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The Role of the transport sector in the linkages between Northern Cape and the rest of South Africa: An economic base and network analysis approach

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Abstract

Northern Cape has been one of the provinces that make a relatively small contribution to South Africa's gross domestic product. However, there is room to improve the province's contribution through enhanced connectivity with the rest of the provinces and targeting specific industries with high concentration. The question that remained unclear was how the transport sector facilitates the linkage within the Northern Cape and between the Northern Cape and the rest of South Africa. This paper investigated this issue using an approach that employed Network and I-O analyses. The economic analysis reveals that Northern Cape's Other mining and quarrying sector is the most concentrated. However, the 'transport and storage' cluster is also among the strong sectors in the Northern Cape. Network analysis shows that the mining industry, metals, and agriculture are Northern Cape's anchors, while transport and storage are among the few sectors that show significant intra- and inter-regional linkages. The results of this study provide important insights into the industries that should be actively cultivated to maximise their economic contribution. Policymakers can categorise the sectors into different clusters as 'mature', 'star', 'transforming', and 'emerging'; each cluster necessitates a customised policy decision.

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1. Introduction

The role of transport in societies and economic development is well-established in the literature. Early theories such as Rostow (1959) underscored the necessity of transport infrastructure development, which is vital in the take-off stage of development. Among the critical implications is that the availability of better transport services in a country or region creates a competitive advantage. Nevertheless, of note in the field of geography is the claim that the development of a region may generate critical spillover effects that can boost the surrounding areas. Lychagin, Pinkse, Slade, and Reenen (2017) established that physical location is essential for productivity, just as technology spillovers, and that intra- and inter-regional spillovers matter. There has been a push for regional integration (both country and municipal levels) meant to narrow income gaps, among other objectives.

South Africa has nine provinces (Northern Cape, Western Cape, Eastern Cape, Free State, KwaZulu-Natal, North West, Gauteng, Limpopo, and Mpumalanga) and the performance of each province is reported, including employment, output and trade from each sector. These provinces are not equally strong. For instance, despite a small land size, Gauteng has been the country's economic centre, while Northern Cape has been amongst the smaller players (Stats SA, 2019). However, it is noted that agriculture, forestry and fishing, and mining and quarrying have been vital sectors in the Northern Cape. Given this background, critical analysis is required regarding the concentration and linkages of the various sectors in the Northern Cape and the rest of South Africa. This article seeks to investigate the connectivity of the Northern Cape and its various sectors using economic, network, and spatial analyses. In line with Hirschman's (1957) viewpoint, this analysis allows practitioners to target specific sectors that promise to boost economic growth. Such sectors have a strong connection with others.

This paper's remainder is structured as follows: In section 2, we discuss the relevant literature on the importance of transport as an enabler of connectivity to support economic activity, especially for remote and sparsely populated regions. In section 3, we explain our methodology and data used. Section 4 presents the analysis of intra- and inter-regional economic linkages between the Northern Cape and the rest of South Africa, focusing on the transport sector's importance, while section 5 concludes.

2. Literature

2.1. *Concept of connectivity*

Multiple definitions of connectivity exist. In short, connectivity is defined as "the degree to which two things are connected" (Oxford Dictionary, 2020). Connectivity is essential to most countries' policy agendas and sub-national regions, such as provinces and metropolitan or local municipalities. Therefore, connectivity can be explored at different scales, i.e., locally, within-country, cross-country regions, and globally.

To assist in understanding connectivity, the World Bank (2019) responded to what is meant by connectivity by expressing that an intrinsic characteristic of connectivity is that it is synonymous with networks, a set of interconnected nodes. Such nodes can be a person, a firm, a city, a country, or other spatial entity. Therefore, connectivity is a multi-layered concept comprised of different networks, including both physical and virtual (Roberts, 2019). This implies that connectivity, which facilitates access to markets, has hard and soft dimensions and includes access concepts that determine the impacts experienced by households, firms, cities, countries, and regions (World Bank, 2019).

Connectivity is, therefore, an attribute of a network. It also measures how well connected any one node is to all other network nodes. The value of connectivity and its significance lies in the role that a node and its hinterland play or are expected to play within a network, the cost of accessing that node, and the reliability of connecting to the node (OECD, 2018).

According to Rodrigue (2017), connectivity has three dimensions: economic, network, and spatial. These three dimensions are important, as they speak to the connectivity within the Northern Cape and between the province and the rest of South Africa. Therefore, it is necessary to include them when analysing to ensure that each dimension's critical linkages are considered and measured. The following brief synopsis (based on Rodrigue, 2017) relates to connectivity's main dimensions (or effects).

The first dimension (or effect) of connectivity is economic connectivity. Economic connectivity concerns interactions made possible between actors such as producers, retailers, or wholesalers. Thus, an increase in connectivity enables less costly commercial interactions, resulting in more trade opportunities. Economic connectivity outcomes are often difficult to predict, as commercial decisions about, for example, importing and exporting are made by numerous entities (called beneficial cargo owners (BCOs)). These entities make their assessments and independently act upon them, thus complicating predictability. The interlinked nature of industries (another form of economic connectivity) within the Northern Cape and between the Northern Cape and the rest of South Africa determines the spillover effects across industries and beyond the geographic areas where the activities are located, propagated through the various industry value chains (Rodrigue, 2017).

The second dimension (or effect) of connectivity is the network. The network involves the configuration of transport services and physical infrastructure between nodes. Here capacity, reliability, and even resilience are essential attributes. Connectivity remains strongly dependent on transportation networks that provide the physical capability to reach places through a single or a series of modes. Actors in the network include the terminals that provide intermodal handling of flows, the modes (e.g., maritime shipping, air, rail, or road transport) that handle the movements between nodes, the shippers (e.g., companies themselves or their logistics service providers) that organise the distribution of cargoes and infrastructure managers (e.g., port authorities, transport ministries) that maintain and expand nodes and modal links (Rodrigue, 2017).

The third dimension (or effect) of connectivity is the spatial structure. Nodes service spatial entities such as metropolitan areas or regions that act as their hinterland, which makes connectivity a critical element of spatial competitiveness. For example, the outcome of connectivity differences is usually the clustering of activities around the most connected nodes, resulting in inequalities in opportunity development. Consequently, governments and civil society have an interest in maintaining and improving connectivity, as it directly impacts their territories. As such, the spatial structure is subject to policy interventions (Rodrigue, 2017).

This paper focuses predominantly on the economic dimensions of connectivity regarding the transport sector's facilitating role within the Northern Cape and between the Northern Cape and the rest of South Africa. For this reason, the section sub-section discusses the concept of economic connectivity a bit further.

Concept of Economic Connectivity

Economic connectivity between different spatial scales is the ability to trade goods and services in markets at a local, metropolitan, provincial, national, and international level (Berube & Parilla, 2012). Access to markets is facilitated by physical (hard) and non-physical (soft) connections (illustrated in Figure 1). While traditionally access to markets was mainly through physical means whereby traders move physically from one place to another using various transport modes, nowadays mainly through technology, traders can easily access even international markets through virtual means. What is interesting though as shown in Figure 1 is the interaction between physical and virtual infrastructure.

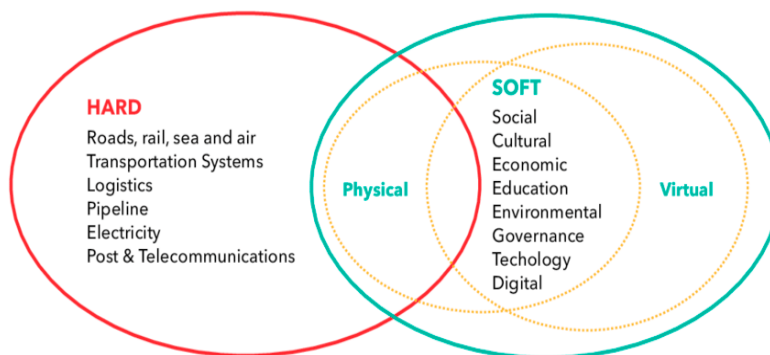


Fig. 1. Inter-relationship between hard and soft connectivity and network infrastructure.

Source: Roberts (2019)

In terms of access to markets, this is where one may use virtual or non-physical infrastructure to access markets, but there will be a role played by physical infrastructure such as transport in moving the goods from point A to point B. Reducing transport costs can improve physical access to markets and enable businesses to move goods more quickly. Soft infrastructure, such as strong business relationships, the right commercial access, trade agreements between countries, and access to connective technology, is equally important (Roberts, 2019). By their nature, some businesses focus on the local (domestic) market. For example, demand for health and community services is primarily driven by local consumption, as they serve specific local needs and focus on relatively small local markets. However, other industries, particularly primary producers, are more outwardly oriented and have more substantial export potential. Growth in these sectors is greatly aided by building more and better-quality connections (and access) to larger trade markets beyond the local market's borders (Department of Regional Australia, Local Government, Arts and Sport, 2013).

Regions well connected to large or diverse markets can access a broader range of potential customers. Greater market access allows local businesses to grow by trading more goods and services. Further, producing on a larger scale can help businesses bring down costs through economies of scale, making them more competitive. However, when entering a new market, producers must have the knowledge and ability to provide attractive goods and services that meet local regulatory requirements, such as safety and quality standards. Connections and access to markets are not solely restricted to building international links. Connecting with other South African areas can impact the Northern Cape's economic development in a similar way to international trade, supporting businesses that operate across multiple sub-national regions (Department of Regional Australia, Local Government, Arts and Sport, 2013).

Greater access to markets opens the door to new investment and innovation by sharing information, knowledge, and technology. Furthermore, greater access to multiple markets of the sub-national regions or countries also creates the opportunity to purchase from a broader range of sellers. It provides a wider choice of suppliers and can potentially lower costs. Moreover, consumers benefit from access to a more extensive range of goods and services (Roberts, 2019).

Therefore, economic connectivity is a key factor driving sustainable local economic growth and is a fundamental precondition for private sector investment that sustains economic growth (Department of Regional Australia, Local Government, Arts and Sport, 2013). Consequently, all government levels should support these preconditions to maximise investment attractiveness and business retention in the Northern Cape.

