

Developing Functional Networks of Frontier Capital Markets

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Capital Markets and Development

Individuals make economic decisions in a market context that is influenced by their social interactions and opportunities. Examining the structure, dynamics, and unique characteristics of the capital market network in which they operate is vital to understanding how capital markets evolve. Especially in developing economies, individuals make reciprocal exchanges and clan or family interests, social norms, and institutions are as important as individual self-interest. Thus, harnessing the personal, corporate, and information networks that underlie developing capital markets is a critical component for creating programs that expand economic opportunities.

Economic research has recognized that well-functioning financial markets are associated with economic growth.¹ However, little is understood about the individual and functional networks in capital markets in the world's less-developed countries. These capital markets, often termed frontier markets,² are ones in which social connections play a much more critical role than in developed capital markets. Vibrant capital markets enable developing economies to attract the domestic and international investment needed to support entrepreneurs and expand economic opportunities. Frontier markets have a smaller scope and fewer institutional controls, and social relations and human behavior have a greater impact. Thus, the study of frontier capital

¹ Levine and Zevros found that developed capital markets are correlated with improved economic performance and there is a link between the size and liquidity of stock markets and easy access to information, rigorous accounting standards, and strong investor protections. Levine, Ross and Sara Zervos (1996), "Stock Market Development and Long Run Growth," *World Bank Economic Review*, Vol. 10, No. 2.

² Financial analysts classify capital markets as Developed, Emerging, or Frontier. This paper focuses on Frontier Markets, the smallest, less developed, less liquid investable markets.

markets provides a unique opportunity to examine the network-based intersection of human behavior and economics. The individual motivations, information availability, transaction systems, and cultural realities in these markets provide a rich context of study.

Capital Market Network Analysis

Network analysis can inform behavioral, financial and development economists seeking to understand the essential characteristics that foster capital market development in countries where social capital can be as important as financial capital. As Stiglitz and Gallegati (2011) note, “Some network designs may be good at absorbing small shocks, when there can be systemic failure when confronted with a large enough shock. Similarly, some typologies may be more vulnerable to highly correlated shocks.”³ Goyal (2007) found that, “Network structure has significant effects on individual behavior and on social welfare.” He concluded that some networks are better than others to promote socially desirable outcomes, and both the quality and quantity of the links in the networks are important.⁴

Our network approach is revealing existing qualities of market behavior that do not adhere to traditional economic assumptions contributing to our understanding of network science, economics and capital markets. This social network analysis provides interesting insights about how interrelationships among actors, roles, and organizations affect market operations and development. Network analysis offers both a visual representation and a quantitative assessment of the relationships and information flows between people, organizations, and knowledge entities enabling classification of capital market structure and functions in innovative ways.

³ Stiglitz, Joseph E. and Mauro Gallegati, “Heterogeneous Interacting Agent Models for Understanding Monetary Economics,” *Eastern Economic Journal*, Volume 37, Winter 2011, Bloomsburg, PA, Eastern Economic Association, p. 37.

⁴ Goyal, Sanjeev (2007). Connections: An Introduction to the Economics of Networks, Princeton: Princeton University Press, pp. 54, 27.

