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Heterogeneity of assets, structure of interbank market and systemic risk: Evidence from East African banking sector

By Peter Wamalwa, Cappitus Chironga, Anne Kamau and Samuel Tiriongo

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HETEROGENEITY OF ASSETS, STRUCTURE OF INTERBANK MARKET AND SYSTEMIC RISK: EVIDENCE FROM EAST AFRICAN BANKING SECTOR[*]

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Abstract

The linkages in the interbank market play a critical role in liquidity distribution in the banking sector, but at the same time propagate risks. This paper analyses architecture of interbank interconnectedness and its impact on systemic risk in the banking sector of the East African Community (EAC), using bank level data for the period 2010 to 2020. The results indicate that the interbank market is more segmented in Burundi compared to Kenya, Uganda, Tanzania and Rwanda. As a result, banks in Burundi are least susceptible to contagion risk compared to other banks in the EAC countries. Further, there are also linkages among banks in the region due to similarities in the structure of assets and liabilities, income statements and sectoral loan portfolio, which elevates systemic risk. However, heterogeneity of assets and robust economic growth reduce systemic risk, while an increase in capital predisposes the banking sector to systemic risks due to increase in financial linkages. Overall, the main findings suggest there is need to minimize contagion risk in the region through integrating interbank markets, enhancing their efficiency and increasing diversity of assets and liabilities.

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1. Introduction

The integration of the East African Community (EAC) has increased trade in goods and services and created commensurate demand for financial services. Consequently, banks have established subsidiaries and intensified cross border operations in the EAC region, thereby increasing banking sector interconnectedness. On the one hand, the intensity of linkages among banks in the EAC enable them to obtain and manage liquidity more efficiently and at lower cost. This has led to better intermediation of funds, thus contributing to economic growth. On the other hand, interlinkages propagate shocks in the banking sector, which may undermine stability and economic growth (Gofman, 2017; Roukny et al., 2016; Silva et al., 2016). In addition, concentration of loan portfolio in a few sectors of the economy, for instance; the real estate, households, manufacturing, and accumulation of government securities[5] elevates systemic risk. The structure of assets and liabilities as well as interlinkages of the banks elevate contagion and systemic risks in an economy and across economies with similar structures when a shock to one sector or asset is transmitted to the rest of the banking sector across the region.

Susceptibility of the banking sector to contagion risk has provided an impetus to understanding the role of the structure of asset and liabilities and interconnectedness in propagating systemic risks. Extant literature on the impact of the structure of assets and liabilities on systemic risk is inconclusive. In particular, whereas accumulation of similar assets across banks increases vulnerability of the banking sector to common and idiosyncratic shocks (Chu, 2015), diversification of assets and liabilities increases connections among banks, which propagates and amplifies contagion (Banwo *et al.*, 2016 Cacioli *et al.*, 2015). In addition, interconnectedness of banks not only alleviates liquidity risk, but also increases default risks (Hausenblas, Kubicová, & Lešanovská, 2015; Elsinger, Lehar & Summer, 2006).

Theoretical debate and empirical evidence on the link between asset /liability portfolio structure and financial system risks is underpinned by interconnections among financial institutions and correlation of assets and liability (Chu, 2015). Whereas Chu (2015) acknowledges that financial institutions have become more homogeneous and intertwined in general, Roukny *et al.*, (2016) and Silva *et al.*, (2016) argue that structure of banking sector affects its vulnerability to systemic risks. In fact, increased homogeneity of assets in the banking sector may support stability of financial institutions but at the same time elevate their vulnerability to same risks (Wagner, 2010). Hence, there is a tradeoff between a lower probability of an idiosyncratic failure and a higher probability of a systemic adverse effect. Relatedly, Ibragimov *et al.* (2011) show that diversification of assets and liabilities is suboptimal for a banking system. Furthermore, linkages with other financial institution as well as the diversity of assets increases in tandem with the size of banks. However, an increase in the diversity of assets associated with changes in the size of banks reduces liquidity risk, but increases counter party and systemic risks due to heterogeneity of interlinked firms (Volcker, 2012). Indeed, Fisher (2011) argues that markets with smaller banks are less complex and less inter-connected; which buttresses their stability. Nevertheless, small sized banks are relatively more vulnerable to liquidity risks.

In view of the inconclusive literature, this paper analyses the architecture of interconnectedness of the banking sector and its impact on systemic risk in the EAC using bank-level data. In

[5] investment in government securities account for about 30 percent of the assets of banks in the region.

particular, the paper first analyses the architecture of the in-country interbank market and linkages in EAC. The paper then analyses heterogeneity of assets to establish idiosyncratic and common risk exposures of banks in the EAC. We employ a network analysis method to establish the architecture of interconnectedness and then estimate a fixed effects model to analyse the contribution of asset heterogeneity to systemic risk.

The results indicate that the interbank market is more segmented/less connected in Burundi compared to Kenya, Uganda, Tanzania and Rwanda. As a result, the Burundian interbank market is least susceptible to contagion risk compared to the other markets in the EAC region. The interconnectedness among banks in the interbank market in Kenya, when compared to the rest of the markets in the region, is the highest enabling banks to access liquidity in the interbank market with ease. At the regional level, however, linkages among banks are underpinned by similarities in their structure of assets and liabilities, income structures as well as common exposure to risks due to concentration of loans to trade, manufacturing and transport and communication sectors. These similarities may trigger systemic risks in the event of a shock, and are pointers to the need to explore assets and liability diversification. Overall, heterogeneity of assets and robust economic growth systemic risk reduces.

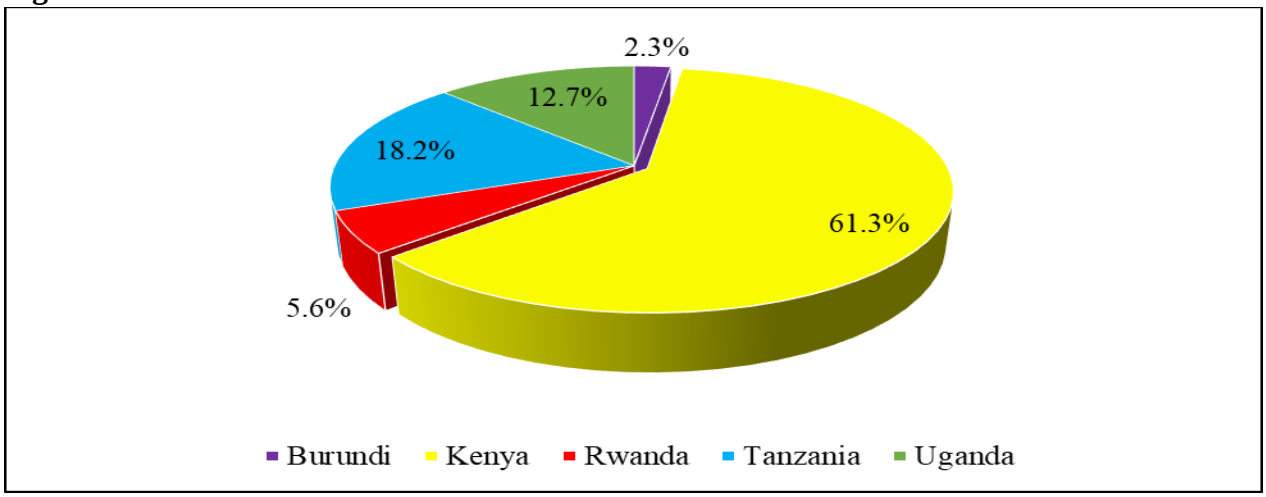
The rest of the paper is organized as follows. An overview of banking sector and interbank market in the EAC is presented in Section 2. Section 3 covers a review of the literature on the interbank market topology, heterogeneity of assets and systemic risks, while Section 4 outlines methodology. The empirical model and a description of the data used. The exploratory analysis and empirical results are reported in Section 5, while Section 6 provides the conclusion and policy implications.

2. The Context

The banking sector in the EAC consists of multinational corporations, banks incorporated in the EAC countries but with cross border operations and domestic banks, both private and government owned. Kenya's banking sector is the largest in the region in terms of the number of institutions and assets. In total, there are 39 commercial banks operating in Kenya, of which, seven (7) banks have cross-border operations in in other EAC countries[6]. Tanzania's banking sector is the second largest in the region with 35 commercial banks[7] and Uganda follows with 26 commercial banks. In the EAC, Kenyan banks account for 61.3 percent of the total assets, with Tanzania and Uganda banks accounting for 18.2 percent and 12.7 percent of the banking sector (**Figure 1**). This reflects each country's relative importance in the region and the exposure to contagion of shocks.

[6] The seven include, the Kenya Commercial Bank (KCB), Cooperative Bank, Equity Bank, NCBA, Diamond Trust Bank, Investment & Mortgage and ABC Bank.
[7] CRBD bank incorporated in Tanzania established operations in Burundi.