2.2. Transport as an enabler of economic connectivity

The role of transport is established in early theories such as Rostow's (1959) stages of economic growth theory. In his theory, transport infrastructure such as roadways and railways are central overhead capital requirements in the take-off stage. Several empirical studies have demonstrated the importance of transport in economic undertakings. Baporikar (2015) demonstrated transport infrastructure's role in facilitating economic integration and trade. It connects areas of production and those of consumption and hence affords market access. Rodrigue and Nottenboom (2020) regarded the transport industry as an essential element of the economy that can be used as an instrument for development, especially now, when economic opportunities are increasingly connected to the movement of freight, people, and technologies. The main role of transport as an enabler of economic connectivity is to improve access to diverse locations for businesses and individuals (New Zealand Ministry of Transport, 2016).

Focusing on China, Zhao, Sun, and Webster's (2022) results revealed that investment in transport infrastructure could raise connectivity and economic integration in certain major cities and regions in Pakistan, yet it would broaden inequality in the country. These results have critical implications as there are implied spillover effects among regions. Condeco-Melhorado et al. (2014) demonstrated the existence of road infrastructure spillovers among Dutch municipalities. Several other studies (e.g., Arbues et al., 2015; Li et al., 2017; Tong et al., 2013) established positive spillovers of transport infrastructure development.

While development in one region may improve development in other regions, there is also a possibility of growing regional inequalities when certain places become more attractive, pulling key economic factors to themselves. Thus, for instance, negative spillovers from infrastructure development may also occur (Zhang, 2008 &

2013); according to Condeco-Melhorado et al. (2014), it could be because of relocation of economic factors to places with better access due to sound transport and telecommunication connectivity.

As discussed above, the various views concerning the role of transport give us insight into connectivity among the nine provinces of South Africa. The Western Cape Government (2022) pointed out that the transport network of South Africa assumes a critical role in enabling the mobility of people, goods, and services in the economy. However, in line with the literature, while transport plays a key role in the integration of South African provinces and their development, other provinces (e.g., Gauteng) will be more competitive than other provinces due to better transport connectivity, among other factors. It is imperative to investigate how regions such as the Northern Cape are positioned in the economy in terms of transport and other sectors.

3. Data and Method

This paper focuses on activities, specifically the transport sector, located in the Northern Cape Province of South Africa and its various local municipalities. The geographic areas, broken down by district municipality, are illustrated in Figure 2. The district on top in terms of GDP contribution is Frances Baard (0.7%), followed by John Taolo Gaetsewe (0.5%), ZF Mgcawu (0.4%), Pixley ka Seme (0.2%), and Namakwa (0.2%).

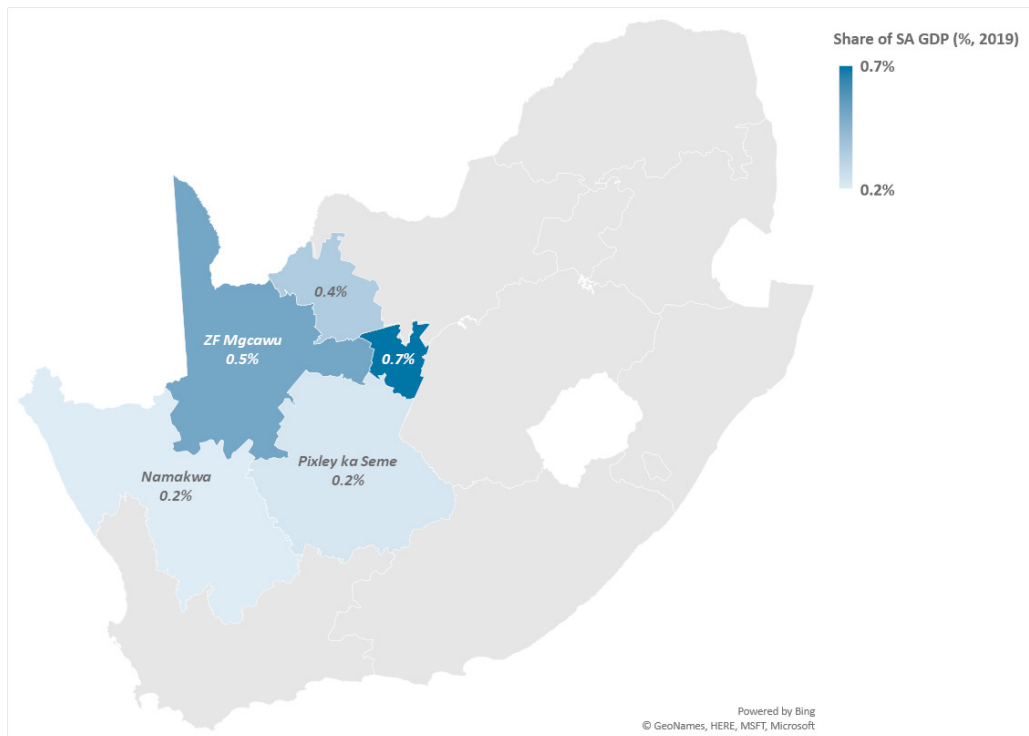


Fig. 2. Geographic area of analysis – Northern Cape Province of South Africa.

Note: Colour scale based on each district municipality's share (%) of the national nominal GDP.

Source: Authors' illustration using Excel Maps based on Quantec Research – EasyData (2020)

The Republic of South Africa (RSA) Standardised Regional Service data provided by Quantec Research's EasyData at the local municipality level form the primary basis for information used in the Northern Cape analysis. The most populated and developed business centre in the Northern Cape is the Sol Plaatje local municipality, with the four other most populated local municipalities being Dawid Kruiper (//Khara Hais/Mier), Ga-Segonyana, Joe Morolong, and the Kai! Garib local municipalities (see Table 1). Both government and businesses use the Standard Industrial Classification (SIC) to classify businesses based on the type of activity that they undertake. Note that the

Standard Industrial Classification of all Economic Activities (SIC) is based upon the (5th revision which appeared in 1990) International Standard Industrial Classification of all Economic Activities (ISIC) with suitable adaptations for local conditions – published by Statistics South Africa (Stats SA). The number of digits utilised is an indication of how specified the classification is. The two-digit SIC is the broadest and is defined as sectors; three and four-digit SIC are more specialized and are defined as subsectors and industries, respectively. All references to the two-digit SIC throughout this paper, therefore, refer to ‘sectors.’ Sector comparisons in Quantec’s EasyData can be made either in terms of the primary, secondary, and tertiary aggregates, the nine broad, one-digit level of the SIC sectors, or the 50 detailed, two-digit level SIC sectors. Detailed descriptions of each sector classification (based on the SIC) are provided in Table A1 in the Appendix.

Table 1. Local municipalities in the Northern Cape Province, 2019.

Province / District / Local Municipality	Size of the Area (km ²)	Population (2018)	Population Density (number of people per km ²)
Northern Cape	1 344 878	3.61	372 889
Namakwa	139 381	1.10	126 836
Richtersveld	15 055	1.57	9 608
Nama Khoi	56 138	3.12	17 990
Kamiesberg	11 456	0.81	14 208
Hantam	26 148	0.67	39 085
Karoo Hoogland	15 898	0.53	30 230
Khai-Ma	14 685	0.93	15 715
Pixley ka Seme	220 842	2.14	103 411
Ubuntu	22 224	1.09	20 393
Umsobomvu	34 000	4.99	6 813
Emthanjeni	51 678	3.84	13 472
Kareeberg	14 884	0.84	17 701
Renosterberg	13 533	2.45	5 529
Thembelihle	18 686	2.33	8 023
Siyathemba	26 583	1.81	14 727
Siyancuma	39 253	2.34	16 753
ZF Mgcau (Siyanda)	284 391	2.77	102 484
Kai !Garib	74 929	2.84	26 377
!Kheis	18 591	1.67	11 107
Tsantsabane	44 331	2.42	18 290
Kgatelopele	23 369	9.43	2 478
Dawid Kruiper (//Khara Hais/Mier)	123 172	2.78	44 231
Frances Baard	438 901	34.19	12 836
Sol Plaatje	293 113	93.19	3 145
Dikgatlong	49 639	6.79	7 316
Magareng	27 685	17.90	1 546
Phokwane	68 464	82.68	828
John Taolo Gaetsewe (Kgalagadi)	261 363	9.57	27 322
Joe Morolong	86 322	4.28	20 180
Ga-Segonyana	116 646	25.95	4 495
Gamagara	58 395	22.05	2 648

Source: Quantec Research – EasyData (2020)

Two complementary methods are applied to quantify the importance of the transport sector in the Northern Cape. The first methodology identifies sectors with high regional concentrations in the Northern Cape compared to the rest of the country. The purpose of this analysis is to identify prominent sectors that have high regional concentrations in the Northern Cape compared to the rest of the country and ultimately have the potential to drive growth in the

province and broader economy. Economic base analysis (Klosterman, 1990) is the first methodology used to understand the Northern Cape's regional economies better. It is a simple yet valuable tool that can be used to understand a sub-national region's economic structure. It provides comparative information on the economic status across periods and other localities in terms of competitive advantages, employment conditions, and trends.

According to Klosterman (1990), the economic base analysis assumes that the local economy can be divided into two main sectors, namely basic and non-basic. The basic sector comprises those local businesses that produce goods and services sold to consumers outside the community/ region. The approach assumes that the sales of a basic firm are dependent almost entirely on export markets. For example, some companies based in a location (municipality) in South Africa might sell to customers worldwide. Their sales to consumers in the specific location (municipality) are negligible compared to their total sales outside of the municipality. The non-basic sector, on the other hand, is composed of those firms that produce goods and services that are sold and consumed primarily locally. Almost all local businesses such as hairdressers, dentists, restaurants, and pharmacies can be categorised as non-basic because they depend almost entirely on local market sales (Klosterman, 1990).

An economic base analysis is grounded on the premise that the basic sectors form the economic base of a locality, and all other non-basic sectors flourish by servicing these basic sectors. Through its non-local market sales and resulting injection of new money into the local economy, the basic sector is an essential contributor to and drives local economic growth and progress. Changes in the basic sector's composition or performance usually also impact the non-basic sector and overall local economic trends. Evidence from the economic base analysis has shown that the local economy is strongest when it develops those economic sectors that bring new money (Rands) into the local economy.

Although there are several ways to estimate a sub-national region's economic base, the location quotient (LQ) approach represents a good starting point for understanding the regional economy and providing information to support regional planning efforts (Indiana Business Research Center, 2006). In the case of the Northern Cape, three steps are taken to identify its prominent sectors, namely: Step 1: Identifying sectors with higher employment concentrations in the Northern Cape versus the rest of the country, based on a LQ analysis (using two-digit SIC code sectors and 2019 data). An LQ analysis identifies how concentrated a particular sector is in a region than the rest of the country. Therefore, it can identify sectors where the Northern Cape has distinctive strengths concerning employment opportunities. Step 2: Determining the classification and importance of the Northern Cape's transport sector. Step 3: The undertaking of a network analysis of the economic activity in the province. This analysis emphasizes visualization using network diagrams that reveal the structural makeup of the regional economy. The visualization sheds valuable insight into the Northern Cape economy by identifying the key industries and the interlinkages more easily understood by decision-makers.