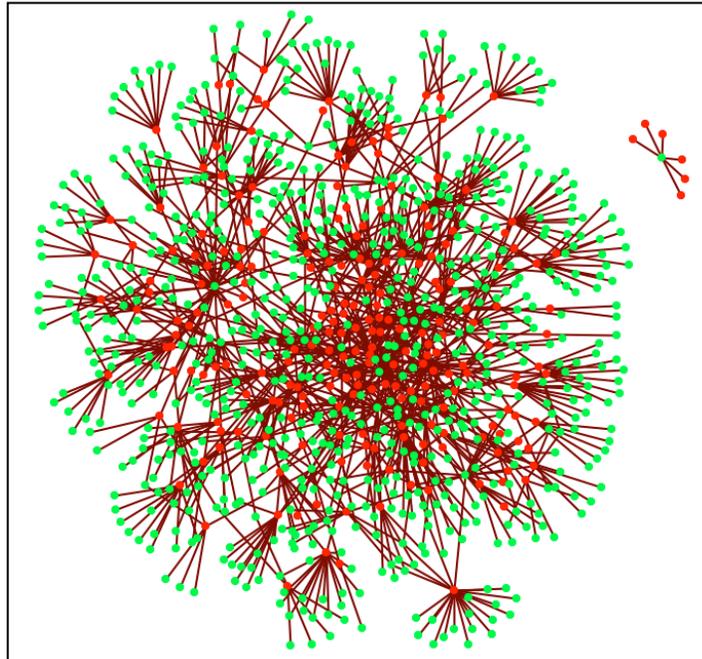
Functional Network Development

Our research focuses on the capital markets in three frontier markets: Ghana, Tanzania, and Trinidad and Tobago. The research team collected extensive résumé data about the actors in these markets and used mathematical network analysis techniques to identify and evaluate the agents (or nodes) in each network. The initial focus was on stock exchange personnel and government regulators, but the networks expanded to encompass public companies, banks, brokers, and key personnel in government, the military, professional associations, and parastatal organizations. For each individual identified, the team recorded the organizations with which they were associated, including public and private firms, clubs and professional associations, as well as nationality, educational attainment, university affiliations, and teaching expertise. The team then used Organizational Risk Analyzer (ORA)⁵ network analysis software to evaluate the data sets and develop social networks that describe the interrelationships among the individuals and organizations in the networks. Figure I shows a sample agent-organization capital market network. The agents are in red, the organizations in green. This type of diagram may be useful for identifying key nodes in smaller datasets, but for datasets comprising hundreds of agents and organizations, its utility is somewhat limited.

Using relational algebra (discussed below) and the capabilities of ORA, researchers also built networks to illustrate how individuals (agents) are connected through organizations and how organizations are connected to other organizations through individuals. These agent-agent and organization-organization adjacency matrices proved useful in identifying key individuals and entities in each of the selected capital markets. However, our goal was to compare capital market networks (with different agents and organizations) at the macro level. Thus, we developed an innovative analytic framework that focused on the roles of individuals and organizations within the markets. Researchers reviewed each individual's résumé data and assigned

⁵ Carley, Kathleen M. (2001-2010). ORA: Organizational Risk Analyzer v.2.0.4. [Network Analysis Software]. Pittsburgh: Carnegie Mellon University.

Figure I: Sample Agent-Organization Network



them up to three functions that best described their roles within the network based on both organizational affiliations and professional expertise. These functions encompassed both the types of organizations with which an individual was associated and the professional expertise individuals had attained. For example, lawyers, accountants and consultants were assigned the professional services function while a member of a trade union received the association function. Table I contains the list of functions assigned to individuals. Three functions were sufficient to cover the roles for the majority of the capital market participants studied.

Once functions had been assigned, researchers used ORA to analyze the agent-function data sets. We created a matrix depicting how people are connected to functions such as the matrix shown in Table II below. We transposed the agent-function matrix to create a Function-Agent matrix (Table III) and multiplied the matrices to obtain a Function-Function matrix (Table IV), which reveals how functions are related to other functions through individuals.

Table I: Functions Listing

Agriculture	Government
Association	Healthcare
Banking	Industrial
Communications	Parastatal
Conglomerate	Professional Services
Consumer	Real Estate
Education	Tourism
Financial Services	Transportation

Table II: Agent-Function Matrix

	Banking	Consumer	Parastatal
Smith	1	0	1
Jones	0	1	1
Miller	1	0	0

Table III: Function-Agent Matrix

	Smith	Jones	Miller
Banking	1	0	1
Consumer	0	1	0
Parastatal	1	1	0

Table IV: Function-Function Matrix

	Banking	Consumer	Parastatal
Banking	1	0	1
Consumer	0	1	1
Parastatal	1	1	1

The ORA-generated functional network typologies for Tanzania, Trinidad and Tobago, and Ghana are depicted in Figures II - IV. The node size was scaled based on the functions' row degree centrality, providing a visual representation of which functions were most important in each capital market.

