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Assessing economic vulnerability in South African municipalities: A focus on mining-dependent regions using the Economic Complexity Index

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Abstract

South Africa's historical reliance on mineral resources has established thriving towns and settlements, sustaining households for decades. However, the decline in demand for these resources and mine closures pose significant threats to the future of these areas, creating vulnerabilities in towns and their dependent regions. This article addresses concerns about the vulnerability of certain South African municipalities, particularly those heavily dependent on mining. Employing an Economic Complexity Index (ECI), the study identifies and classifies vulnerable mining towns and regions. The methodology involves applying the concept of economic vulnerability, utilising sub-national economic and trade data to determine the complexity of municipal economies. In addition, geospatially linked data is employed to identify mining-dependent areas at risk. The results highlight municipalities with low economic complexity, signalling the need for targeted interventions and emphasising the importance of economic diversification in mitigating risks. The study not only serves as a warning for current planning, but also lays the groundwork for future research and evidence-based policymaking to ensure the sustainability and resilience of regional economies in South Africa.

Keywords: Economic Complexity Index, vulnerable mining areas, local municipal level, South Africa

EVALUERING VAN EKONOMIESE KWESBAARHEID IN SUID-AFRIKAANSE MUNISIPALITEITE: 'N FOKUS OP MYNBOU-AFHANKLIKE STREKE DEUR GEBRUIK TE MAAK VAN DIE EKONOMIESE KOMPLEKSITEITSINDEKS

Die historiese afhanklikheid van Suid-Afrika op minerale hulpbronne het welvarende dorpe en nedersettings gestig wat dekades lank huishoudings onderhou het. Tog, die afname in die aanvraag vir hierdie hulpbronne en die sluiting van myne stel beduidende bedreigings vir die toekoms van hierdie gebiede, en skep kwesbaarhede in dorpe en hul afhanklike streke. Hierdie artikel spreek bekommernisse aan oor die kwesbaarheid van sekere Suid-Afrikaanse munisipaliteite, veral dié wat sterk afhanklik is van mynbou. Deur 'n Ekonomiese Kompleksiteitsindeks (EKI) toe te pas, identifiseer en klassifiseer die studie kwesbare mynboudorpe en streke. Die metodologie behels die toepassing van die konsep van ekonomiese kwesbaarheid, waar sub-nasionale ekonomiese en handelsdata gebruik word om die kompleksiteit van munisipale ekonomieë te bepaal. Daarbenewens word geo-ruimtelik gekoppelde data gebruik om mynbou-afhanklike areas in gevaar te identifiseer. Die resultate beklemtoon munisipaliteite met 'n lae ekonomiese kompleksiteit, wat die noodsaaklikheid van doelgerigte ingrypings aandui en die belang van ekonomiese diversifikasie beklemtoon om risiko's te verminder. Die studie dien nie alleenlik as 'n waarskuwing vir huidige beplanning nie, maar lê ook die grondslag vir toekomstige navorsing en bewys-gebaseerde beleidsformulering om die volhoubaarheid en veerkrag van streekekonomieë in Suid-Afrika te verseker.

1. INTRODUCTION

Historically, mining in South Africa has given rise to the development of several cities and towns. According to Marais, Cloete and Lenka (2022: 1), approximately nineteen of these towns and cities have or had substantial mining economies. There are, however, signs that the mining sector is waning, with some mining operations showing a significant decline (Banya, 2013; Njini, 2023). In light of these trends, mining regions (municipalities, cities, and towns), overly reliant on a mining economy, have become highly vulnerable, raising concerns about their ability to adapt to a future without mining. With some mines closing (evident in the Klerksdorp-Stilfontein-Orkney area of North West) or facing closure, the need to clearly reflect

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the economic vulnerabilities and resilience of regions has come to the fore, resulting in recent research to develop an Economic Complexity Index (ECI).