The calculation of an LQ in step 1 is done using the following formula:

$$LQ = \frac{\left(\frac{\text{Employment of sector X in NC}}{\text{Total employment in NC}} \right)}{\left(\frac{\text{Employment of sector X in SA}}{\text{Total employment in SA}} \right)} \quad (1)$$

where NC stands for Northern Cape province and SA stands for South Africa.

If an industry's $LQ > 1$, the industry is considered to be more highly concentrated in that area versus the rest of the country. Sectors within the Northern Cape with an $LQ > 1.25$ are considered "exporters" to other countries/regions. An LQ with a value of 1.5 indicates that the region has 50% more "cluster employment" on a per capita basis than South Africa, which is a sign of relative local strength in that cluster. The analysis makes use of an LQ "Bubble Graph," illustrated in Figure 3. The LQ graph for industries (in a "bubble" type format) is based on concepts developed at Purdue University. The vertical axis has the basic LQ measurement, while the horizontal axis shows the percent change in LQ over time. ***Entities such as industries are plotted as circles (or "bubbles"), with the circle size corresponding to their relative size (in jobs).*** The graph's four quadrants can be used to categorise various industries, occupations, or clusters. This analysis enables the classification and identification of the key sectors of importance (or prominence) within the Northern Cape.

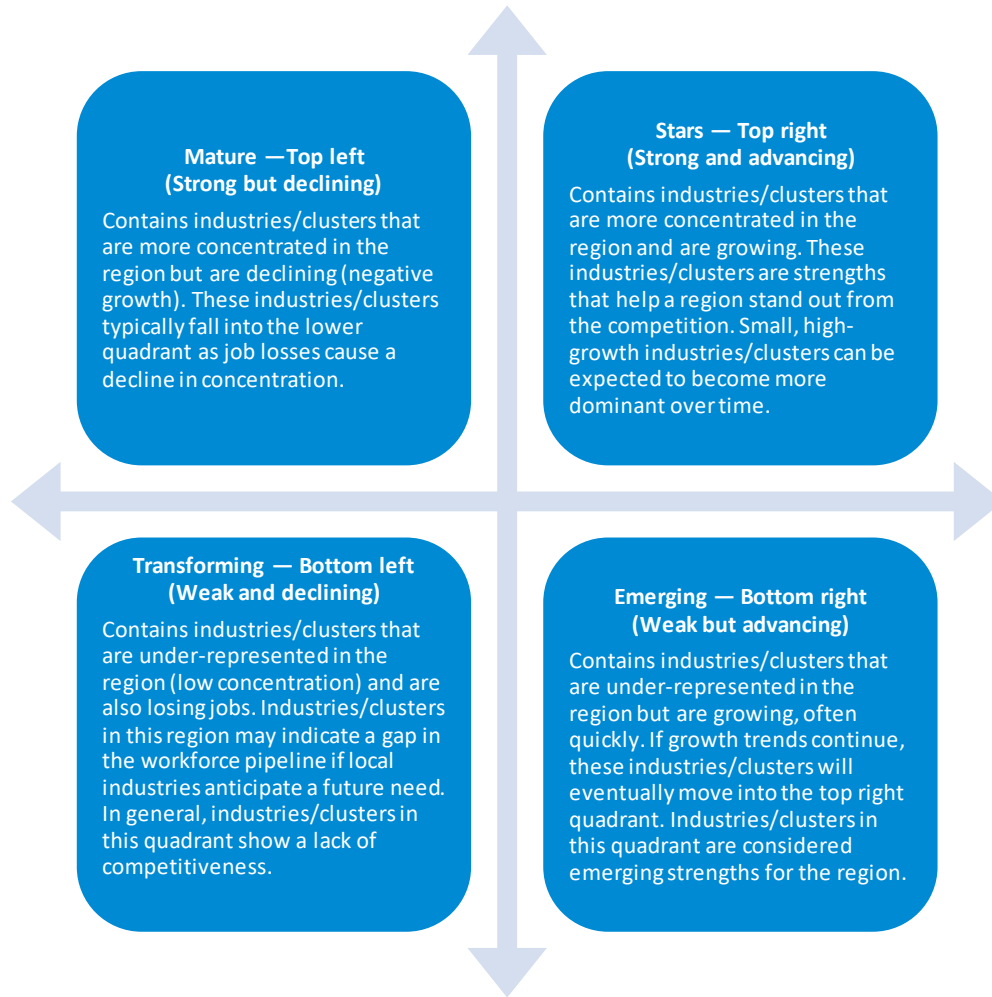


Fig. 3. How to interpret the LQ analysis results.

Note: The graph's four quadrants each tell a different story for each industry/cluster.

Source: Modified from <http://www.charlestonregionaldata.com/bubble-chart-explanation>

The second methodology, which complements the first, summarises the analysis of the Northern Cape and its sub-regional economies using Network and I-O Analysis. An I-O and multiplier database for the Northern Cape, sourced from the Quantec Economic Impact Analysis Service database, is used for visualizing the economy of the Northern Cape and its sub-regions (i.e., Local Municipalities) and for the computation of a set of network metrics which identify the interrelationships among industries within the economy (i.e., intra-regional linkages) and between sectors in the Northern Cape and the rest of the South African economy (i.e. inter-regional linkages with other provinces). The methodology is described in Fabusuyi and Juergen (2018).

Assume an economy with n industries. Each industry i produces X_i amount of goods, which are consumed within the industry, traded to other industries, consumed by end-users, or exported. This is illustrated in Equation (2):

$$X_i = \sum_{v=1}^n z_{iv} + V_i = \sum_{j=1}^n a_{ij}X_j + V_i \quad (2)$$

where X_i denotes the joint value of both local and non-local production-related demand. The term V_i which represents non-local production demand, shows the total value of consumption by the end-users, usually households within the domestic economy, and the amount exported. If we assume that f_{ij} denotes the money that flows from

industry j to industry i , and that a constant return to scale production processes is applicable, then the technical coefficient, a_{ij} , stands for the input requirement of industry i 's output for a unit Rand product output of industry j is (Blöchl *et al.*, 2011):

$$a_{ij} = \frac{f_{ij}}{x_j} = \frac{f_{ij}}{\sum_{i=1}^n f_{ij}} \quad (3)$$

This coefficient shows the direct impact of a rand change in the demand for good j on industry i . However, it does not describe the indirect impact of that change across the economy. Consequently, a measure that accounts for the direct network effect and the indirect or interdependencies among the regional industries is required. Stretching Equation (3) to the n industries and using a matrix form for the representation, the following equation emerges:

$$(I - A)X = V \Rightarrow X = (I - A)^{-1}V \quad (4)$$

where I is an identity matrix, while A is the matrix of the technical coefficient values. Furthermore, it is assumed that $M = (I - A)^{-1}$ (the Leontief inverse) is the vector of elements w_{ij} , where w_{ij} or the output multiplier shows the value of direct and indirect impact on good i needed to make an additional rand amount of final demand for good j (Leontief, 1936).[†] The term $\sum_{j=1}^n w_{ij}$ gives the total influence on the provincial economy of a unit change in demand for good j . What is of interest in this study are the output multipliers.

Since these values express the impact on the economy, supposing that a good j 's demand changes by a unit, scaling up by industry j 's production volume will give us an idea of its importance in the domestic economy. This notion can be used by policymakers to justify industries to target in the economy, which promises to boost economic growth (see Hirschman, 1957). Such industries or sectors would have robust connections with other industries given that demand in other industries depends on these key industries. Similarly, the outputs from the key industries can be consumed as intermediate products by other industries. However, Fabusuyi and Pfeffer (2018) indicated that to reduce the impact of adverse shocks, there is a need to create redundancies around dominant industries with greater influence across the economy. The authors also stated that this kind of thinking lends itself to being represented by a network approach. Recently, the economic applications of network analysis have become common (Miller, 1998; McNerney and Kryazhimskiy, 2009; McNerney, Fath and Silverberg, 2013), encompassing dealing with resiliencies in the economy and improving resource allocations. In this study, industries are shown as nodes while the weighted edges denote the volume of transactions between the nodes.

For this analysis, the same level of SIC disaggregation is used as in the previous section. This enables the analysis at a detailed production level, limiting the aggregation challenges created particularly for self-loop transactions. The data used is localized, allowing the identification of region-specific (provincial- and local municipality-level) production attributes and, consequently, fashion policy prescriptions that speak to a specific geographical area. Using this data enables the use of relevant network metrics such as authority weight that enrich the conventional entropy and variance measures typically used in the economic development domain and provides a first step in exploring what empirical network metrics mean for regional development. The analysis also emphasizes visualization using network diagrams that reveal the regional economy's structural makeup and inter- and intra-regional connections. The visualization sheds valuable insight into the economy by identifying the key industries and the interlinkages more easily understood by decision-makers.

For the network analysis, a multi-region input-output (MRIO) model was developed to assess the intra-regional and inter-regional economic linkages within the Northern Cape and between the Northern Cape and the rest of South Africa. I-O analysis is an analytical framework with the primary purpose of analysing the interdependence of industries and tracing the flow of money through the economy to capture how the output of one sector becomes the input of another (O'Connor and Henry, 1975).