Figure II: Tanzania Functions Network

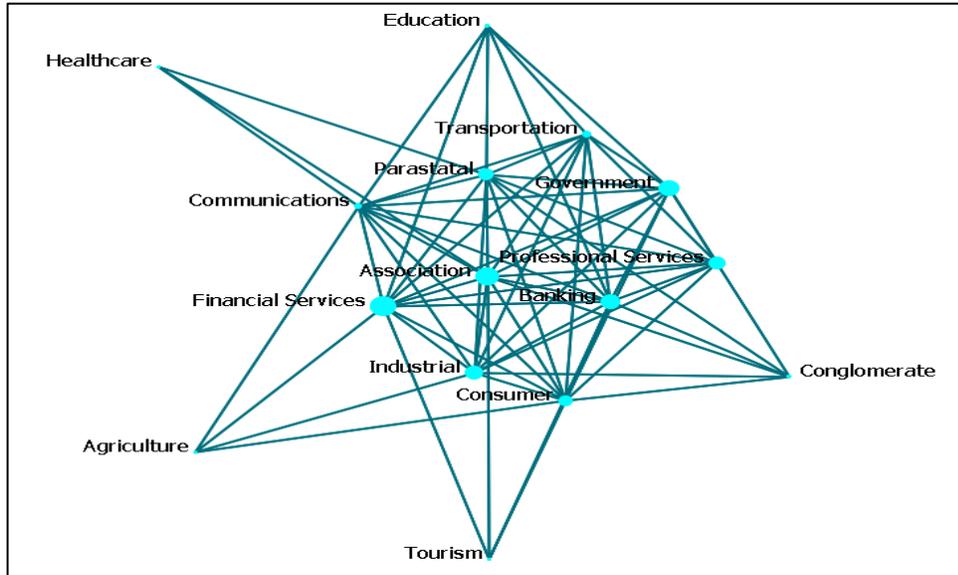


Figure III: Trinidad and Tobago Functions Network

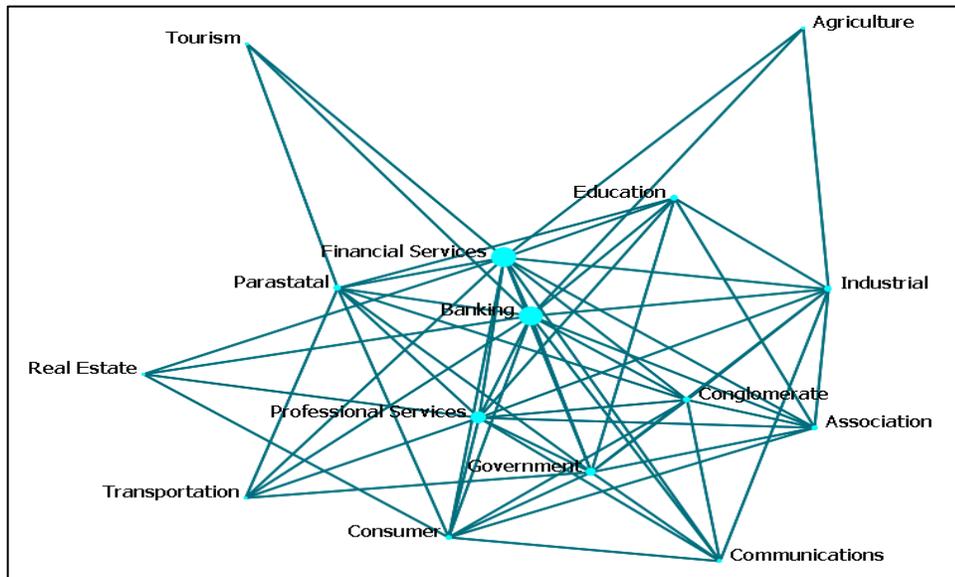
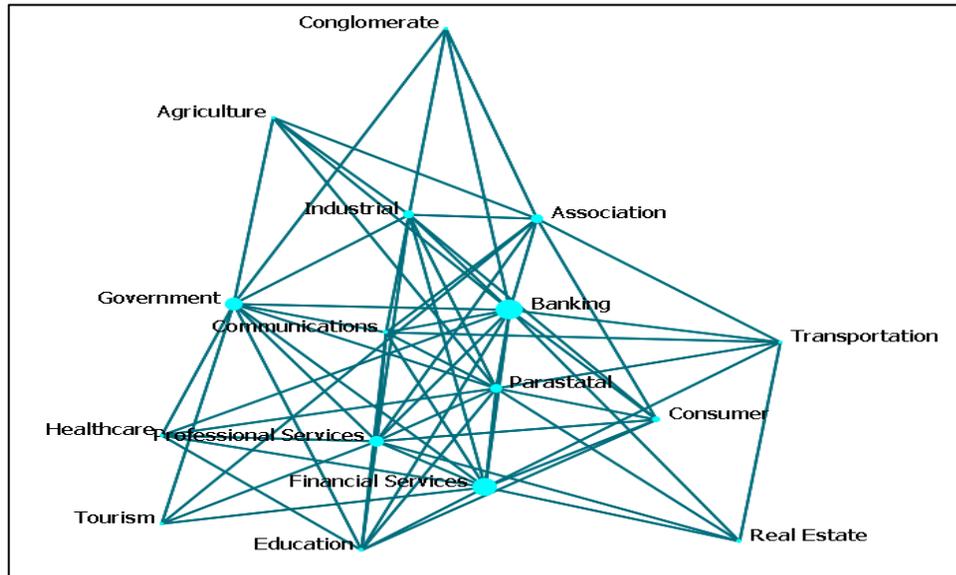


Figure IV: Ghana Functions Network



We then created a weighted network by assigning weights to each function in order to favor current roles over prior roles. Current functions were weighted twice as heavily as past functions. For example, an individual currently serving on the board of an oil company, who had formerly been a member of parliament would have two functions: industrial with a weight of two and government with a weighted of one. Using the same matrix algebra detailed previously, we created weighted networks relating functions to other functions through people. This network analysis highlighted the functions that serve as central hubs and power brokers. It also identified potential points of failure, the nodes on the shortest paths between nodes that exhibit the most influence on other nodes, and the nodes on the periphery, lacking information or resources. These network typologies enable analysts to classify, compare and contrast capital market networks.

