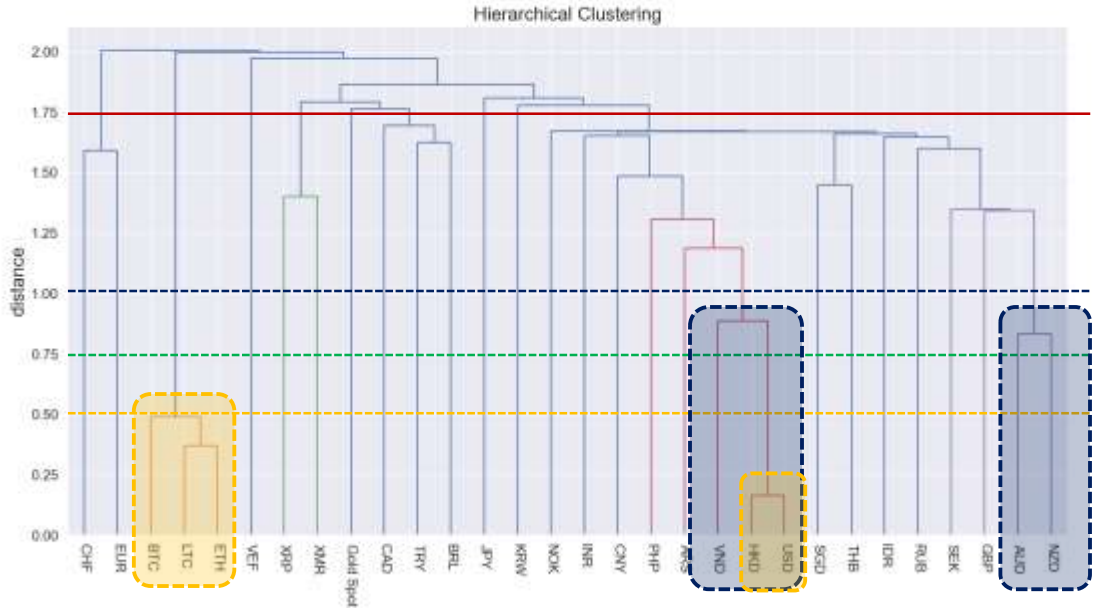


C1 - Onset of COVID-19

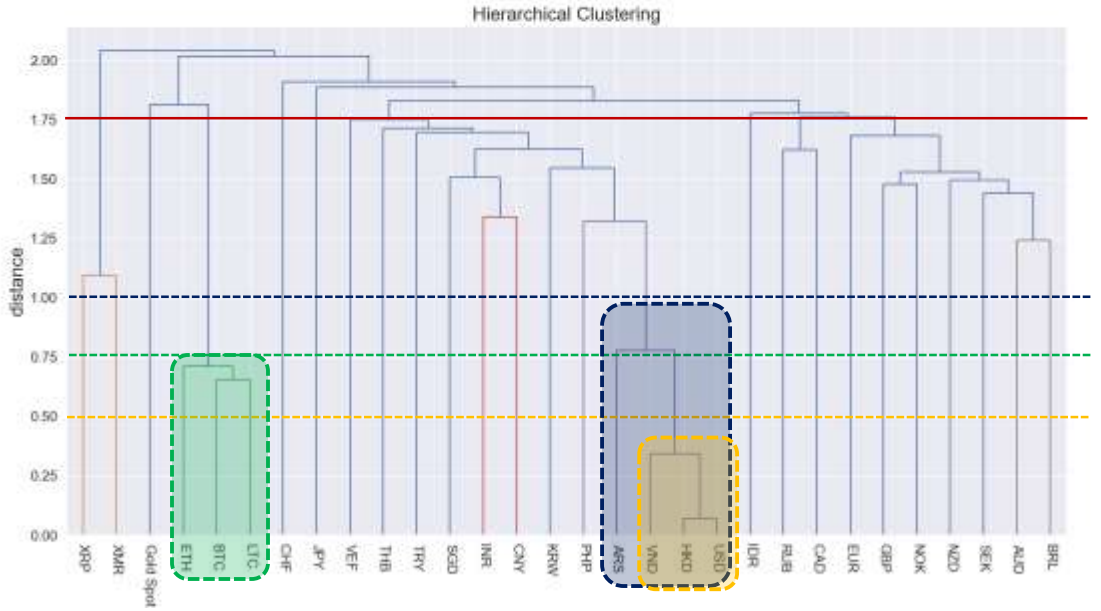


Results: Hierarchical Cluster Evolution

C2 – COVID-19 Pandemic



C3 – First Lockdown Eased



Implications/Conclusions

- Currencies are more connected during harsh financial conditions, e.g., COVID-19
  - Most assets are more correlated and may be more connected to subgroups.
  - During normal time, currencies tend to co-move with their regional peers. Regional cluster relationships do not hold during difficult market conditions.
  - Relationships of currencies in the same clusters intensify.
- Cryptocurrencies and gold movements are disconnected to other currencies.
- Gold, Japanese Yen, (and Swiss Franc) are more of safe-haven assets compared to other currencies.
  - Observations: JPY & CHF returns are more positively-skewed and fat-tailed than others.

Appendix

Appendix - Normalized Exchange Rate Time Series: Jan 2019 – July 2020