Lundberg *et al.* (1995) identified I-O analysis as a mainstay method for assessing external shocks' economic impacts on an economy. I-O analysis is an analytical framework with the primary purpose of analysing the

[†] Leontief Inverse Matrix (or Total Requirements Matrix) is a central mathematical object in Input-Output Analysis. The matrix represents the amount of gross output from sector i that is produced to satisfy a unit of Final Demand y from sector j (Open Risk Manual, 2023).

interdependence of industries in an economy (O'Connor & Henry, 1975:1). An I-O model comprises a system of linear equations, each one of which describes the distribution of an industry's output throughout the economy. In other words, an I-O traces the flow of money through the economy to capture how the output of one sector becomes the input of another, that is, how the industries in an economy are dependent on one another. An I-O model makes provision for two kinds of activities on a sectoral level, namely 1) the purchase of intermediate inputs and 2) the supply of intermediate and final outputs. The total output/production of Sector 1 (X_1) is, therefore, the sum of the intermediate outputs, plus final demand/output of Sector 1 (F_1), alternatively stated, final demand is the difference between output and intermediate demand (Van Wyk *et al.*, 2015):

$$F_1 = X_1 - a_{11}X_1 - a_{12}X_2 - a_{1n}X_n \quad (5)$$

To extend the application across all industries, equation (1) can be re-written in matrix format as:

$$F = (I - A)X \quad (6)$$

where F is a vector of final demand, I is an $n \times n$ identity matrix, A is the technical coefficient matrix, and X is a production vector. To determine the impact of a shock to final demand (F) on output or production (in this case, changes in consumer spending and displacement), the Leontief inverse is applied, that is:

$$X = (I - A)^{-1}F \quad (7)$$

The above general I-O model framework makes it possible to quantify the economy-wide impact of a shock to the economy. This framework can also be extended and applied at different economic levels (national, regional, county, district). Such regionalization of an I-O model from one of a higher scope (in the current case, from regional to district level) can be done by applying several well-known variations of regionalization methods (see e.g., Norbert, 2015 for a comprehensive summary). These can be divided into three central groups, namely 1) Survey, 2) Non-survey, and 3) Hybrid methods (Greenstreet, 1989). For the current study, we use a specific non-survey method known as the FLQ formula (Flegg *et al.*, 1995).

The FLQ formula is derived from a popular non-survey method and is based on the well-known LQ. Flegg *et al.* (1995) proposed a new variant of the existing LQ method, known as the Flegg location quotient (FLQ) formula. The authors suggested an inverse relationship between a region's relative size and its propensity to import from other regions (Parra, 2018).

According to Flegg *et al.* (1995), the factors that can affect a region's self-supplying ability expand by the region's relative size. Thus, FLQ considers relative specialization, the size of the purchaser and producer sectors, and the region's size (Norbert, 2015). The FLQ formula is defined as:

$$FLQ_{ij}^r = CILQ_{ij}^r \times \lambda^r \quad (8)$$

where $CILQ_{ij}^r$ is the inter-industry LQs for a given region r , that is, the relative importance of the supplying industry i concerning the purchasing industry j (see, e.g., Schaffer and Chu, 1969), and λ^r captures the relative size of a region r . The latter can be calculated as:

$$\lambda^r = \left\{ \log_2 \left[1 + \left(\frac{x_E^r}{x_E^n} \right) \right] \right\}^\delta, 0 \leq \delta < 1 \quad (9)$$

where x_E^r and x_E^n are the respective regional and national production totals for a given region r .

Based on Equation (9), the quotient is not modified directly by the relative size, but by its logarithmic value, ensuring that the scaling is not so intensive, and the whole expression is then raised to the power of δ , which is a sensitivity parameter. The larger the value of δ , the stronger the adjustment in FLQ (Norbert, 2015). For the current study, we used the sectoral share of each district's GDP as the value for δ . The quotient can then be applied like its predecessor:

$$a_{ij}^{rr} = \begin{cases} (FLQ_{ij}^r) a_{ij}^{n,ha} FLQ_{ij}^r < 1 \\ a_{ij}^{n,ha} FLQ_{ij}^r \geq 1 \end{cases} \quad (10)$$

where a_{ij}^{rr} denotes regional input, a_{ij}^r denotes national coefficients, "ha" is used as a notation to indicate a condition but can also be replaced by an "if". For the diagonal ($i = j$) elements of the MRIO, the traditional LQ can substitute the FLQ again (Norbert, 2015).

The starting point for the current analysis is the Northern Cape I-O table (for 2019, in millions of Rands), capable of depicting the inter-industry relationships of the whole Northern Cape economy and linkages with the rest of South Africa – and transforming it using the FLQ method. This produces an estimated MRIO table that is not consistent. By balancing the Northern Cape MRIO model using the RAS technique, the final derived MRIO model is then converted to a Leontief model and used for the network analysis. The RAS is a widely used method to balance matrices.

The 2019 Northern Cape I-O table covered 50 industries and shows transactions engaged by industries in their production process. Of these industries, only 48 are active in the Northern Cape. The estimated MRIO model for the Northern Cape Local Municipalities covers 50 industries per local municipality, thus 1,350 across all 27 local municipalities. Though different kinds of multipliers could be calculated from the data, the focus is on Type I output multipliers that describe the total economic activity generated in the local economy due to spending an additional rand for any industry within the Northern Cape economy. Only the direct and indirect effects of the unit rand change are captured by the Type I multiplier. Excluded from this measure are the induced effects, which are increased household spending generated by the direct and indirect impacts.

4. Results discussion

4.1. Economic base analysis

"Bubble charts" are a handy tool for analysing cluster strength in a sub-national region. A bubble chart provides three metrics for each cluster: the growth rate (%), the LQ (which is the per capita concentration in the region relative to national) and the number of employees (the relative size of the bubble) (see Figures 5 and 6).

The LQ for each industry or cluster is presented on the vertical axis, which shows the relative concentration of employment in this cluster versus the national concentration. A LQ is a relative measure, and this implies that a high concentration in one cluster means that other clusters will have lower LQs. $LQ < 1$ indicates a lower concentration relative to the denser clusters.

Figures 5 and 6 illustrate the results of applying the LQ analysis to industries in the Northern Cape (at an aggregate provincial level only). The results are shown relative to South Africa (i.e., on the national level) and the rest of South Africa (i.e., all other provinces in South Africa, excluding the Northern Cape). The different clusters of industries are also shown in Tables 2 and 3; the four quadrants.

As indicated in Figure 4, only one industry cluster in the Northern Cape is in the Maturing stage: Metals Mining [24]. This industry is relatively concentrated, but its growth is trending downward. However, the Northern Cape may find it worthwhile to invest in shoring up this industry's concentration.

Star industry clusters are highly concentrated, exporting and still experiencing regional growth. The most highly concentrated of the Star industry clusters in the Northern Cape is Other mining and quarrying [22, 25-29]. Its location quotient is 6.78, indicating that the cluster is almost seven times more concentrated in the region than in South Africa. The other strong clusters in the province are Agriculture [11], Water [42], Electricity and gas [41], **Transport and storage [71-74]**, and Local government [913].

Transforming clusters capture the mix of industries that are experiencing relative decline and limited export capability. In the Northern Cape, the National and Provincial government [911], Communication [75], Wholesale and retail trade [61-63], and Catering and accommodation services [64], among others, are all Transforming clusters. Any amount of growth in these industries would require relatively large investments.

Industry clusters poised for future growth are classified as "Emerging." There are 20 Emerging clusters in the Northern Cape, of which the top 5 include Education (Private) [92], Non-metallic mineral products [342], Health and social work (Private) [93], Business activities n.e.c. [889], and Forestry [12].

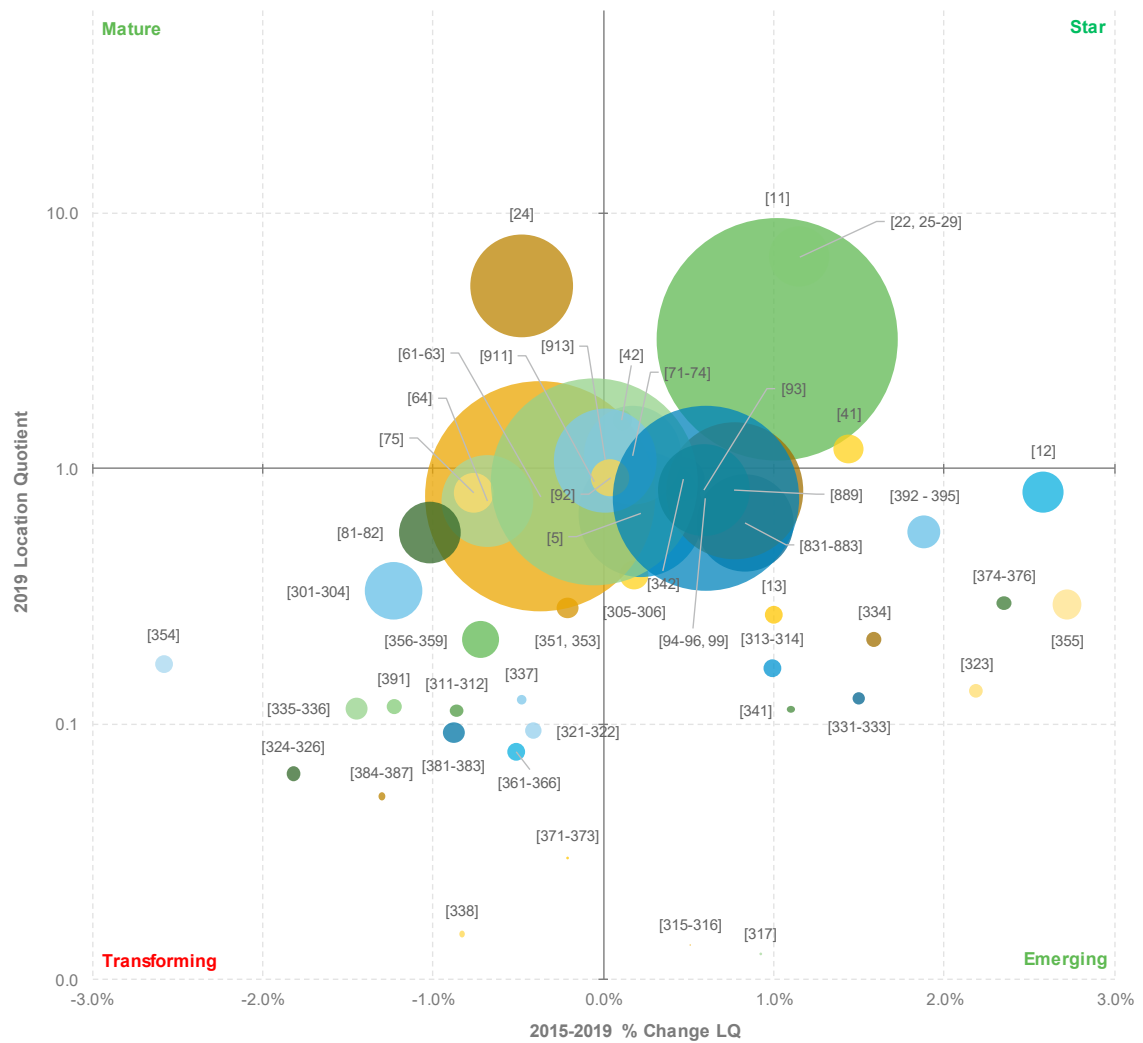


Fig. 4. Northern Cape industry size, LQ and LQ change 2015-2019 (relative to National)

Note: Bubble size corresponds to each industry's relative size (in jobs). Based on 2-digit SIC definitions.