Table V provides summary statistics for each of the weighted and unweighted functional networks calculated using ORA. (Detailed calculations and definitions may be found in *Social Network Analysis* by Wasserman and Faust⁶ and in *Technical Report*,

⁶ Wasserman, S. and Faust, K. (1994), Social Network Analysis: Methods and Applications. Cambridge: Cambridge University Press.

CMU-ISR-11-107 by Carley, et. al.⁷) The weighted and unweighted networks in each country were largely the same in terms of density, link count, and clustering coefficients. However, the characteristic path lengths were longer in the weighted networks as would be expected. In Ghana, the path length was 2.45 times higher in the weighted network, while in Trinidad and Tobago and Tanzania, path lengths tripled. The other major differences in the weighted and unweighted network metrics involved betweenness and closeness centralization. Networks with higher betweenness centralization have more intermediaries or bridges connecting disconnected groups. Our weighted networks had significantly more intermediaries than the unweighted networks indicating fewer groups were disconnected. Closeness centralization measures the extent to which information flows are centralized around single agents or groups. Interestingly, in Trinidad and Tobago, weighting the network almost halved the level of closeness centralization, while there was little difference between the weighted and unweighted networks in the other countries according to this measure.

Table V: Comparative Weighted Network Statistics

Average Measure	Ghana		Trinidad and Tobago		Tanzania	
	Weighted	Unweighted	Weighted	Unweighted	Weighted	Unweighted
Link Count	67	68	62	62	68	68
Density	0.5580	0.5670	0.5900	0.5900	0.6480	0.6480
Characteristic Path Length	5.4670	2.2330	7.3520	2.4000	7.8000	2.3900
Clustering Coefficient	0.7120	0.7130	0.8200	0.8200	0.8560	0.8560
Degree Centralization	0.2450	0.2550	0.2090	0.2080	0.1710	0.1880
Betweenness Centralization	0.2790	0.0790	0.1520	0.1320	0.3020	0.1830
Closeness Centralization	0.1610	0.1760	0.0750	0.1640	0.2230	0.2420
Eigenvector Centralization	0.5780	0.5640	0.6010	0.5750	0.3780	0.3830

⁷ Carley, Kathleen & Reminga, Jeffrey & Storrick, Jon & Columbus, Dave. (2011). ORA User's Guide 2011. *Carnegie Mellon University, School of Computer Science, Institute for Software Research, Technical Report, CMU-ISR-11-107.*

Because our assumption is that an agent's current functions are more important than functions previously performed, the following discussion focuses on similarities and differences among the weighted functions networks in each country. Tanzania had the highest network density, 65% versus Ghana's 56%. Higher density is associated with greater information sharing which is characteristic of learning organizations. Ghana's functional network had the shortest path length, meaning information flows more directly in its network. The clustering coefficients for Trinidad and Tobago and Tanzania were similar; however, Ghana's was 11% - 14% lower. Ghana's network shows the highest degree centralization, almost 1.4 times that of Tanzania. Closeness centralization was dramatically different among the networks with Tanzania's measure almost three times that of Trinidad and Tobago and 1.4 times higher than Ghana's. Eigenvector centralization, which measures the connectedness of functions to highly connected functions, was 1.6 times higher in Trinidad and Tobago than in Tanzania.

Figure V highlights the most prominent functions or key nodes in each of the networks based on ORA's summary of centrality measures (which counts the number of times a function is in the top ten in a centrality measure). The top three nodes for Ghana and Trinidad and Tobago were identical in the weighted networks with financial services (such as broker dealers and asset managers), professional services (including attorneys and accountants) and banking, each recurring in 70% of ORA indications. In Tanzania, financial services was as important as in the other capital markets; however, association and industrial functions each had a 58% rate of recurrence and banking was not prominent. In the unweighted networks, however, government appeared to be a prominent function in both Ghana and Tanzania. Because both countries evolved from socialist roots in the recent past, had we not weighted the networks, we may have overestimated the importance of the role of government in current capital market networks.