In the context of this study, 'economic vulnerability' refers to the exposure of communities and regions to risks and shocks, emphasising the sustainability of settlements, particularly mining towns, in South Africa. This includes an assessment of the potential risks associated with economic dependencies on specific sectors such as mining in the face of dynamic global economic changes (Adger, Amell & Tompkins, 2005; Béné *et al*., 2017). 'Resilience', on the other hand, denotes the capacity of regions to withstand and recover from economic shocks, highlighting the importance of adaptive strategies and economic diversification (CSIR, 2019). The study explores these concepts to discern vulnerable regions and towns, especially those reliant on a dominant economic sector, providing insights for proactive planning and policy development in the context of changing economic dynamics and declining mining activities.

In recent years, a significant shift towards data-driven methodologies for evaluating economic complexity and forecasting future economic growth has occurred (Török *et al*., 2023). A key development in this domain is the Economic Complexity Index (ECI), introduced by Hidalgo and Hausmann (2009) based on the analysis of productive capabilities and international trade flows. This approach has global application and has been employed at sub-national levels, as seen in studies conducted in Romania (Török, Benedek & Gómez-Zaldívar, 2022; Gómez-Zaldívar & Llanos-Guerrero, 2021). The method has been extensively used in social and economic contexts, covering areas such as economic growth, population growth of cities, business cycles, human development, income inequality, labour market dynamics, foreign direct investment, and sustainability, applied across diverse geographical scales and regional databases, including the USA, Mexico, China, Brazil, Australia, Italy, New Zealand, the UK, and Romania (Gao & Zhou, 2018; Hidalgo & Hausmann, 2009; Balland & Rigby, 2017; Gómez-Zaldívar & Llanos-Guerrero, 2021).

These studies contribute to a growing body of literature that extends economic complexity analysis from global to sub-national levels, addressing contexts such as regional inequality impact on economic growth (Panzera & Postiglione, 2022), synchronisation of business cycles in Mexican states (Gómez-Zaldívar & Llanos-Guerrero, 2021), and the impact of economic complexity on carbon emissions in France (Can & Gozgor, 2017).

Despite these advancements, a discernible gap exists in adapting such methodologies to address economic vulnerabilities in regions heavily reliant on specific sectors such as mining. This article aims to bridge this gap by applying the ECI to South African municipalities, shedding light on potential risks posed by economic dependencies and the need for diversified economic strategies.

The rationale for this research lies in proactive planning for future-oriented aspects, often overlooked in traditional economic analyses. Recent studies undertaken in the Bojanala district, including a regional baseline study for SALGA (Maritz *et al*., 2021), indicated a need for significant exploration of the economic vulnerabilities of municipalities and towns heavily dependent on mining activities. The urgency lies in the changing dynamics of the mining sector, prompting the critical need to develop strategies for economic diversification.

The study seeks to contribute by developing an ECI tailored to identify municipalities at risk due to a lack of economic diversity, guided by the pioneering work of Hidalgo and Hausmann (2009). This proactive approach aids in guiding investment decisions within the mining sector and promotes non-mining opportunities, fortifying the economic foundations of these regions.

The potential contributions of this article extend beyond understanding economic vulnerabilities. The introduction of the ECI presents opportunities for strategic investment decisions, especially in regions dependent on mining. The findings can potentially shape policy recommendations to enhance economic diversity and resilience.

Following this introduction, the article delves into a comprehensive literature review, explores the methodology behind the ECI's development, presents findings, and concludes with policy implications and potential recommendations.

2. LITERATURE REVIEW

2.1 Commodities, vulnerability, and resilience

The terminology of vulnerability, risk, resilience, and adaptation, previously prominent in climate change discussions (Adger *et al*., (2005); Béné *et al*., 2017), has gained renewed significance amid events such as the COVID-19 pandemic. This has underscored the vulnerability of communities and brought attention to the sustainability of settlements and regions across South Africa (CSIR, 2019).