Source: Authors' calculations based on data from Quantec Research – EasyData (2020)

Table 2. Northern Cape vs National bubble chart interpretation.

Mature Clusters — Top left (strong but declining)	Star Clusters — Top right (strong and advancing)
Metals [24]; 5.19; 11,611	Other mining and quarrying [22, 25-29]; 6.78; 3,957
	Agriculture [11]; 3.21; 64,364
	Water [42]; 1.55; 419
	Electricity and gas [41]; 1.20; 951
	Transport and storage [71-74]; 1.13; 10,573
	Local government [913]; 1.08; 11,781
	Percent growth in specialisation →
Transforming Clusters — Bottom left (weak and declining)	Emerging Clusters — Bottom right (weak but advancing)
National and Provincial government [911]; 0.89; 47,122	Education (Private) [92]; 0.92; 1,599
Communication [75]; 0.81; 1,724	Non-metallic mineral products [342]; 0.91; 2,065
Wholesale and retail trade [61-63]; 0.78; 58,509	Health and social work (Private) [93]; 0.83; 9,109
Catering and accommodation services [64]; 0.74; 9,299	Business activities n.e.c. [889]; 0.82; 20,804
Finance and insurance [81-82]; 0.56; 4,209	Forestry [12]; 0.81; 1,863
Food [301-304]; 0.33; 3,705	Other community, social and personal services [94-96, 99]; 0.77; 38,073
Basic iron and steel products; casting of metal [351, 353]; 0.28; 0,487	Construction [5]; 0.67; 17,434
Machinery and equipment [356-359]; 0.21; 1,473	Professional business services [831-883]; 0.61; 10,311

Level of specialisation ↑

Note: The first number after each cluster represents its location quotient, while the second number represents the total jobs in that cluster in the region in 2019. The clusters are sorted in decreasing order by location quotient.

As presented in Figure 5 and Table 3, industry clusters that may be poised for future growth in the province when looking at concentration relative to the rest of South Africa (excluding the Northern Cape Province), then the “Emerging” clusters include Communication [75], Business activities n.e.c. [889], Health and social work (Private) [93], Other community, social and personal services [94-96, 99], Forestry [12], Professional business services [831-883], Other manufacturing groups [392 - 395], and Professional equipment [374-376]. Unlike in Table 2 where NC is compared against the national bubble, in Table 3, the **transport and storage [71-74]** sector is classified as a mature cluster. In both instances, the **transport and storage [71-74]** sector plays a prominent role. This is one NC’s sectors that can meaningfully contribute to the province and the whole economy at large.

However, the insight revealed by the above economic base analysis is limited even when analysing multi-year LQ’s that allow for an inter-temporal analysis of industry growth patterns in the Northern Cape. What makes an economy flourish hinges on the multitude of transactions conducted among the industries within the economy. The metrics that capture output distribution across industries or indicators representing the proportionate distribution measured relative to a reference economy provide such insight. This shortcoming provides the rationale for employing measures that consider the interdependencies among the Northern Cape industries using a dataset that captures such transactions. The results of such an analysis of the Northern Cape are discussed in the next section.

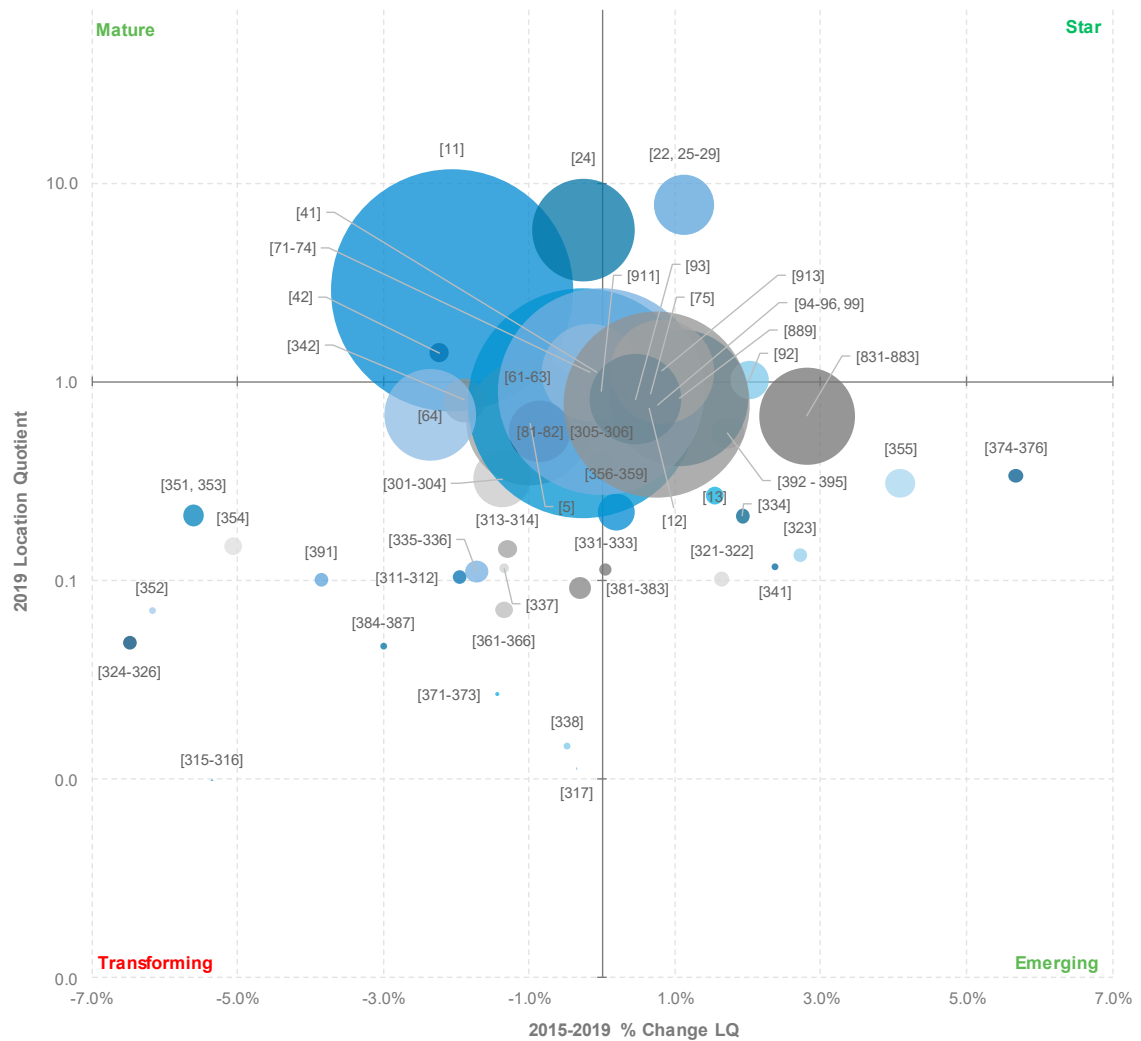


Fig. 5. Northern Cape industry size, LQ and LQ change 2015-2019 (relative to other SA regions).

Note: Bubble size corresponds to each industry's relative size (in jobs). Based on 2-digit SIC definitions.

Source: Authors' calculations based on data from Quantec Research – EasyData (2020)

Table 3. Northern Cape vs Rest of SA Regions bubble chart interpretation.

Mature Clusters — Top left (strong but declining)		Star Clusters — Top right (strong and advancing)	
Metals [24]; 5.83 ; 11,611		Other mining and quarrying [22, 25-29]; 7.76; 3,957	
Agriculture [11]; 2.89 ; 64,364		Local government [913]; 1.12; 11,781	
Water [42]; 1.39 ; 0,419		Education (Private) [92]; 1.01; 1,599	
Electricity and gas [41]; 1.11 ; 0,951			
Transport and storage [71-74]; 1.11 ; 10,573			
		Percent growth in specialisation →	
Transforming Clusters — Bottom left (weak and declining)		Emerging Clusters — Bottom right (weak but advancing)	
National and Provincial government [911]; 0.89 ; 47,122	Level of specialisation →	Communication [75]; 0.86 ; 1,724	
Non-metallic mineral products [342]; 0.80 ; 2,065		Business activities n.e.c. [889]; 0.83 ; 20,804	
Wholesale and retail trade [61-63]; 0.78 ; 58,509		Health and social work (Private) [93]; 0.82 ; 9,109	
Catering and accommodation services [64]; 0.68 ; 9,299		Other community, social and personal services [94-96, 99]; 0.77 ; 38,073	
Construction [5]; 0.62 ; 17,434		Forestry [12]; 0.74 ; 1,863	
Finance and insurance [81-82]; 0.56 ; 4,209		Professional business services [831-883]; 0.67 ; 10,311	
Beverages and tobacco [305-306]; 0.37 ; 0,925		Other manufacturing groups [392 - 395]; 0.55 ; 1,173	
Food [301-304]; 0.32 ; 3,705		Professional equipment [374-376]; 0.34 ; 0,235	

Note: The first number after each cluster represents its location quotient, while the second number represents the number of total jobs in that cluster in the region in 2019. The clusters are sorted in decreasing order by location quotient.

4.2. Network analysis

Multiple dimensions speak to the Northern Cape's connectivity, which should be considered. The interlinked nature of industries within the Northern Cape determines spillover effects across industries and beyond the places where the activities are located, propagated through the various industry value chains. These measures would require analyses to reveal the regional economy's structural makeup, specifically regarding inter-sectoral linkages and the economy's dynamic nature. *The insights revealed by such analyses may provide information such as how industries are embedded within the economy; the optimal allocation of resources to attract prospects that result in the greatest “bang for the buck” for the region; the revelation of latent opportunities within the provincial economy and the identification of bottlenecks within the economy that may be binding constraints to economic growth.* This connectivity level can be better understood by analysing the structure of a Social Accounting Matrix (SAM) or I-O table of each sub-region within the province. This section provides a first step towards providing this type of information. It introduces the economic development network analysis that utilises a relatively novel approach for studying an economy's structure using a combination of network analysis and I-O analysis. The approach enriches entropy indicators such as shift-share analysis, and LQ measures typically used to characterise economies by computing a set of network metrics that identify the industries' interrelationships with the economy. The findings facilitate the ability to discern the provincial economy's structural makeup and enable a retrospective assessment of the economy, affording decision-makers the ability to influence how the provincial economy evolves.