Figure V: Most Prominent Functions Comparison

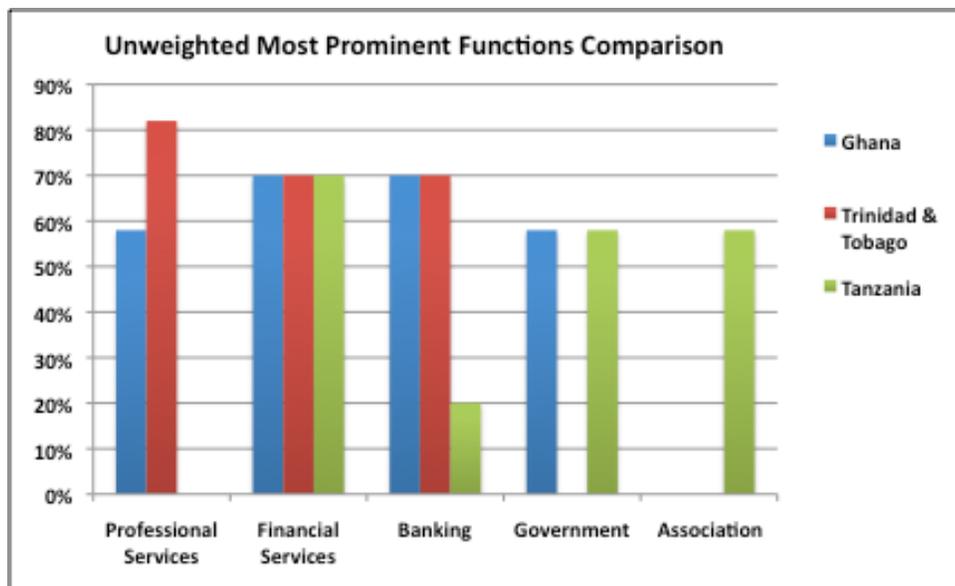
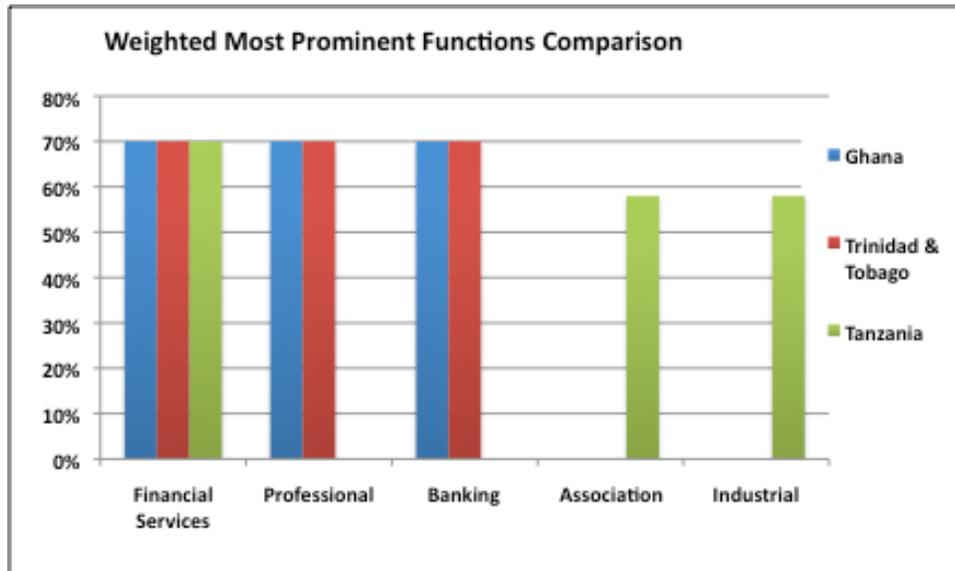
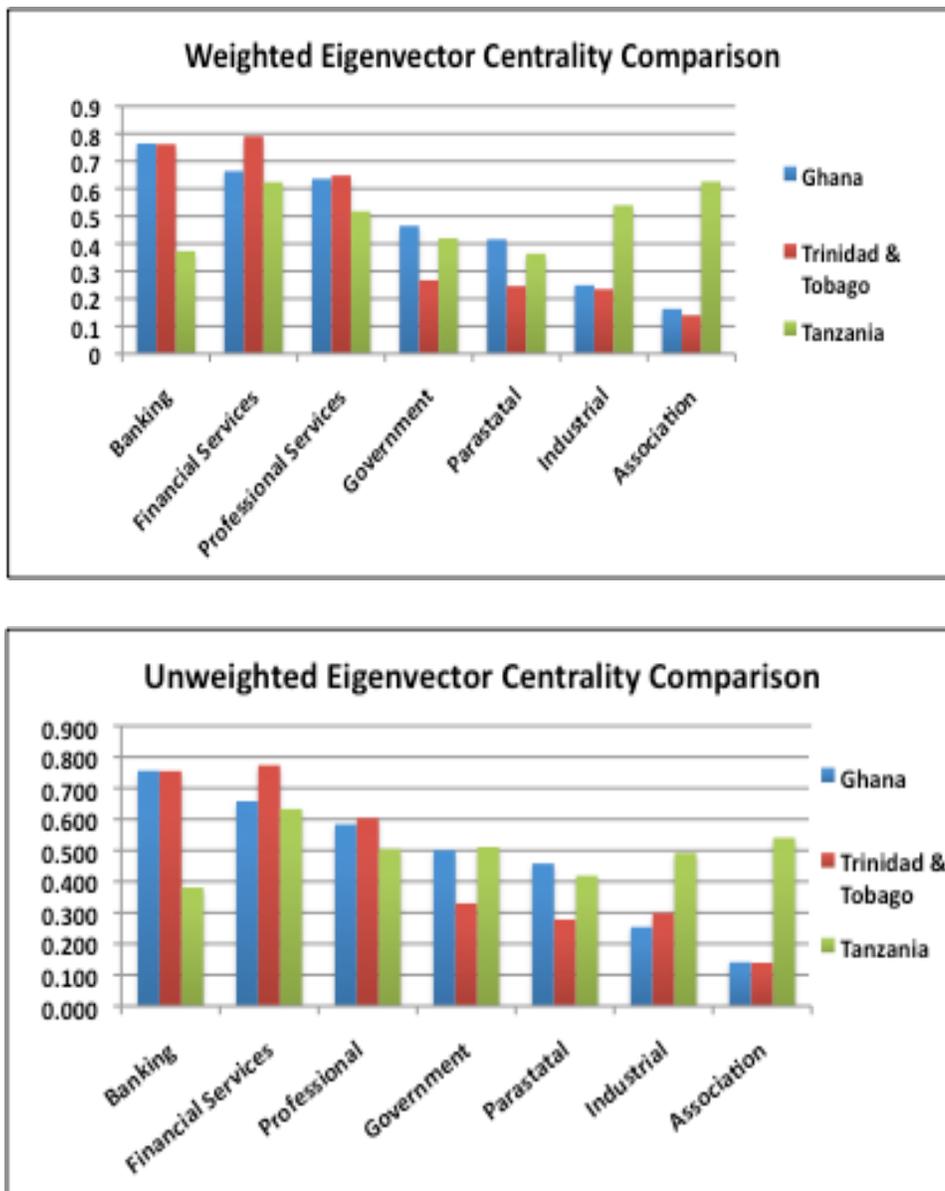