Figure 1: Structure of Assets



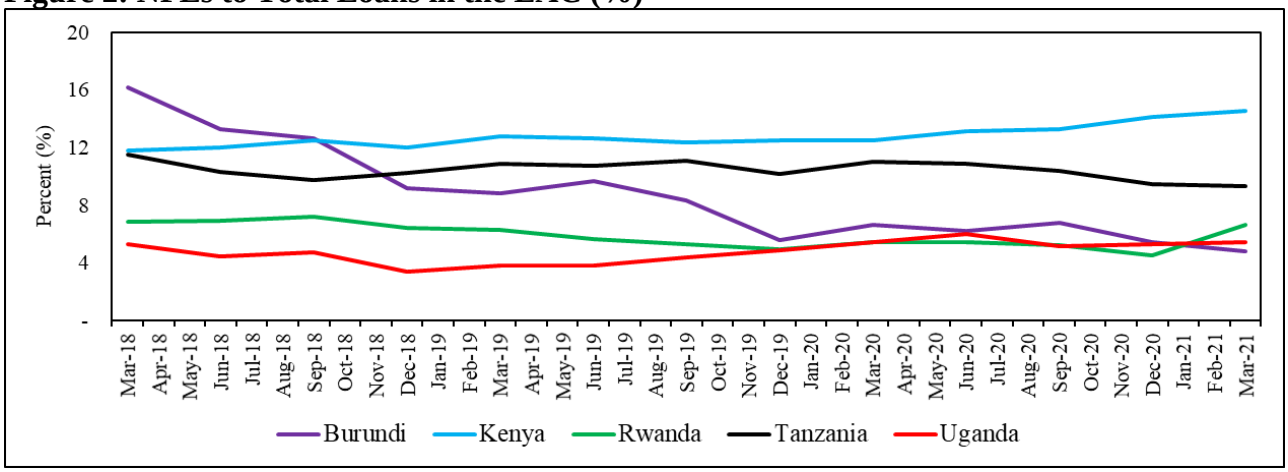
Source: EAC Central Banks

The expansion of banks across borders is beneficial to the countries in terms of; enhanced stability, competition, efficiency and improved financial deepening and inclusion. However, expansion of large banks across borders increases correlation of banking sector shocks in the trading block due to financial interlinkages, which elevates contagion risks (Cacioli *et al.*, 2015).

In addition, contagion risk in the region is also elevated by the similarity of the composition of assets and liabilities. In the EAC countries, loans and advances, Government securities and placement investments account for 70 percent, 25 percent and 5 percent, respectively. In addition, lending is concentrated in construction and real estate, household, manufacturing and trade, which accounts for about 50 percent of the total loans. The sectors have strong backward and forward linkages and hence, economic shocks to one sector affects the other sectors. Therefore, concentration of credit in the sectors predisposes the banks to economic shock. Moreover, a shock to one bank (parent or lending partner) in one country may spillover to a bank in another country.

The EAC economies are also interlinked through cross border operations of firms; backward and forward sectoral linkages and exposure to weather condition, which affects agricultural production. As a result, fluctuations in the ratio of non-performing loans (NPLs) to gross loans is correlated in most of the EAC economies due to symmetry of economic shocks. For instance, with the exception of Kenya, the quality of assets improved from 2018 to 2020. However, the asset quality deteriorated in 2021 in EAC except for Burundi and Tanzania (**Figure 2)**.

Figure 2: NPLs to Total Loans in the EAC (%)



The increase in non-performing loans was prevalent in the households, real estate, manufacturing, and agriculture sectors. For Kenya, the impairment of loans emanates mainly from households, agriculture, real estate and trade, while in Tanzania, it is mainly concentrated in real estate, agriculture and trade sectors (**Table 1)**. The prevalence of loan default in the households, real estate, manufacturing, and agriculture sectors can be propagated among EAC countries, due to linkages within sectors and across countries. This implies that economic shocks affect asset quality and profitability of the banking sector, despite the low reliance of these economies on the banking sector.

Table 1: Sectoral Distribution of NPLs as at March 2021 (percent %)

	Households	Real Estate	Manufacturing	Trade	Agriculture
Burundi	5.65	3.07	0.61	4.13	18.22
Kenya	27.38	10.80	17.11	19.02	27.38
Rwanda	6.61	8.80	1.20	9.19	3.49
Tanzania	3.51	22.55	10.16	18.40	13.28
Uganda	4.30	5.91	1.77	7.13	6.90

Source: EAC Central Banks

A vibrant interbank market enables banks with inadequate liquidity to borrow from banks with excess liquidity thus contributing to effective intermediation of funds. In the EAC, trading in the interbank market is at the national level and in domestic currency and the tenor ranges from overnight to 14-30 days. The number and value of interbank transactions increased significantly between 2010 and 2020, in Rwanda, Tanzania and Burundi. For instance, in Rwanda, the total transactions in the interbank market increased from FRW 613 billion in 2013-2015 to FRW 3255 billion in 2016-2019, an increase of 531 percent. In 2018 and 2019, the total transactions in interbank market increased by 20.3 percent and 45.1 percent respectively from an average of 14.9 percent in the period 2015-2017. Similarly, Kenya and Uganda experienced an increase in the value and number of transactions (Ndirangu et al 2021; Mugenzi et al 2021 and Bwire 2019), except for 2016.

The trading in the interbank market in the three countries is mainly uncollateralized. Banks have established credit lines with other banks in the interbank market, mainly based on size, ownership and assessment of counterparty risk. Accordingly, banks offer differential interest rate and amount depending on the risk assessment of the counterparty. Generally, large banks in the three countries incur the lowest borrowing costs in the interbank market while small banks incur the highest costs irrespective of the lender as they are viewed as risky. Moreover, small and medium sized banks borrow more from large banks compared to their peer (Ndirangu et al 2021 and Bwire 2019). The size of the bank also influences the liquid assets holdings, where large banks have more liquidity compared to small and medium banks and hence are major suppliers of liquidity in the market

Moreover, the large banks have lower demand for liquidity in the interbank market by virtue of their high number of diverse depositors and deposits compared to small and medium sized banks. This results to lower borrowing and lending costs for the large banks compared to small and medium sized banks. The ability of large banks to control amount, number of transactions interest rate and select banks to lend and borrow from the interbank market indicates imperfections in the interbank market in the EAC countries. As such, the Kenyan, Ugandan and Rwandan interbank markets are segmented/fragmented and may be classified as incomplete market structure Rwanda (Ndirangu *et al.,* 2021, Mugenzi *et al* 2021 and Bwire 2019). The imperfections in the interbank market in distributing liquidity are often corrected by central banks through provision of emergence liquidity support or lending against collateral at the discount window, albeit at interest rate above money market rate. The central banks' intervention in the foreign currency interbank market depends on the demand and supply condition of foreign currency.

Segmentation of the markets is an indicator of risk averseness of banks and lack of risk-sharing behavior. This increases vulnerability of the banking system to instability and risk of contagion, in the event of a shock or disruption of liquidity flow, in a few core banks. The distribution of the liquidity and its availability as and when required is uneven, thus increasing volatility of interbank interest rates in the EAC countries.

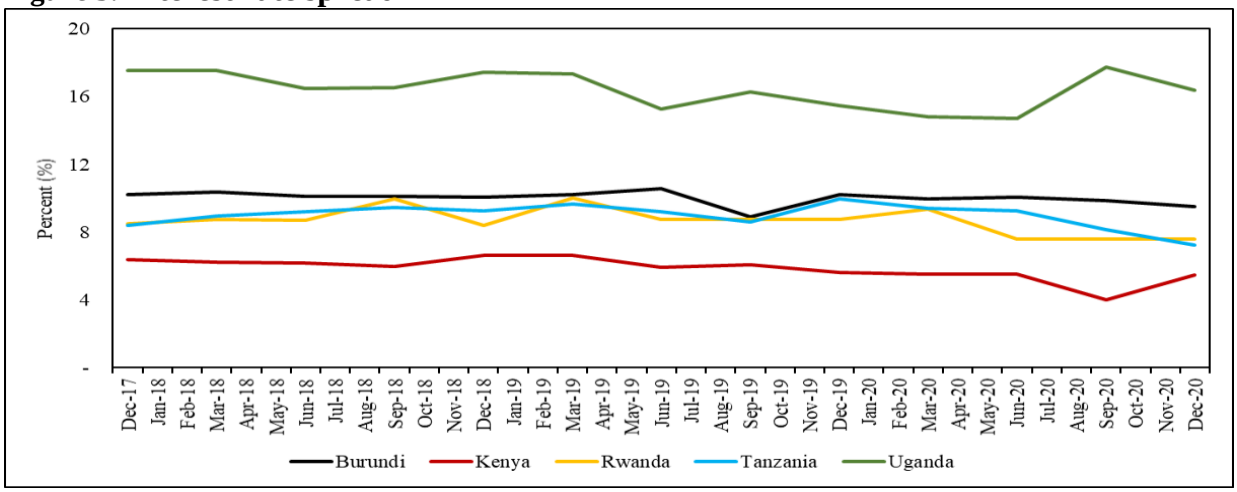
The collateralized horizontal interbank market transaction has eased information asymmetry in the EAC. The horizontal repurchase agreement bills in the interbank consist of short term high liquid Treasury bills pledged as collateral for interbank swaps. However, there it is not possible to transfer the bills to the lender due to banks not being able to access Central Securities Depository. Consequentially, the horizontal repurchase agreement segment has neither grown nor developed to effectively intermediate funds in the interbank market. The development of East African Payment system will immensely catalyse the development of the interbank market by enabling easy flow of funds in the region[8].