Social networks consist of nodes and links that connect the nodes (Hennig et al., 2012; Wasserman & Faust, 1994). For the current analysis, the SIC (industry) codes form the set of nodes. The Northern Cape I-O network contains 50 nodes (SIC codes) and 10,000 links, while the MRIO network contains 50 nodes (SIC codes) for each of the 27 local municipalities in the Northern Cape and 1,048,575 links. An obvious challenge with this level of aggregation is that the self-loop gets larger, which may further be compounded by the fact that most network computations omit self-loops to maintain analytical tractability. Self-loops occur when industries supply themselves (i.e., their outputs are used as inputs in production). Complementing the node representations are the weighted edges that use the multipliers to proxy the linkages' strength between industries. This approach strips the subjectivity of data often encountered with network data, given that the data is factual and objective. Many variations across

multiple local municipalities are not expected to the degree to which the same production process exists with similar parameter values for production factors.

Conventional approaches to characterising regional economies revolve around two broad sets of metrics – entropy and portfolio approaches to address economic stability (Wagner & Deller, 1998). In economic development, entropy measures are used to capture the distribution of economic activity across the economy. Stock variants of entropy measures include LQ and the Herfindahl-Hirschman Index (HHI), while the flow variant of entropy measures includes shift-share analysis. Implicit in using these measures is that more proportionate distribution of economic activities across the industries provides more economic stability. The second set, which is rarely used in practice, is the portfolio measures. This approach borrows from the portfolio theory in making a case for an economy-wide industrial portfolio. Although the portfolio measures relax the requirement of evenness in economic activities across the industries as in the entropy measures, it does not consider the interdependencies of economic transactions across industries.

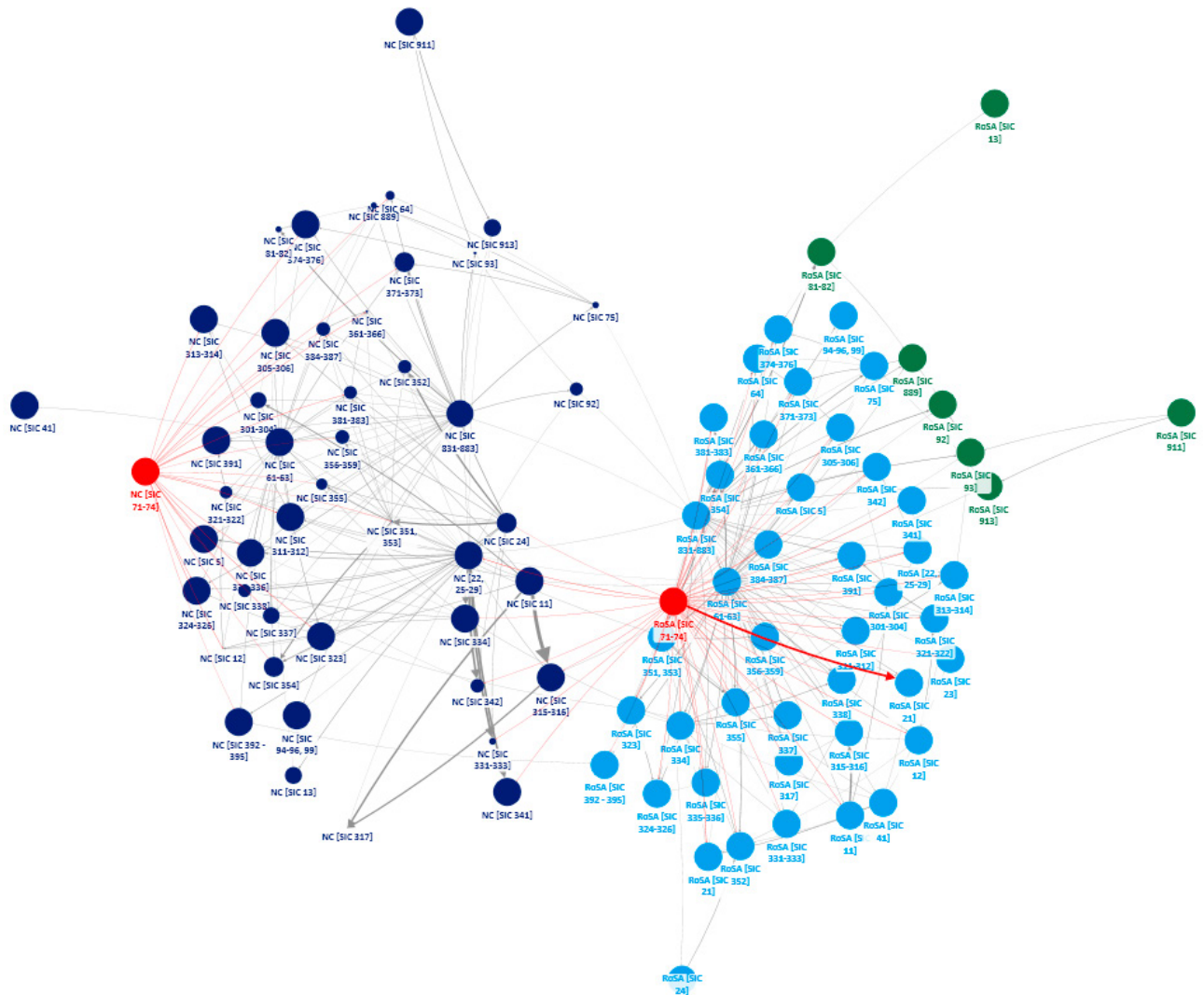


Fig. 6. Intra-sectoral and inter-regional connectivity between the Northern Cape and the rest of South Africa (2019).

Note: Multiplier cut-off: 0.05. Node size: number of employees. NC represents all Northern-related nodes, and RoSA represents the Rest of South Africa-related nodes.

Source: Author's calculation based on data from Quantec Research – EasyData (2020) using NodeXL.

Even though multi-year LQ figures that allow for an inter-temporal analysis of industry growth patterns are used for the LQ analysis, the insight revealed by Figures 4 and 5 is limited. What makes an economy flourish hinges on the multitude of transactions conducted among the industries within the economy. The metrics that capture output distribution across industries or indicators representing the proportionate distribution measured relative to a reference economy provide us with this insight. This shortcoming provides the rationale for employing measures that take into consideration the interdependencies among the industries. Figure 6 provides a panoramic view of the core of the Northern Cape's economic landscape, with the nodes representing SIC codes and the edges or arcs representing the output multipliers for any pair of connected SIC codes. The figure also captures the inter-regional connections between sectors in the Northern Cape (NC) and the rest of South Africa, RoSA (i.e., sectors located in other provinces). The **transport and storage [71-74]** sector and its connections are highlighted in red.

The visualisation in Figure 6 was generated using a 0.05 or a 5 cent output multiplier cut-off threshold with the size of the output multiplier captured by the edges' thickness. All nodes are labelled, and the number of employees in each industry is used to proxy the node size. The visualisation clearly shows that in the Northern Cape, the mining industry (i.e., other mining and quarrying [22, 25-29] and metals [24]) and agriculture [11] are the regional economy's primary anchors. *These sectors show strong and multiple linkages intra-provincially (within the Northern Cape) and inter-provincially (between the Northern Cape and the rest of South Africa).* While wholesale and retail trade [61-63], national and provincial government [911] and other community, social and personal services [94-96, 99] are among the province's top employers, the footprint they have within the provincial economy is quite limited, judging from the minimal visible edges they facilitate. *Other sectors in the Northern Cape that show substantial intra- and inter-regional linkages are professional business services [831-883], transport and storage [71-74] and basic chemicals [334].*

Figure 7 shows the intra-regional connectivity between sectors in each local municipality in the Northern Cape. In Figure 7, the node sizes are determined by the number of employees with the nodes unlabelled for a clearer view of the various network connections. In Figure 7, only the top 20 nodes by the number of employees across all 27 local municipalities in the Northern Cape are labelled, and the same attribute is used to proxy the node size with the **transport and storage [71-74]** sector and its connections highlighted in red. The top 20 nodes (local municipality and SIC sector combinations), based on the network analysis of the Northern Cape MRIO, are Kai !Garib [11], Sol Plaatje [94-96, 99], //Khara Hais [61-63], //Khara Hais [911], Phokwane [11], Sol Plaatje [831-883], Ga-Segonyana [61-63], Gamagara [61-63], //Khara Hais [11], Gamagara [24], Sol Plaatje [5], //Khara Hais [94-96, 99], Sol Plaatje [93], Joe Morolong [24], Kai !Garib [61-63], Sol Plaatje [913], Phokwane [94-96, 99], Gamagara [911], Ga-Segonyana [911], and Sol Plaatje [64]. *Figures 19 and 20 also highlight a large concentration and linkages stemming from the Gamagara [24] and Joe Morolong [24] nodes, clearly visible in the depicted networks.*

Apart from eyeballing the network map, the network's statistical properties produce invaluable insight both at the node and the network level. Many metrics have been developed to describe the structure of networks and the importance of nodes (Newman, 2010). Centrality metrics analyse a node's position in a given network and assess its "centrality" (Bavelas, 1948). Different centrality measures consider the directly connected neighbours of a node, the shortest paths from a node to all other nodes, or all paths from a node to all other nodes (Freeman, 1977; Stephenson & Zelen, 1989).

Node-specific measures provide rich information that enables economic development practitioners to answer many questions they often grapple with. These include knowing which industries provide the most significant benefit for the local economy. They can help them make resource allocation decisions that reflect the economy's structural makeup and provides the biggest "bang for the buck." Of direct relevance to these questions is the SIC code authority weight, a well-known centrality metric (Kleinberg, 1999). Authority weight $x^{(p)}$ of a node p is defined as the sum of the hub weights $y^{(q)}$ of all its connected neighbours multiplied with the respected link weight $w^{(q,p)}$:

$$x^{(p)} \leftarrow \sum_{q:(q,p) \in E} y^{(q)} w^{(q,p)} \quad (11)$$

The hub weight y is defined analogously as:

$$y^{(p)} \leftarrow \sum_{q:(q,p) \in E} x^{(q)} w^{(q,p)} \quad (12)$$

[illegible]

Source: Author's calculation based on data from Quantec Research – EasyData (2020) using NodeXL.