Figure VI identifies the functions that exhibited the highest eigenvector centrality in each network. In this context, eigenvector centrality measures the functions that are most connected to other highly connected functions. In both the weighted and unweighted networks, financial services and professional services were very important functions; however, banking was extremely important in Ghana and Trinidad and

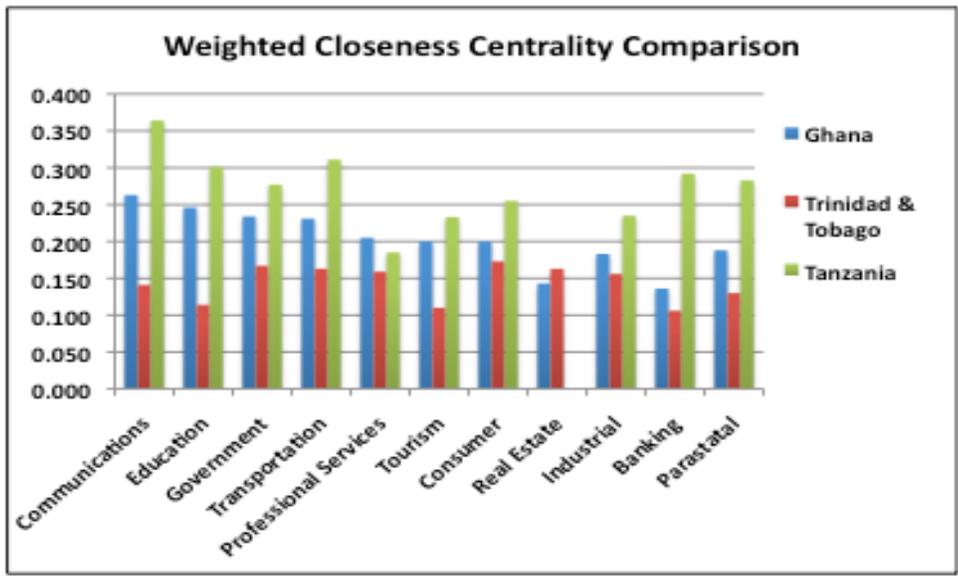
Tobago but not as prominent in Tanzania. The government, parastatal, and industrial roles were less important in Trinidad and Tobago than in the African countries. In contrast, Tanzania's associations and industrial organizations exhibited high eigenvector centrality indicating the manufacturing base is still quite important in Tanzania's capital market network.

Figure VI: Eigenvector Centrality Comparison



Closeness centrality measures the average proximity of a function to other functions in the network. Nodes high in closeness centrality are considered hubs and efficient communicators. Figure VII identifies the functions that exhibited the highest closeness centrality in each network. Of particular note is the fact that in Trinidad and Tobago, all of the weighted closeness centrality values were lower, especially relative to Tanzania, possibly indicating a higher level of functional specialization in Trinidad and Tobago's more developed capital market. The communications function was most important in Tanzania based on closeness centrality, but transportation, education, banking and parastatal roles were prominent as well. One would have expected that in the island nation of Trinidad and Tobago, tourism would have been a played a more central role. In the unweighted network, the closeness centrality measures were higher across the board and the range of values was smaller. Had we focused solely on the unweighted network, we might have overstated the importance of health care, conglomerates, and associations.