The EAC member countries have lengthened maturity of security and facilitated liquidation of collateral in the interbank market, as well as enhanced efficiency to catalyse growth and

[8] Future interbank market developments may include introduction of guarantee facility to manage counterparty risks, introduction of SWAPs in the domestic interbank as well as across borders and development of the foreign exchange interbank operations. Initiatives in the development of the interbank market in the next few years should be geared towards reducing information asymmetry, integration of the interbank markets to facilitate interbank transactions and integrating Central Securities Deposits and settlement platforms.

development of the interbank market. Despite these efforts, the ratio of the settlement amount to collateral is about 80 percent, while interest rates on collateralized and uncollateralized are high and volatile suggesting presence of inefficiencies in the interbank market. The high interest rate in the interbank market not only elevates interest rates in the retail segment, but also widens their spread. In figure 3 interest rate spread in the EAC countries ranges between 4.5 percent and 18.0 percent, compared to an average of 7 percent in West African Monetary Union (WAEMU) and 4 percent in South African Development Community (SADC) regions. In 2020 for instance, Uganda had the highest average interest rate spread of 15.9 percent, while average interest rates spread Burundi and Tanzania were 9.9 percent and 8.5 percent, respectively. Kenya and Rwanda had the lowest spread of 5.1 percent and 8.0 percent. The high and divergent interest rate spreads in the region not only reflect inefficiency in intermediating funds, but also imply low competition, which impede harnessing full benefits of cross border operations.

Figure 3: Interest rate spread[9]



Source: EAC Central Banks

The interbank interest rates largely reflect a confluence of a number of factors including banks assessment of counterparty risks (assessed on the basis of bank size), the structure of the market – particularly the level of segmentation (mostly underpinned by banks' asset base and ownership structures), the inefficiencies in the interbank market and central bank policy actions. Banks in Uganda for instance, seem to have operational challenges with high and volatile interbank rates (**Table 1**). For Kenya and Tanzania, tight liquidity conditions were partly experienced in the years 2015 and 2016, but eased in the first three months of 2021.

Table 2: Interbank Rates

	2015	2016	2017	2018	2019	2020	Mar-21
Uganda	14.1	16.3	11.4	9.5	10.3	8.5	7.3
Kenya	11.3	5.1	6.4	5.2	4.3	3.7	5.0
Tanzania	12.3	13.5	5.6	2.3	5.3	4.5	4.4
Rwanda	4.1	5.4	6.2	5.5	5.5	5.4	5.2

[9] Defined as the difference between average lending and deposit rates offered by commercial banks

Source: EAC Central Banks

In bid to minimize counterparty risks in the interbank market, commercial banks lend against short term treasury bills. The short-term treasury bills and repurchase agreement pledged as collateral, enable banks reduce exposure to default risk by counterparties. However, in the EAC, collateralized interbank market amounts to about 2 percent of the market, with collateral comprising of Treasury bills of less than 90 days to maturity, while repurchase agreement bill of less than 14 to 28 days to maturity. Some of the collateral may be encumbered, which makes it difficult to liquidate. As result of undeveloped collateralized interbank market, banks tend to trade with counterparties they have information, which encourages segmentation and impairs efficiency of the interbank market in redistributing liquidity.

Participation in the interbank market is influenced by liquidity and the ease with which fluctuation in liquidity can be mitigated. In the EAC, particularly in Kenya, Uganda, Tanzania and Rwanda[10] banks hold excess liquidity in relation to the statutory minimum requirement of 20 percent. Kenyan banks tend to hold the highest liquidity, at 57.30 percent, followed by Ugandan banks at 47.58 percent. This is due to inefficiencies in the interbank market, which increases the cost of smoothening fluctuation in liquidity. As a result, banks self-insure against changes in liquidity by holding excess liquid assets instead of relying on the interbank market. In addition, counterparty risks also discourage banks from participation in the interbank market. Conversely, the liquidity levels in the banks depict stability conditions in the entire banking system, since highly liquid banks are able to fund assets and meet their obligations when they fall due.

Despite banks in the EAC holding excess liquid assets, which have low returns, they are profitable with high return on equity, implying efficient use of equity by banks in the region (**Table 3)**.

Table 3: Indicators of liquidity and profitability as at March 2021 (percent %)

	Liquidity assets to liquid liabilities	**Return on assets**	**Return on Equity**
Burundi	11.10	1.10*	10.00*
Kenya	57.30	2.65	21.96
Rwanda	35.90	2.88	11.78
Tanzania	35.57	2.40	10.01
Uganda	47.58	3.44	20.00

**refers to March 2020*

The asset quality, profitability and composition of assets and liabilities influence not only risk profile of counterparties and hence participation in the interbank market, but also susceptibility of the market to systemic risks. The differences in the risk profile of counter parties influences the volume, value as well as the lending rate in the interbank market, resulting to clusters. In the EAC, the interbank market is fragmented in clusters in which the intensity and the amount lend is high (Ndirangu *et al*., 2021; Mugenzi *et al.*, 2021 and Bwire, 2019). Furthermore, small banks borrow at relatively high interest rate and small amounts compared to large and medium

[10] These countries use a similar definition of the liquidity ratio that includes treasury bills and bonds as part of liquid assets. Liquidity ratio is the ratio of liquid assets/liquid liabilities

banks, due to perceived riskiness. The fragmentation of interbank market impedes distribution of liquidity, but reduces counterparty. The persistence of high liquidity, increase in financial interlinkages amid fragmentation of the interbank market calls for the analysis of the role of architecture of the interbank market in propagating systemic risk in the EAC.

3. Literature review

Two distinct schools of thought exist in the empirical and theoretical literature. One suggests 'incompleteness' may be a source of fragility as a bank is exposed to the liabilities of a few institutions and propagates to incomplete financial networks which limit exposure to counterparty risk thus reducing systemic failure. The second view is that interconnection in bank network leads to a more fragile financial system, as distress would spread faster. Acemoglu et al (2013 and 2015), provide a framework for analyzing financial network and systemic failure arising from contagion of counterparty risk. They find that when the number of negative shocks affecting the financial system was below a certain threshold, more complete interbank networks enhanced stability of the financial system. Thus, complete networks provided a way of redistributing losses as well as excess liquidity in the system. This finding is corroborated by Allen and Gale (2000). However, when the number of shocks was above a certain threshold, then interconnectedness led to systemic risk. In other words, the study finds the same factors that contributed to stability conditions also contributed to instability under different conditions.

Some studies advocate for more interconnectedness through participation of commercial banks in the interbank market (Hausenbals et al 2012 and Castiglionesi et al 2014) thereby reducing contagion risk. Participation in the interbank introduce an element of risk sharing (co-insuring) rather than hold liquid assets or use capital. Hausenbals et al (2012), using Czech's data for the period March 2007 to June 2012, examines the potential of contagion within the Czech banking system emanating from interbank exposure of banks through liquidity, credit and asset price channels. The study uses network analysis to explore the heterogeneity structure of the interbank market in Czech and also undertakes simulations using three versions of the model that capture likely contagion channels—credit, liquidity and asset price. The results reveal that contagion emanating from credit losses on interbank exposures was very low. However, introducing liquidity condition in the model, increased the contagion risk. Nonetheless, it remained relatively low when assets were considered. Overall, the study finds low systemic risk in the form of interbank contagion in the Czech banking system.

The relevant question that naturally arises from the foregoing is the relationship between bank capital and participation in the interbank market network. Castiglionesi et al (2014) examines the hypothesis that there is a negative relationship between bank capital and participation in the interbank market. Using bank data for 1995Q1 to 2008Q4, for US commercial banks, and a theoretical model, the study finds that banks that did not participate in the interbank market held more capital which was also costly. The study advocates for bank participation in the interbank market in order to diversify liquidity risk-interconnection.

Earlier empirical studies, in several advanced countries, have modeled the structure of the interbank market and the likely contagion risks thereof (Blavarg and Nimander (2002), Mistrulli (2005), and Iman and Franka 2006). The studies have used balance sheet or large

exposures data to proxy interbank structure. Blavarg and Nimander (2002) and Mistrulli (2005) use bilateral observed data to model contagion risk. Mistrulli (2005) concludes that for Italian banks, the estimation based on aggregate data underestimated the contagion risk. They also found that depending on the size of the interbank market, the presence of large banks, complete markets were more conducive to contagion than incomplete ones thus negating the notion that complete markets were more resilient to financial contagion.