Figure 8 shows a graph of the ranked authority weight values for the SIC codes. The graph produced is similar to a power-law – only eight nodes have weight values above 0.1. The approximately 210 nodes' balance makes up the long tail observed towards the graph's right hand. It is evident that controlling for industries' output, only a handful of SIC codes can have a profound impact on the local economy. To reiterate, we would like to point out that these are per-dollar flows. Essentially, the measures are normalised by the production volume and thus, what is measured is how widespread the SIC code footprints are within the local economy, complemented by the importance of the codes the reference code is linked to. A simple cumulative flow strength for a SIC code i , measured simply by $\sum_{j=1}^n w_{ij} + \sum_{j=1}^n w_{ji} - w_{ii} \forall j$ has a similar power-law like profile, though not the same ordinal ranking when compared to the authority weight. Subtracting a self-loop from the cumulative flow strength avoids the double-counting of the self-loop.

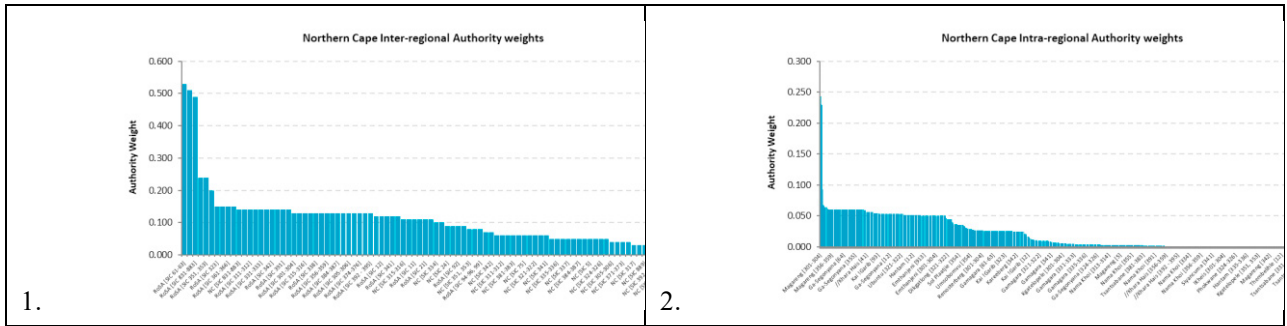


Fig. 8. Ranked inter-regional [left] and intra-regional [right] authority weights by node (LM + SIC).

Source: Authors' calculations based on data from Quantec Research – EasyData (2020)

The high impact provincial and local municipality-specific SIC codes obtained using the authority weight measures provide insight into the industries that should be actively cultivated within the economic network. This information may allow economic development practitioners to be more strategic about their policy options. Decisions on resource allocation or incentives related to attraction and retention programs for firms could be influenced by this realisation even when the number of employees or the production volume attributable to the region and SIC code is relatively low. Of particular interest is looking at the top twenty nodes, an appreciable number of manufacturing-related industries, as shown in Table 4 for the Northern Cape and Table 5 for the province's local municipalities. The **sector of transport and storage [71-74]** in bold which is ranked number five (Table 4). Moreover, when comparing the network analysis results with those of the LQ analysis, the results show that only two of the five sectors are critical industries in the province based on their connectivity. Table A1 in the Appendix shows the authority weights for all the SIC codes.

Table 4. Top 20 SIC codes by authority weight in the Northern Cape.

Rank	SIC code	Weight
1	Northern Cape: Other mining and quarrying [22, 25-29]	0.240
2	Northern Cape: Professional business services [SIC 831-883]	0.140
3	Northern Cape: Agriculture [SIC 11]	0.120
4	Northern Cape: Leather and leather and fur products [SIC 315-316]	0.110
5	Northern Cape: Wholesale and retail trade [SIC 61-63]	0.110
6	Northern Cape: Basic chemicals [SIC 334]	0.100
7	Northern Cape: Metals [SIC 24]	0.090
8	Northern Cape: Transport and storage [SIC 71-74]	0.090
9	Northern Cape: Basic iron and steel products; casting of metal [SIC 351, 353]	0.080
10	Northern Cape: Education (Private) [SIC 92]	0.070
11	Northern Cape: Non-metallic mineral products [SIC 342]	0.070
12	Northern Cape: Food [SIC 301-304]	0.060
13	Northern Cape: Textiles [SIC 311-312]	0.060
14	Northern Cape: Machinery and equipment [SIC 356-359]	0.060
15	Northern Cape: Motor vehicles, parts and accessories [SIC 381-383]	0.060
16	Northern Cape: Other fabricated metal products [SIC 355]	0.060
17	Northern Cape: Communication [SIC 75]	0.060
18	Northern Cape: Paper and paper products [SIC 323]	0.060
19	Northern Cape: Wood and wood products [SIC 321-322]	0.060
20	Northern Cape: Coke, petroleum products and nuclear fuel [SIC 331-333]	0.060

Source: Authors' calculations based on data from Quantec Research – EasyData (2020).

Table 5 also highlights several manufacturing industries as potential sectors for promotion and are linked or part of the downstream value chain of one of the province's anchor industries, namely, metals [24]. In this table, we

have “Other transport equipment” amongst the highly ranked activities in certain local municipalities (Kai!Garib, Emthanjeni, and Tsantsabane).

Table 5. Top 20 local municipality and SIC code combinations by authority weight.

Rank	SIC code	Weight
1	Joe Morolong: Metals [SIC 24]	0.24309
2	Gamagara: Metals [SIC 24]	0.22951
3	Ga-Segonyana: Metals [SIC 24]	0.0932
4	Kgatelopele: Basic iron and steel products; casting of metal [SIC 351, 353]	0.06759
5	Kai !Garib: Other transport equipment [SIC 384-387]	0.06415
6	Emthanjeni: Other transport equipment [SIC 384-387]	0.06415
7	Tsantsabane: Other transport equipment [SIC 384-387]	0.06415
8	Nama Khoi: Furniture [SIC 391]	0.06146
9	Phokwane: Basic iron and steel products; casting of metal [SIC 351, 353]	0.06068
10	Sol Plaatje: Structural metal products [SIC 354]	0.06021
11	Tsantsabane: Basic iron and steel products; casting of metal [SIC 351, 353]	0.06021
12	Sol Plaatje: Basic iron and steel products; casting of metal [SIC 351, 353]	0.06021
13	Nama Khoi: Machinery and equipment [SIC 356-359]	0.06021
14	Gamagara: Other fabricated metal products [SIC 355]	0.06021
15	Siyathemba: Machinery and equipment [SIC 356-359]	0.06021
16	Tsantsabane: Structural metal products [SIC 354]	0.06021
17	Richtersveld: Machinery and equipment [SIC 356-359]	0.06021
18	Sol Plaatje: Other transport equipment [SIC 384-387]	0.06021
19	Nama Khoi: Basic iron and steel products; casting of metal [SIC 351, 353]	0.06021
20	//Khara Hais: Structural metal products [SIC 354]	0.06021

Source: Authors' calculations based on data from Quantec Research – EasyData (2020).

It is also possible to focus on a specific local municipality, SIC sector or combination of both to have a closer look at specific sectoral/regional nodes and, therefore, zoom in and out and examine the economic network of the Northern Cape with its 506 nodes and 1,048,575 links on different levels.

5. Conclusion

This paper used an approach that employs a combination of economic base analysis, Network Analysis and I-O Analysis in studying the enabling role of transport at a sub-national level in South Africa. Apart from visualising the economy, information obtained from the typical I-O analysis is enriched by generating network analysis metrics. This information reveals what SIC codes and inter-industry linkages should be actively cultivated and nurtured.

The economic analysis of the study reveals that the Other mining and quarrying sector is the most concentrated one in the Northern Cape, but the transport and storage cluster is also among the strong sectors in this province. The transport sector plays a key enabling role, which ensures the movement of commodities and human capital. The network analysis shows that the mining industry, metals, and agriculture are Northern Cape's anchors, while transport and storage are among the few sectors that show significant intra- and inter-regional linkages.

Policy-wise, the results of this study provide invaluable insight into the industries that should be actively cultivated to maximise their economic contribution. This analysis allows practitioners to categorise various sectors into clusters as 'mature', 'star', 'transforming', and 'emerging'; each cluster necessitates a customised policy prescription. For instance, although strong, metal mining in the maturity stage is now associated with declining growth. The prospect for future harvests is low, and policymakers should take necessary measures to deal with job losses.

Irrespective of the insightful results, this study did not perform other robust econometrics analyses to ascertain the critical role of transport in the linkage between Northern Cape performance and that of the rest of South African

provinces. Future studies may apply moderation analysis to determine the moderation role of the transport sector in the link between South African provinces. Secondly, spillover effects that may occur between regions can be ascertained to show that the development of certain regions may influence development in the surrounding regions.

Appendix

Table A1 shows the authority weight of all the 2- and 3-digit SIC sectors active in the Northern Cape, based on the Northern Cape economy's network analysis results.

Table A1: Detailed sectoral (SIC) codes by authority weight in the Northern Cape

SIC	Description of the 50 detailed SIC sectors	Authority weight
SIC 22, 25-29	Other mining and quarrying	0.238
SIC 831-883	Professional business services	0.138
SIC 11	Agriculture	0.122
SIC 61-63	Wholesale and retail trade	0.112
SIC 315-316	Leather and leather and fur products	0.107
SIC 334	Basic chemicals	0.095
SIC 24	Metals	0.091
SIC 71-74	Transport and storage	0.089
SIC 351, 353	Basic iron and steel products; casting of metal	0.085
SIC 92	Education (Private)	0.067
SIC 342	Non-metallic mineral products	0.066
SIC 381-383	Motor vehicles, parts and accessories	0.064
SIC 331-333	Coke, petroleum products and nuclear fuel	0.063
SIC 311-312	Textiles	0.062
SIC 323	Paper and paper products	0.062
SIC 75	Communication	0.057
SIC 321-322	Wood and wood products	0.057
SIC 356-359	Machinery and equipment	0.056
SIC 355	Other fabricated metal products	0.056
SIC 341	Glass and glass products	0.056
SIC 301-304	Food	0.055
SIC 12	Forestry	0.051
SIC 335-336	Other chemical products	0.050
SIC 338	Plastic products	0.050
SIC 337	Rubber products	0.050
SIC 361-366	Electrical machinery	0.050
SIC 5	Construction	0.048
SIC 391	Furniture	0.048
SIC 324-326	Printing, recorded media	0.048
SIC 384-387	Other transport equipment	0.047
SIC 354	Structural metal products	0.046
SIC 305-306	Beverages and tobacco	0.041
SIC 371-373	Radio, television and communication apparatus	0.040
SIC 352	Non-ferrous metal products	0.039
SIC 93	Health and social work (Private)	0.036
SIC 317	Footwear	0.035
SIC 64	Catering and accommodation services	0.033
SIC 392 - 395	Other manufacturing groups	0.032
SIC 374-376	Professional equipment	0.031
SIC 313-314	Wearing apparel	0.030
SIC 913	Local government	0.028
SIC 94-96, 99	Other community, social and personal services	0.028
SIC 889	Business activities n.e.c.	0.027
SIC 13	Fishing	0.019
SIC 81-82	Finance and insurance	0.016
SIC 41	Electricity and gas	0.008
SIC 911	National and Provincial government	0.005

Source: Authors' calculations based on data from Quantec Research – EasyData (2020).