Figure VII: Closeness Centrality Comparison



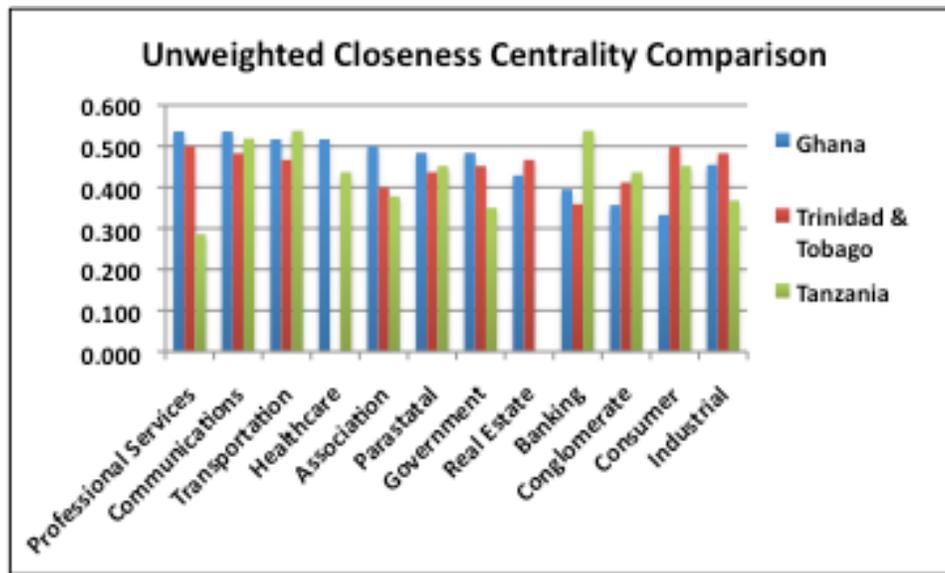
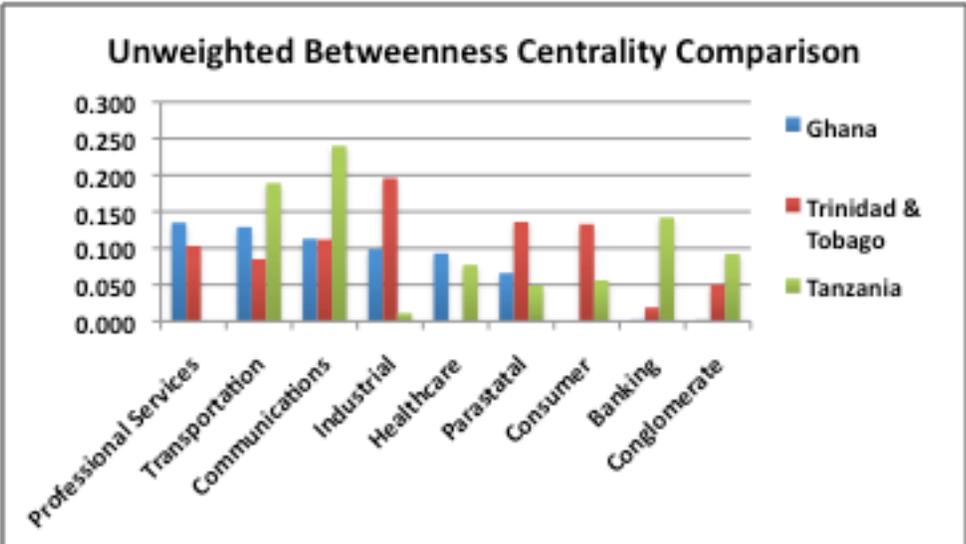
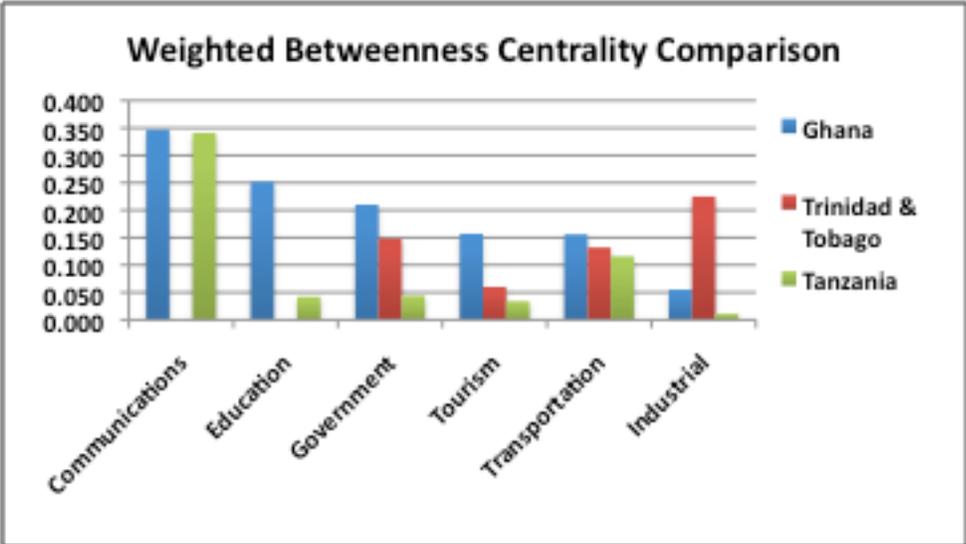