Blavarg and Nimander (2002) and Iman and Franka (2006), show that risk of contagion mainly emanated from interbank exposure to foreign banks through exchange rate settlements and foreign borrowing exposures. Blavarg and Nimander (2002) in their study on Swedish interbank market, find that interbank exposures in the highly concentrated Swedish banking system were less than expected and main risk exposure to contagion emanated from abroad in the foreign exchange settlement exposures. Iman and Franka (2006) analyze the interlinkages and contagion risks in the Dutch interbank market. Using survey data and bank balance sheet data, the study uses entropy estimation to examine large exposures in the interbank market at bank level and also measures contagion risks. The study finds that bankruptcy of one large bank puts considerable burden on other banks but does not lead to a complete collapse of the interbank market. Moreover, they find exposures to foreign counterparties to be large and risk of contagion large, thus warranting more research.

Muller (2003) analyses the Swiss interbank market using new data from the Swiss National Bank. Applying network analysis, the study shows systemically important banks and possible contagion paths. The study introduces liquidity risk in the Swiss interbank market through the existence of credit lines but finds that such contagion effects are smaller compared with the credit risk exposures. Craig (2003) examines whether bilateral credit exposures between banks arising from overnight transactions in the interbank market, would cause systemic failure if one bank failed. The study based on US banks, while undertaking simulations, finds that multiple rounds of failures were unlikely, at lower rates. However, sudden illiquidity of a major institution would spread to other banks quickly and be systemic. Cocco, *et al.,* (2003) model lending relationships in the interbank market and the behavior of market participants, suggesting that such relationships are important in enhancing interbank activity and stability.

Elsinger et al (2006), assess risk for the Austrian banking system using network model of interbank credit. The study finds that correlation in assets increased exposure of banks to contagion and systemic risks more than financial linkages. In the event that contagion occurred, it would affect a big part of the banking system in Austria. The value at risk computed showed that a small amount of funds was needed to prevent a contagion from occurring.

The literature reviewed from advanced economies, gives us diverse findings. One, is that participation in the interbank market is appropriate for risk sharing, and thereby reduces contagion risk in complete markets. Two, some studies find that contagion is present in complete markets compared to incomplete ones and negates the notion that complete markets were more resilient to financial contagion. Three, other studies find that large interbank exposures to foreign banks and foreign exchange settlements were the source of systemic risks while others have shown that a contagion may arise whenever centrally placed banks in

provision of liquidity collapsed. Therefore, literature is divergent and inconclusive in its finding on assessment of structure of the market and its impact on contagion or systemic risks.

In the context of EAC, there exist a few country-specific empirical studies that have attempted to understand the interbank market particularly covering segmentation, efficiency, price discovery, regulation, market discipline and its microstructure as well as the network structure. For example, Oduor et al (2014), Murinde et al (2018), Tiriongo and Kanyambu (2019), Ndirangu et al (2021) and Mugenzi et al (2021) use network method to analyse segmentation, efficiency and propagation of risk in interbank market, while Bwire et al (2019) analyse effectiveness of interbank interest rate as an indicator of financial stability of banks. The literature on the interbank market finds evidence that similar structures in assets and liabilities that elevate systemic risk, depending on the topology of the interbank market. However, some studies find that trading in the interbank provides risk insurance as the risk is co-shared among many banks, thereby reducing systemic risk. there is also consensus in the literature that large exposures to domestic or foreign banks in the interbank is a source of systemic risk.

However, studies in advanced economies and EAC have not focused on the impact of heterogeneity in assets on systemic risk and how they propagate systemic risks across banking systems. Moreover, the studies have extensively covered other aspects of the interbank markets in Kenya, Uganda and Rwanda; without examining cross-border contagion risk and its determinants. Yet, integration of East African Countries and establishment of subsidiary banks in the EAC has increased cross border interlinkages, which elevate contagion and systemic risks. This study attempts to fill these gaps by analyzing the structure of interbank market and then establishing common exposures across the EAC countries, to shed some light on the impact of architecture on systemic risk. Additionally, this paper extends discourse on the interbank market by analyzing the interconnection that is anchored on the composition of the assets and its contribution to systemic risk.

4. Methodology

This paper analyses linkages in the banking sector and their impact on systemic risks. The interbank market generates assets and liabilities in the banking sector. A default on liabilities by one bank in the interbank market, may cause other banks to default, triggering a domino effect in the banking sector. These interlinkages in the interbank market can be described using a network analysis method. The network analysis method quantifies the intensity, the direction and quantum of interbank transactional relationship. As a result, the network method traces the distribution of liquidity and exposure in the interbank market.

Furthermore, similarities in balance sheets and income statement structures increase correlation of the portfolio. The commonality in the data is effectively captured by machine learning technique. In particular, we exploit Latent Dirichlet Allocation (LDA) Blei et al. (2003), to identify commonality in the normalized data and the underlying relationships among banks. The LDA involves normalizing the accounts in financial statement for banks and then draws accounts and banks based on the analysis of variance of normalized data. The clustering of accounts and banks is based on the sum of squares, whereby for each cluster the between sum squares are the maximised, while within cluster sum of squares are minimized. The LDA assignment ensures that the mean deviations of each bank and the accounts is largest between clusters and the smallest within clusters. As a result, banks and accounts that are similar and

highly correlated will be assigned on the same tree and the same branch or on the same dendogram in dichotomy. This develops a network of relationships among banks and account, whereby the distance and size of the edge indicates proximity and similarity. The LDA technique also computes correlation matrix and generates risk heat map, which shows correlated exposures in the banking sector (Edwards & Cavalli-Sforza, 1965 and Everett *et al*.,2011). Correlated exposure can be accentuated by economic shocks to become systemic risk in the banking sector. One of the common exposures linked to economic cycle is sectoral loans. In this regard, we generate correlation matrix and interlinkages by sector using LDA.

Whereas LDA identifies commonality and hence relationship in the interbank market, it cannot show the drivers of commonality in asset and liabilities. Proximate drivers of liquidity risk include economic performance, bank management, capital, and lending practices. Altman (2000) and Mercieca et al. (2007) argue that financial stability of banks can be summarized using Z score measure, given as:

$$Z\ score = \frac{RoA - \frac{Equity}{Assets}}{\sigma(RoA)} \qquad [1]$$

However, the Z score and Value at Risk (VaR) are bank specific and do not consider the contribution of each bank to aggregate stability. In this regard, expected short fall given by two standard measures of firm-level risk are (VaR) and expected shortfall (ES). These seek to measure the potential loss incurred by the industry as a whole in the event of an extreme shock. Specifically, VaR is the maximum loss that a bank incurs measured with 1−α confidence, where $\Pr(R - VaR_{\propto}) = \propto$. The parameter α is taken to be 5%, so that bank losses are determined at 95% confidence. The ES is the expected loss as a result of default in the interbank loan conditional on the loss being greater than the VaR:

$$ES_{\propto} = -E[R|R \leq -VaR_{\propto}] \qquad [2]$$

The expected shortfall is the average of returns when the portfolio's loss exceeds its VaR limit. We focus on ES rather than VaR for several reasons. First, VaR is not robust given that it is asymmetric, and that very risky investment may not produce a large VaR. The reason is that if the negative payoff is below the 5% VaR threshold, then VaR does not capture it. In contrast, ES does not suffer from this problem since it measures all the losses beyond the threshold. This distinction is especially important when considering moral hazard of banks in the interbank market, because the large losses beyond the VaR threshold are often borne by the lender of last resort or the Government. Second, VaR is not a coherent measure of risk because the VaR of the sum of the assets of two banks can be higher than the sum of their individual VaRs, which cannot happen with ES (Artzner et al. 1999).

Consider the EAC banking system constituting a number of banks. Therefore, to examine the expected shortfall of the overall banking system, we let R be the return of the aggregate banking sector in the EAC. Then each bank's contribution to this risk can be measured by changes in the ES, the marginal expected shortfall (MES). MES is the measure of the contribution of the banking sector in country i to the regional systemic risk that is influenced by the propensity to undertake risky investment and liquidity conditions in the banking sector. The macroeconomic environment accentuates idiosyncratic shocks, which metamorphose to systemic risks. In this regard, proximate drivers of MES include, core capital (K), liquidity in the banking sector proxied by interbank interest rate (IBR), output gap Y and the gap between private sector credit

and output trend Z and heterogeneity of assets. Heterogeneity in assets is measured by the Hirschman Herfindal index[11] .in this regard, estimable equation can be specified as follows

$$MES_{it} = \beta_0 + \beta_1 k_{it} + \beta_2 IBR_{it} + \beta_3 Y_{it} + \beta_4 Z_{it} + \beta_5 H_{it} + \varepsilon_{it} \quad [3]$$

Where MES is marginal expected shortfall, k_{it} core capital, IBR_{it} liquidity in the banking sector proxied by interbank interest rate (IBR), Y_{it} output gap, Z_{it} the gap between private sector credit and output trend Z and H_{it} heterogeneity of assets. ε_{it} is the error while β_i where $i = 0 \ldots 5$ are coefficients

A fixed effects model for equation 3 is estimated based on the results from Hausman test [12]. This paper utilizes bank level data for the period 2010 to 2020 on interbank, balance sheet and profit and loss data sets collected from the EAC central banks. The countries included in study are Kenya, Uganda, Tanzania, Rwanda, and Burundi.[13]

5. Results

The interbank market in the EAC consists of banks that borrow and lend to manage liquidity and earn returns on excess liquidity. Table 4 provide a summary of network metrics for interbank markets in the EAC region observed as averages per month. The degree measure indicates that, on average, about 12 lending and borrowing transaction occur in Tanzania, while Rwanda had an average of 7 transactions per bank per month. This indicates that the frequency of lending and borrowing in Tanzania is the highest and lowest in Rwanda.