References

- Arbues, P., Banos, J.F., Mayor, M., 2015. The spatial productivity of transportation infrastructure. *Transportation Research Part A* 75, 166-177.
- Baporikar, N., 2015. Transport as an Enabler for Infrastructure Development in African Countries. 10.13140/RG.2.2.18775.42408.
- Bavelas, A., 1948. A Mathematical Model for Group Structures. *Human Organization* 7.3, 16-30.
- Berube, A., Parilla, J., 2012. Metropolitan Trade: Cities Return to Their Roots in the Global Economy. The Brookings Institution, Metropolitan Policy Program. [Online:] <https://www.brookings.edu/wp-content/uploads/2016/06/26-metro-trade.pdf>
- Blöchl, F., Theis, F.J., Vega-Redondo, F., Fisher, E.O., 2011. Vertex centralities in input-output networks reveal the structure of modern economies. *Physical Review E* 8.4, 046127.
- Bloechl, F., Theis, F.J., Vega-Redondo, F., Fisher, E.O. 2010. Which Sectors of a Modern Economy are Most Central? Social Science Research Network, Rochester, NY, SSRN Scholarly Paper ID 1681277, Sep. 2010.
- Bonacich, P., 1972. Factoring and weighting approaches to status scores and clique identification. *Journal of Mathematical Sociology* 2, 113-120.
- Bonacich, P., 1987. Power and Centrality: A Family of Measures. *American Journal of Sociology* 92.5, 1170-1182.
- Condeco-Melhorado, A., Tillema, T., de Jong, T. and Koopal, R., 2014. Distributive effects of new highway infrastructure in the Netherlands: the role of network effects and spatial spillovers. *Journal of Transport Geography* 34, 96-105.
- Department of Regional Australia, Local Government, Arts and Sport. 2013. Regional Economic Development Guide, Commonwealth of Australia.
- Dunn, E.S., 1960. A statistical and analytical technique for regional analysis. *Papers of the Regional Science Association* 6.1, 97-112.
- Fabusuyi, T., Juergen, P., 2018. Applying a hybrid Input-Output Model and Network Analysis to Regional Economies 1-6. 10.1109/ISC2.2018.8656698.
- Flegg, A.T., Tohmo, T., 2013. Regional Input-Output Tables and the FLQ Formula: A Case Study of Finland. *Regional Studies* 47.5, 713-721.
- Flegg, A.T., Webber, C.D., 2000. Regional Size, Regional Specialization and the FLQ Formula. *Regional Studies* 34.6, 563-569.
- Flegg, A.T., Webber, C.D., Elliott, M.V., 1995. On the Appropriate Use of Location Quotients in Generating Regional Input-Output Tables. *Regional Studies* 29.6, 547-561.
- Freeman, L.C., 1977. A set of measures of centrality based on betweenness. *Sociometry* 40, 35-41.
- Greenstreet, D., 1989. A Conceptual Framework for Construction of Hybrid Regional Input-Output Models, *Socio-Economic Planning Sciences* 23.5, 283-289.
- Hennig, M., Brandes, U., Pfeffer, J., Mergel, I. 2012. Studying Social Networks. A Guide to Empirical Research. Frankfurt: Campus Verlag; and Wasserman, S. and Faust, K. 1994. *Social Network Analysis: Methods and Applications*. Cambridge, MA: Cambridge University Press.
- Hewings, G.J., Jensen, R.C., 1987. Regional, interregional and multiregional input-output analysis. In *Handbook of regional and urban economics* 1, 295-355). Elsevier.
- Hidalgo, C.A., Hausmann, R., 2009. The building blocks of economic complexity. *Proceedings of the National Academy of Sciences*, 106.26, 10570-10575.
- Hirschman, A.O., 1957. *The Strategy of Economic Development*. Yale University Press.
- Indiana Business Research Center (2006). Location Quotients: A Tool for Comparing Regional Industry. *Compositions. Incontext* 7(3), 1-3.
- Kleinberg, J.M., 1999. Authoritative sources in a hyperlinked environment. *Journal of the ACM (JACM)* 46.5, 604-632.
- Klosterman, Richard E., 1990. *Community and Analysis Planning Techniques*. Rowmand and Littlefield Publishers, Inc. Savage, Maryland. See also Chapter 10; Klosterman, Richard E., Brail, Richard K. and Bossard, Earl G. (1993). *Spreadsheet Models for Urban and Regional Analysis*. See Chapter 20.
- Lahr, M L., de Mesnard, L., 2004. Biproportional Techniques in Input-Output Analysis: Table Updating and Structural Analysis. *Economic System Research*, 16.2, 115-134.
- Leontief, W.W. 1936. Quantitative Input and Output Relations in the Economic Systems of the United States. *Review of Economics and Statistics* 18.3, 105-125.
- Li, Z., Wu, M., Chen, B.R., 2017. Is road infrastructure investment in China excessive? Evidence from productivity of firms. *Regional Science and Urban Economics* 65, 116-126.
- Lundberg, D.E., Krishnamoorthy, M., Stavenga, M.H., 1995. *Tourism economics*. New York: John Wiley & Sons.
- Lychagin, S., Pinkse, J., Slade, M.E., Reenen, J.V., 2016. Spillovers in space: does geography matter?. *The Journal of Industrial Economics*, 64.2, 295-335.
- McNerney, J., Kryazhimskiy, A. 2009. Network properties of economic-input output networks. International Institute for Applied Systems Analysis Interim Report IR-09-003.
- McNerney, J. Fath, B.D., Silverberg, G., 2013. Network structure of inter-industry flows. *Physica A: Statistical Mechanics and its Applications*, 392(24): 6427-6441.
- Miller, R., 1998. Regional and Interregional Input-Output Analysis. *Methods of interregional and regional analysis* 1998, 41-134.
- Newman, M., 2010. *Networks: An Introduction*, 1st edition. Oxford; New York: Oxford University Press.

- New Zealand Ministry of Transport. 2016. Contribution of transport to economic development Economic development and transport project. Summary report. New Zealand Government.
- Norbert, S., 2015. Methods for regionalising input-output tables. *Regional Statistics*, 1.5, 44-65.
- O'Connor, R. and Henry, E.W., 1975. Input-output analysis and its applications. London: Charles Griffin & Company.
- OECD 2018. Enhancing Connectivity Through Transport Infrastructure: The Role of Official Development Finance and Private Investment. Organisation for Economic Co-operation and Development. Presentation by Kaori Miyamoto at the G20 Global Infrastructure Connectivity Alliance (GICA) Annual Meeting. OECD Headquarters, Paris, January 26. <https://www.gica.global/sites/gica/files/Kaori-Miyamoto-GICA-FinancingInfrastructure-Slides.pdf>.
- Open Risk Manual (2023). Leontief Inverse Matrix. https://www.openriskmanual.org/wiki/Leontief_Inverse_Matrix [Accessed 11 November 2023].
- Parra, F., 2018. Utilidades para Análisis de Marcos Input-Output. Retrieved 20 October 2020 from https://rdrr.io/github/PacoParra/UtilMio/f/inst/doc/UtilMio_texto.pdf.
- Roberts, B.H., 2019. Connecting systems of secondary cities: How soft and hard infrastructure can foster equitable economic growth among secondary cities. Brussels, Belgium: Cities Alliance.
- Rodrigue, J-P. (ed), 2017. The Geography of Transport Systems, Hofstra University, Department of Global Studies & Geography, <https://transportgeography.org>.
- Rodrigue, J. P., Nottenboom, T., 2020. The Geography of Transport Systems. 5th edition. New York: Routledge, 456 pages. ISBN 978-0-367-36463-2.
- Rostow, W. W., 1959. The Economic History Review, New Series 12.1, 1-16
- Schaffer, W., Chu, K. 2005. Non-Survey Techniques for Constructing Regional Inter-Industry Models. *Papers in Regional Science* 23, 83-104.
- Stats SA 2019. Four facts about our provincial economies. Online Available: <https://www.statssa.gov.za/?p=12056>.
- Stephenson, K., Zelen, M. 1989. Rethinking centrality: Methods and examples. *Social Networks*, 11.1, 1-37.
- Tong, T., Yu, T.E., Cho, S., Jensen, K., Ugarte, D.D., 2013. Evaluating the spatial spillover effects of transportation infrastructure on agricultural output across the United States. *Journal of Transport Geography*, 30: 47-55.
- Van Wyk, L., Saayman, M., Rossouw, R., Saayman, A. 2015. Regional economic impacts of events: A comparison of methods. *South African Journal of Economic and Management Sciences* 18.2, 155-176. <https://doi.org/10.4102/sajems.v18i2.593>
- Wagner, J.E., Deller, S.C. 1998. Measuring the Effects of Economic Diversity on Growth and Stability. *Land Economy*, 74.4, 541-556.
- Western Cape Government. 2022. Building the economy through transport infrastructure. <https://www.westerncape.gov.za/tpw/building-economy-through-transport-infrastructure>
- World Bank Group. 2019. Infrastructure Connectivity. Japan G20 Development Working Group. January 2019. <https://www.oecd.org/g20/summits/osaka/G20-DWG-Background-Paper-Infrastructure-Connectivity.pdf>
- Zhang, X., 2008. Transport infrastructure, spatial spillover and economic growth: Evidence from China. *Frontiers of Economics in China*, 3: 585-597.
- Zhang, X., 2013. 'Has Transport Infrastructure Promoted Regional Economic Growth? - With an Analysis of the Spatial Spillover Effects of Transport Infrastructure'. *Social Sciences in China* 34, 24-47.
- Zhao, J., Sun, G. and Webster, C., 2022. Does China-Pakistan Economic Corridor improve connectivity in Pakistan? A protocol assessing the planned transport network infrastructure. *Journal of Transport Geography* 100, p103327.