Figure VIII reveals stark differences between the weighted and unweighted networks in terms of betweenness centrality. Nodes high in betweenness centrality measures are often considered power brokers that bridge the gap between connected and unconnected nodes. The difference between the top functions in the weighted and unweighted graphs is noteworthy. For example, in the unweighted network, parastatal and consumer organizations were highly ranked in Trinidad and Tobago while conglomerates and banking were important in Tanzania, which seems counterintuitive. One would expect bankers, but not necessarily conglomerates, to be power brokers in Tanzania, and for parastatal organizations to play a more important role.

As the current roles individuals adopt in a network are considered to be more important than past roles, we focused on the weighted network as more reflective of the actual importance of the functions in the capital market network. The weighted graph also reveals a wide disparity among the markets studied. Those agents who served in the communications role served as liaisons or gateways in Ghana and Tanzania, which seems appropriate in evolving markets where Internet connectivity and phone service are game changers. Individuals in industrial roles in Trinidad and Tobago and education roles in

Ghana were also influential along with government and tourism. However, only those agents with transportation roles were influencers in all three countries.

Figure VIII: Betweenness Centrality Comparison



CONCLUSIONS

This capital market network research generated functional network topologies and descriptive statistics for three frontier capital markets. We identified similarities and differences in the capital market networks using three different centrality measures as a

technique to compare and contrast capital markets. This research comprises one pillar of a unique, quantitative methodology for classifying capital markets.

Overall, the main differences in the weighted versus unweighted networks was that closeness centralization (the extent to which information flows are centralized around single agents or functions) in Trinidad and Tobago was significantly lower than in the African countries. The weighted networks also exhibited higher betweenness centralization. Among the weighted networks, Tanzania's was the most dense, while Ghana's network registered the lowest density. Lower density indicates that power is shared more equally among the functions. The networks also exhibited quite different levels of closeness centralization with Tanzania registering a value three times that of Trinidad and Tobago and 1.4 times that of Ghana. This analysis indicates that the functions in Tanzania's network are more interconnected and tightly knit, while Trinidad and Tobago's functions may be more distinct and specialized. Measures of closeness centrality confirmed this assessment, as Tanzania registered much higher levels than Trinidad and Tobago, with Ghana's measures in between.

In order to distinguish the quantitative difference between these three networks, we suggest that additional analysis should focus on those top ten functions that are distinctively different in each capital market's functions network topology. As would be predicted in a study of capital markets, the key functions in each of the weighted networks were financial services, professional services, and banking. However, associations and industrial functions were quite important in Tanzania. In the unweighted networks, but not in the weighted network, the government function was prominent in the African countries, probably due to their socialist roots. Thus, had we failed to weight the networks, we may have overestimated the importance of government in the current capital market networks.

Differences in results based on the selected metric can potentially lead to the discovery of influential functions that might not be readily apparent at first observation or conversely, might not appear to be as influential as initially supposed. When considering those functions that are connected to other highly connected functions (eigenvector centrality), Tanzania's associations and industrial organizations were quite

prominent. Tanzania's economy may be still be influenced by its manufacturing base and powerful trade unions. Those agents who served in communications roles were most important (based on betweenness centrality) in Tanzania and Ghana confirming the importance of the Internet and phone infrastructure in evolving economies. Education and government functions were also power brokers in Ghana, while industrial roles were bridges in Trinidad and Tobago.

Researchers are also conducting a network analysis of an emerging market, the Czech Republic, to enable a vertical comparison. Such a comparison will reveal similarities and differences in the network structures of developing versus emerging markets furthering an understanding of the types of social networks that have fostered economic growth. These models will offer insights to economists seeking to understand the interconnections between economic actors and their affects on financial markets and economic conditions. This research will also inform governmental and nongovernmental organizations that are creating economic development policies, enabling decision-makers to focus on aspects of the network that will generate results efficiently.