Table 4: Metrics describing the architecture of the interbank market in the EAC

	Burundi	Tanzania	Uganda	Kenya	Rwanda
Degree	9.600	12.474	7.500	8.222	6.615
In-Degree	6.800	8.816	6.500	4.250	4.154
Out-Degree	6.800	8.816	4.000	4.250	4.154
Betweenness Centrality	4.400	27.526	27.776	34.556	6.000
Closeness Centrality	0.056	0.016	0.021	0.015	0.057
Eigenvector Centrality	0.067	0.026	0.021	0.028	0.077
PageRank	1.000	1.000	0.698	1.000	1.000
Clustering Coefficient	0.642	0.479	0.220	0.239	0.475
Reciprocated Vertex Pair Ratio	0.369	0.331	0.214	0.041	0.198
Density	0.486	0.238	0.306	0.121	0.346
Diameter	2	3	3	4	3

Notes: Degree refers to average number of lending and borrowing, In-degree refers to average number of borrowing transactions, out degree refers to number of lending transactions, betweenness centrality is the number of shortest paths from all vertices to all others that pass through it, Closeness Centrality measures the speed at which liquidity is distributed through the network from a specific bank, The Eigenvector Centrality metric takes into account the number of connections a vertex has (i.e., it's Degree), but and the degree of the vertices that it is connecting to, Density is a ratio of the number of

[11] The diversification index is a Hirschman Herfindal index of balance sheet assets. An increase in the index implies a decline in the diversity of assets, implying that the banking sector has a narrow range of assets.

[12] In the Hausman test, a random effects model is preferred to deliver higher efficiency, while a fixed effects model is preferred under the alternative hypothesis – considered efficient.

[13] South Sudan is excluded due to unavailability of data.

observed edges (m) to possible number of edges (n). Diameter, of a network having N nodes is the longest of the shortest distance between any two nodes, D = max {minp[gij], distance(l)}.

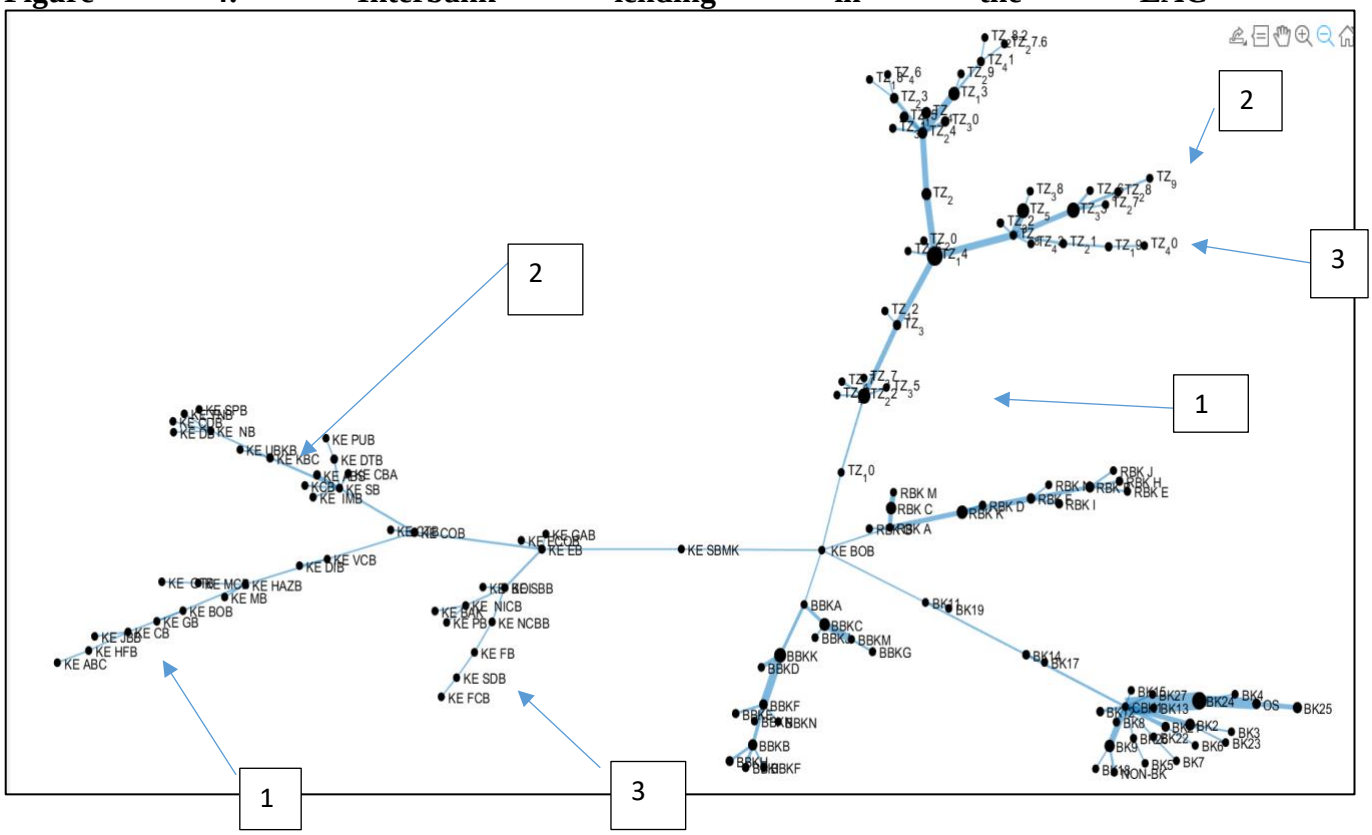
The reciprocated pair ratio in table 1 shows that banks in Burundi have higher number of bilateral borrowing/ lending relationship than banks in Tanzania, Burundi, and Uganda. However, in the Kenyan interbank market, there are about 34 short paths between sets of possible pairs of banks undertaking lending and borrowing, as depicted by the betweenness centrality measure. This implies that interbank market in Kenya, has a higher number of intermediary banks, which enhances distribution of liquidity in the banking system. The closeness centrality indicates that the Kenyan interbank market is the most efficient in spreading liquidity in the banking system relative to interbank market in Tanzania, Uganda, Burundi, and Rwanda.

Whereas it is easier for banks in Kenya to obtain liquidity through the least number of intermediaries, the dense interlinkages increase propensity of contagion risk. In addition, a default by one borrower would affect a higher number of banks in Kenya due to the many banks borrowing and lending in the interbank market; a finding corroborated by Ndirangu et al (2021). Conversely, the clustering coefficient for Burundi indicates that the interbank market is the most segmented, followed by Tanzania and Rwanda. On the one hand, segmentation curtails the distribution of liquidity in the interbank, because banks are more likely to borrow and lend in a cluster and not from a bank with either excess or inadequate liquidity, respectively. On the other hand, segmentation reduces default risk due to banks undertaking transactions with counter parties known to each other.

The diameter indicates that isolated banks in the interbank networks have 2 intermediaries to obtain liquidity or lend in Burundi. However, banks in other EAC countries have 3 to 4 intermediaries, implying that isolated banks have greater difficulties in obtaining liquidity or lending excess liquidity. As a result, the exposure of isolated banks to systemic risk in Burundi is higher compared to Kenya, Uganda, Tanzania, and Rwanda.

The existence of subsidiaries of Pan-African banks and multinational corporations in the EAC enhance distribution of liquidity through the interbank market in the region. The regional interbank market is nonexistent, while data on cross border lending among subsidiaries or other banks is scanty. In this regard, we use correlation in interbank lending to examine lending relationship in the region. Figure 4 indicates that intensity of interbank lending occurs within country. The within country interbank relationship is characterized by segmentation in terms of banks' origin, government ownership and pan African orientation. For example, in Kenya, Pan African banks are clustered on branch labeled 1, banks with significant Government stake are on branch 2, while Pan African banks are on branch 3. The regional link is provided by Pan African Banks such as KE SBMK, KE BOB, TZ10, BBKA, BK 11 and RBKA in Kenya, Tanzania, Burundi, Uganda, and Rwanda, respectively.

Figure 4: Interbank lending in the EAC



The transmission of risks in the banking sector is correlated with diversity of assets, liabilities, income and expenses. Table 5 indicates the correlation of balance sheets and income statements of banks within countries and in the EAC region.

Table 5: Correlation between balance sheet and income statements

COUNTRY	National level		EAC	
	Balance Sheet	Income statement	Balance Sheet	Income statement
Burundi	20.367	21.667	0.233	0.300
Kenya	14.333	16.433	11.167	8.033
Tanzania	17.450	19.200	4.700	5.100
Uganda	17.400	18.333	2.467	2.367
Rwanda	18.325	17.900	1.225	1.300

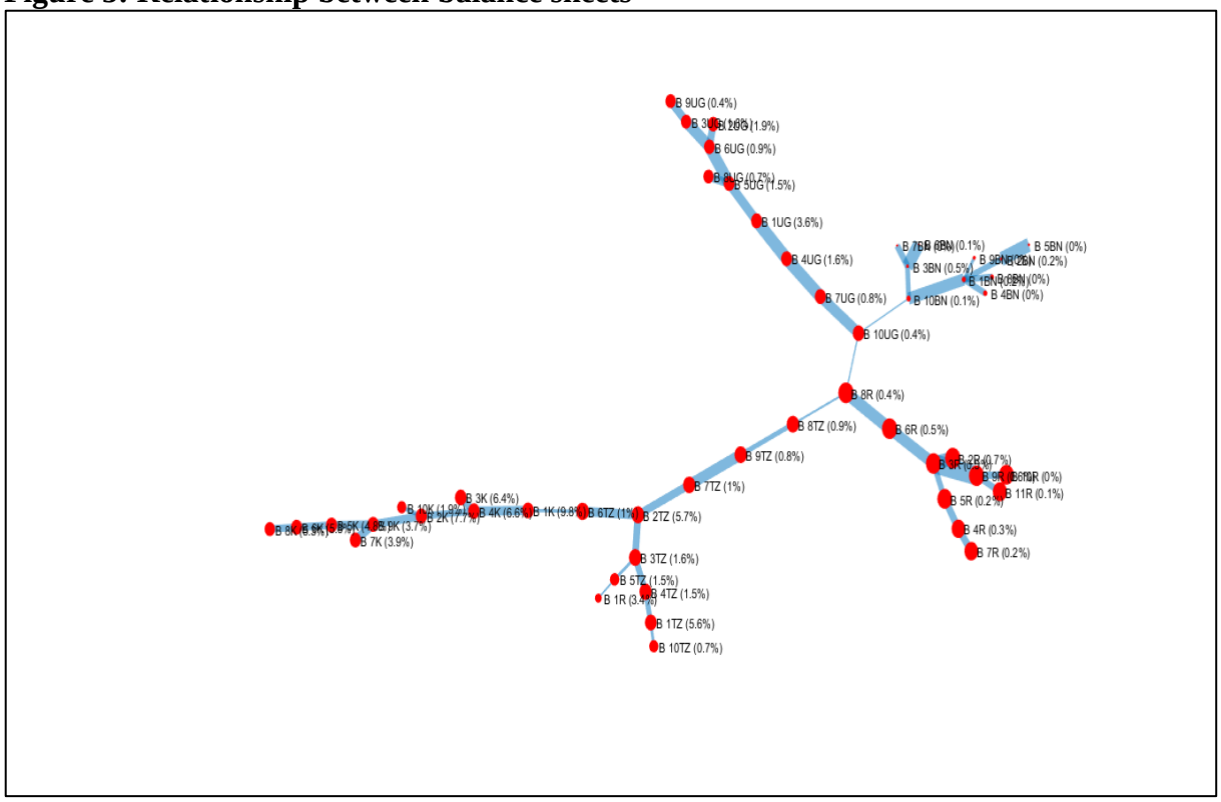
Source: Author's computation

A high correlation indicates that assets liabilities, revenue sources and expenditure items consitute a large proportion of the banking sector and the accounts in balance sheet and profit and loss account are similar to the banking industry at national and in the EAC. The results indicate that balance and income statement have a higher correlation in Burundi compared to banks in other EAC countries. This implies that the assets and liabilities in banks in Burundi are more homogenous compared to banks in Kenya, Uganda, Tanzania and Rwanda. Hence, banks are closely related in Burundi comapred to banks kenya, Tanzania, Rwanda and Uganda. However, at regional level, balance sheet and income statement for banks in Kenya is highly correlated with banks in the EAC. This is due to establishment of subsidiaries in the EAC. Subsidiaries enhance linkages in the region, through common management, investment

strategy and provide a conduit of risk. Banks in burundi have the lowest correlation, implying that they are peripheral in the EAC banking system. The balance sheet relationship among banks is indicated in figure 5, while relationship in their income statements is shown in figure 6.

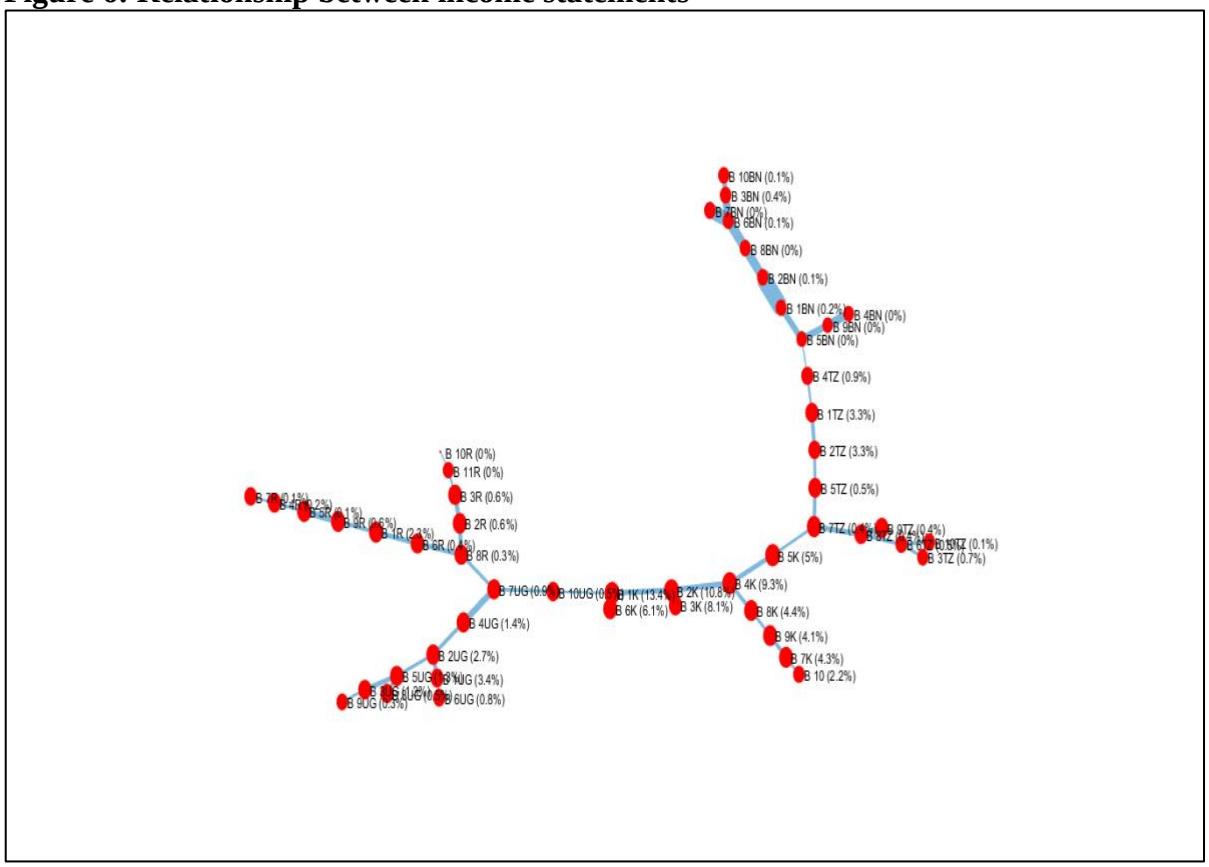
Figure 5 indicates that balance sheet structure of kenyan banks is closely related to the balance sheet structure of banks in Tanzania. The structure of balance sheet of Ugandan banks is also related to that of banks in Burundi and Rwanda. Banks in Tanzania provide a link between banks in Kenya and Uganda, Burundi and Rwanda. This is implies that their exist interlinkages among banks in the EAC.

Figure 5: Relationship between balance sheets



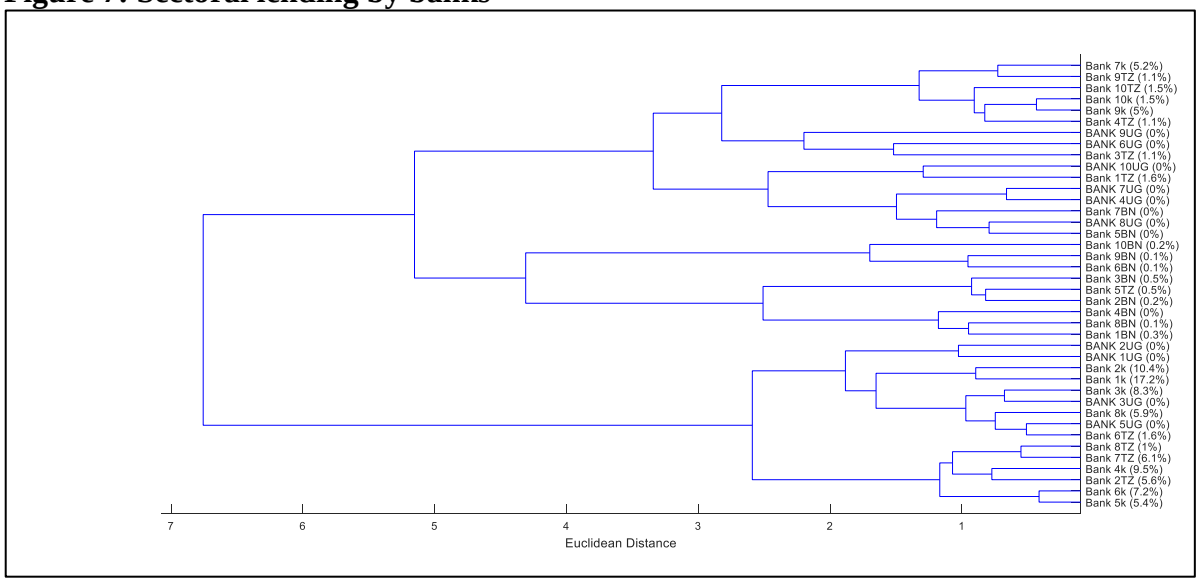
Income statement of banks in Kenya is strongly linked to income statements of banks in other EAC countries (Figure 6). The link between banks in Rwanda and Uganda on the one hand and banks in Tanzania and Burundi is provided by banks in Kenya. Hence, balance sheet risks and a decline in profitability can be transmitted in the region from banks in Kenya.

Figure 6: Relationship between income statements



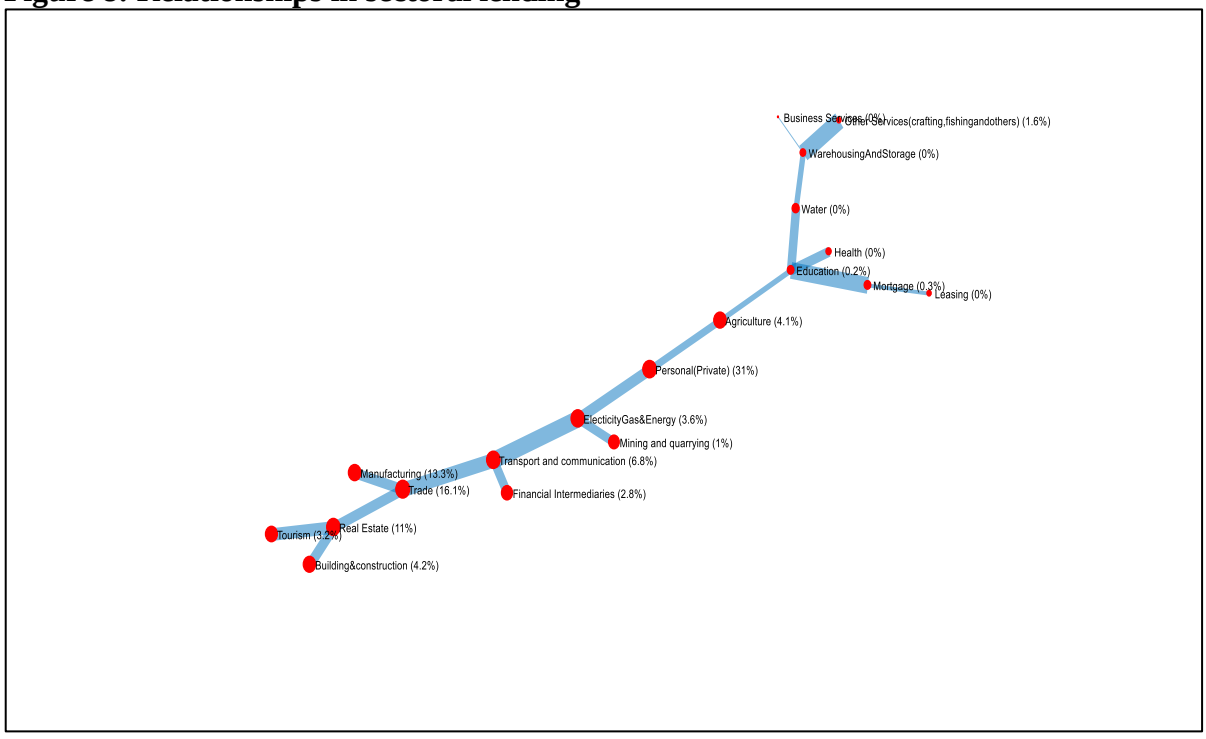
The EAC economies are predominantly agricultural, but lending is not only concentrated in manufacuring, real estate, trade and households. Concentration of loans in a few sectors of the economy by the banking sector increases the correlation between assets and sectroral performance. In figure 7, banks on the same tree have similar loan allocations. Similarity in leading increases exposure to systemic risk.

Figure 7: Sectoral lending by banks



In **figure 8**, banks in Kenya, Uganda and Tanzania have similar sectoral lending patterns. The loan portfolio is also concentrated in sectors that exhibit growth nexus such as trade, electricity, transport and communication, tourism, real estate and construction. This increases vulnerability of banks to the economic performance of the sectors. In particular, shocks in the sectors in which credit is concentrated can be transmitted to other banks due to interlinkages.

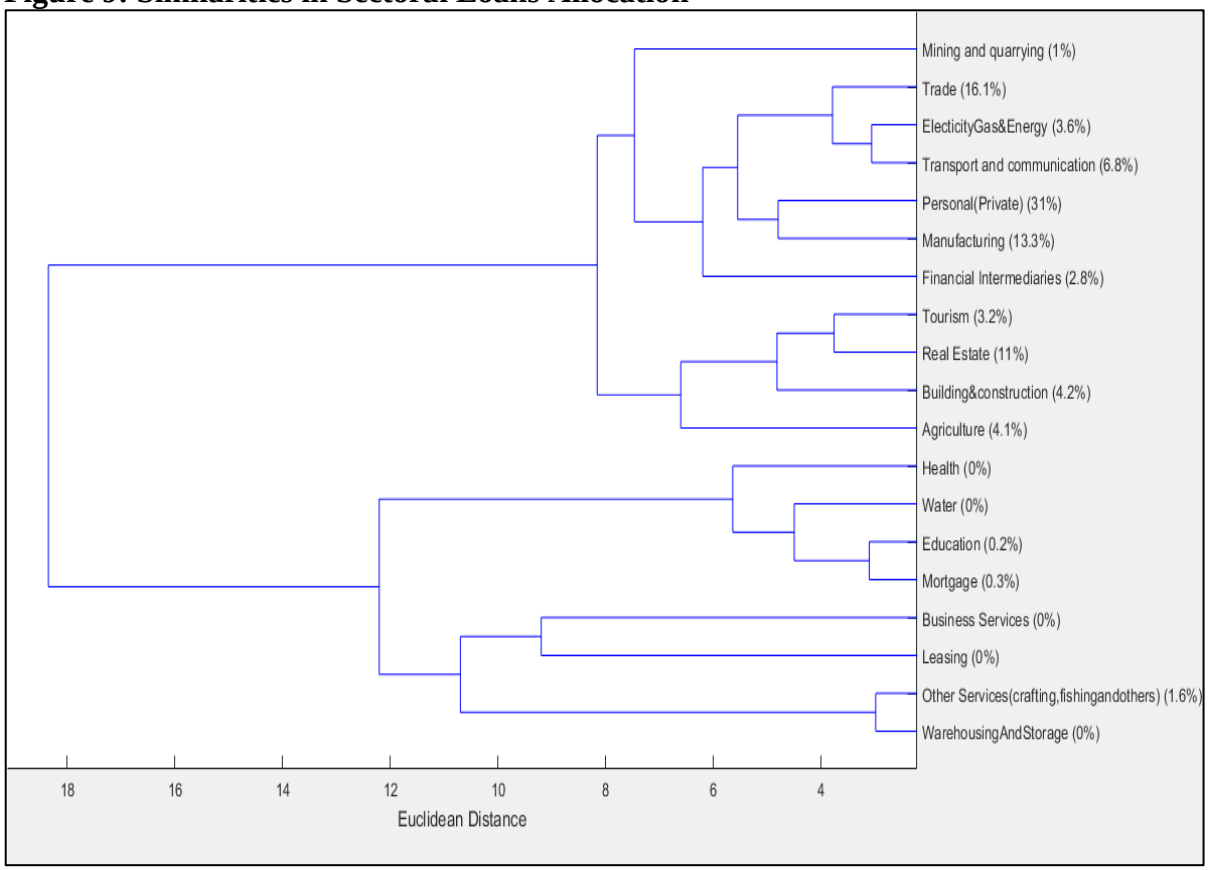
Figure 8: Relationships in sectoral lending



Indeed, figure 9 shows that portfolio allocation is highly correlated, with trade, manufacturing and transport and communication accounting for the largest allocation in the region. Impediments to trade in the region could undermine manufacturing and transport activities. As

result, the ability to service loans extended to trade, transport and manufacturing sectors may decline, elevating credit risk in the region.

Figure 9: Similarities in Sectoral Loans Allocation



5.1 Results: systemic risk and heterogeneity of assets

The interbank market enables banks to obtain liquidity from banks with excess liquidity. However, interbank transactions generate counter party risk, which may metarmophose to systemic risk due to interlinkages in the banking sector. In this regard, the exposure of the banking sector to systemic risk is proxied by MES, which is influenced by economic conditions, liquidity in the interbank market, level of capital and heterogeity of assets. **Table 6** shows regression results for drivers of systemic risks propagated through the interbank market.

The results in column 1 indicates regression of the Z-score on interbank rate, Hirschman Herfindal index and private sector credit and output. An increase in interbank rate reduces the score, while a decline in heterogeneity of assets reduces Z-score of the banks. However, the decline in the Z-score is not statistically significant. An increase in lending to the private sector increases stability of the banking sector. Despite the Z-score being a proximate measure of bank stability, it does not capture contribution of a bank to instability of the banking sector. In this regard, we estimate bank wide instability as a result of trading in the interbank market. The results are presented in **Table 3** columns 2 to 4.

Table 6: Fixed effects estimation for Systemic risk

	Z-score	MES (Full sample)	MES (Full sample)	MES (Domestic banks)	MES (Pan-African Kenyan banks)	MES (Pan-African South African & Nigerian banks)
	1	2	3	4	5	6
IBR	-0.183**	0.004**	0.006**	0.006***	0.020	0.023
	(0.070)	(0.002)	(0.001)	(0.002)	(0.054)	(0.045)
H	-2.552	0.208**	0.241**	0.214***	0.579*	0.584*
	(3.409)	(0.091)	(0.085)	(0.094)	(0.274)	(0.282)
Capital	-0.119	0.325***	-0.011	-0.008	-0.326	-1.248
	(2.401)	(0.036)	(0.048)	(0.067)	(0.824)	(0.953)
LPSC	7.866*	0.362**	0.444***	0.383***	2.973**	2.300*
	(4.489)	(0.107)	(0.152)	(0.125)	(1.515)	(1.923)
GDP	-8.760		-0.404**	-0.106	-9.731	-7.365*
	(10.278)		(0.224)	(0.275)	(4.001)	(3.345)
constant					7.291	7.210
					(0.844)	(0.791)

*Notes: The dependent variable is the marginal Expected shortfall, GDP output growth rate. GDP is the deviation of output from potentailoutput.potential output is the trend obtained using Hodrick prescot filter IBR interbank rate, H is the Hirschman Herfindal index and PSC is private sector credit gap. (..) are standard errors. *10% ** 5% *** 1% denote levels of statistical significance.*

The results show that an increase in interbank rate by 1 percent increases MES by 0.04 percent. Trading in the interbank market exposes banks to counterparty and liquidity risks. Whereas a decline in the number and value of transactions, indicates a reduction in the trading activity to minimize counter party risks, an increase in interbank rate elevates liquidity risk as well as counterparty risk. The increase in risks in the interbank market have domino effect on the liquidity in the banking sector, which increase marginal expected shortfall in the banking sector. A decline in the diversity of assets increases marginal expected shortfall by about 20.8 percent. This implies that returns on a narrow range of assets is highly correlated not only in a portfolio of a bank but also in the banking system. As a result, shocks in the portfolio elevate value at risk from interbank investment and in the entire banking sector. Bank capital is positively related to MES, indicating the role of capital in enhancing a bank's capability to lend. This is contrary to the restraint in risk taking that capital imposes on managers and owners of the bank. Another possible explanation for positive impact of capital on systemic risk is that, large capital enables banks to accumulate diverse assets and hence have interlinkages with many firms within country and in the EAC, which increases exposure to systemic risks (Caccioli et al. 2014; Caccioli et al. 2015).

Results in column 2 controls for output and private sector credit gaps. An increase in the output reduces systemic risk. A robust economic growth improves customers' ability to repay loans, which reduces value at risk as well as marginal expected shortfall. An increase in interbank rate by 1 percent increases MES by 0.006 percent, while a decline in asset heterogeneity increases MES by about 24.1 percent. This indicates that heterogeneity of assets has a larger

impact on systemic risk than economic growth and capital. The pooled results in column 3 in table 6 are consistent with results in column 1 and 2, except for GDP (output).

Results in column 4 are for domestic banks. The coefficient for interbank interest rate, heterogeneity and private sector credit is also almost of the same size as the respective coefficients for the entire sample. This implies that a decline in liquidity in the interbank market have domino effect on the liquidity in the banking sector, which increase marginal expected shortfall . However, increase in heterogeneity of assets reduces systemic risk. Results in column 5 and 6 presents are for Pan African Kenya banks and Pan African South African-Nigerian banks, respectively. The results indicate that a decline in heterogeneity of their assets increases systemic risks by about 58 percent. This can be attributed to the banks being large relative to the banking sector and interbank market in the EAC region. An increase in capital reduces systemic risk, while lending to private sector increases systemic risk. The results in section 3.1 indicate that the assets and liability as well as income statements of banks in the EAC region are highly correlated. Therefore, systemic shocks in one EAC country can be transmitted to other economies, which could undermine stability of banking system in the region.

6.0 Conclusion

This paper analyses interconnectedness of the banking sector and its impact on systemic risk in the EAC. The analysis indicate that the interbank market is more segmented in Burundi compared to Kenya, Uganda, Tanzania, and Rwanda. As a result, banks in Burundi are least susceptible to contagion risk compared to other EAC banks. The interconnectedness among banks in Kenya is higher, enabling banks to access liquidity in the interbank market with ease as compared to banks in Rwanda, Uganda, Tanzania, and Burundi. Pan African Kenyan, South African and Nigeria banks provide linkages in the EAC. However, the linkages among banks in the region are anchored on similarities in assets and liabilities as well as income statement that tend to elevate systemic risks. The systemic risk emanates from exposure to concentration of loans to trade, manufacturing and transport and communication.

In addition, the paper analyses the drivers of systemic risk in the interbank bank market. The MES is positively correlated with interbank rate, private sector credit and homogeneity of assets. This indicates that there is evidence for diversity of asset, robust economic growth and increase in interbank interest rate reducing systemic risks. However, capital has no statistically significant impact on systemic and enhance its price discovery mechanism, and encourage diversification of loan portfolio as well as assets and liabilities, to reduce systemic risks in EAC. Options for market deepening include expanding the scope of traded instruments, the currency mix, and establishment of collateralized markets to mitigate counterparty risk.

Appendix Table 1: Dataset and sources

Dataset	Variables	Frequency	Source of data	Sample period
Interbank data	Amount lender	Monthly	Central Banks	2010-2020
	Interest rate	Monthly		2010-2020
	Type of the bank-foreign or domestic	Monthly	Central Banks	2010-2020
Balance sheet	Loans and advances	Quarterly	Central Banks	2010-2020
	cash	Quarterly	Central Banks	2010-2020
	Government securities	Quarterly	Central Banks	2010-2020
	Placement	Quarterly	Central Banks	2010-2020
	Deposits	Quarterly	Central Banks	2010-2020
	Loans borrowed	Quarterly	Central Banks	2010-2020
	Securities issued	Quarterly	Central Banks	2010-2020
	Core capital	Quarterly	Central Banks	2010-2020
	Retained earnings	Quarterly	Central Banks	2010-2020
Sectoral loans	Agriculture	Quarterly	EAC dashboard	2010-2020
	Financial Intermediaries	Quarterly	EAC dashboard	2010-2020
	Mining and quarrying	Quarterly	EAC dashboard	2010-2020
	Manufacturing	Quarterly	EAC dashboard	2010-2020
	Building & construction	Quarterly	EAC dashboard	2010-2020
	Real Estate	Quarterly	EAC dashboard	2010-2020
	Mortgage	Quarterly	EAC dashboard	2010-2020
	Leasing	Quarterly	EAC dashboard	2010-2020
	Transport and communication	Quarterly	EAC dashboard	2010-2020
	Trade	Quarterly	EAC dashboard	2010-2020
	Tourism, Hotels and Restaurants	Quarterly	EAC dashboard	2010-2020

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