A defining characteristic of South Africa's economic landscape is the prevalence of mining towns shaped by the nation's mineral wealth. While historical mining areas such as Johannesburg and Kimberley played pivotal roles in the nation's development, the past decade has witnessed a decline in mining activities. Gold mining areas such as the Klerksdorp-Stilfontein-Orkney region have experienced reduced activities, due to resource depletion and rising production costs. In addition, sharp declines in commodity prices, particularly platinum, have impacted on Platinum Gold Mining (PGM) areas, significantly affecting towns and settlements dependent on such mining activities. Notably, the City of Johannesburg-Witwatersrand exemplifies a shift towards reduced dependency on mining, demonstrating increased resilience through the development of diverse economic sectors.

Emerging economic shocks highlight the imperative to discern vulnerable regions and towns, especially those relying on a dominant economic sector amid a dynamically changing global landscape. Recognising and classifying vulnerable mining towns and regions in South Africa necessitate a comprehensive understanding of the underlying framework and its intricate links to economic diversity.

2.2 Economic vulnerability and resilience interaction

Figure 1 introduces a conceptual framework for comprehending vulnerability, illustrating the interconnections between exposure sensitivity, potential impact, adaptive capacity, and vulnerability (Allen Consulting, 2005). Sensitivity, exposure, and adaptive capacity collectively determine the magnitude of potential impact. Sensitivity, measuring a region's dependence on changing elements, is a pivotal starting point in the framework. The combined influence of exposure and sensitivity determines the potential impact, highlighting the role of adaptive capacity in mitigating lasting harm (Schröter, Polsky & Patt, 2005).

Rossouw (2020) underscores that the endurance of a region against potential impacts relies on its capacity to adapt. Regions that can 'reinvent' themselves can avert lasting losses and damages. Conversely, those struggling to avoid social and economic setbacks are deemed vulnerable. The vulnerability assessment is contingent upon the magnitude of potential impacts and the region's adaptive capacity. If a region exhibits resilience, it implies that its adaptive capacity minimises the social and economic damage that might arise from potential impacts (Australian Bureau of Agricultural and Resource Economics – Bureau of Rural Sciences, 2010).

Furthermore, the concept of resilience, often intertwined with diversity, becomes central to the discussion. Diversity, particularly in economic activities, amplifies the system's capacity to respond to shocks, enhancing resilience. This paper adopts the definition of resilience proposed by Cutter *et al.* (2013: 26), highlighting its interconnected nature with the ability to prepare for, absorb, recover from, and adapt to adverse events. In this context, resilience is inversely related to vulnerability, representing the community's condition after adapting to a source of stress or shock.

Within this theme, resilience aligns with 'adaptive resilience' or socio-ecological resilience, emphasising the dynamics between continuity and change in self-organising systems. Internal and external pressures influence the system's capacity to absorb and adapt to such pressures. Four critical questions, derived from Carpenter *et al.* (2001), guide the exploration of resilience:

1. Resilience of what?
2. Resilience to what?
3. Resilience by what means?
4. Resilience with what outcome?

These questions provide a comprehensive framework for understanding the critical aspects of resilience concerning regional economic systems. They delve into defining the characteristics of the system, identifying the shock of interest, analysing the mechanisms and processes of regional adaptation, and assessing the outcomes of the system's reaction to the shock.

2.3 Diversity impact: Economy and resilience

While commonplace economic indicators such as Gross Domestic Product (GDP), unemployment rate, and personal income dominate discussions, economic diversity emerges as a critical yet often overlooked measure. Economic diversity gauges the extent to which a region engages in various economic activities, emphasising the stability it provides during unforeseen economic events. Regions overly reliant on a single sector face heightened vulnerability, while those with diverse economic activities demonstrate greater resilience (Chmura, 2022).

The relationship between diversity and resilience takes centre stage, echoing studies such as Folke *et al.* (2002), which argue that increased diversity enhances the system's capacity to respond to shocks. In this context, diversity refers to the differences in economic structures (Milizia & Shansi, 1993), with a more diverse economy, theoretically

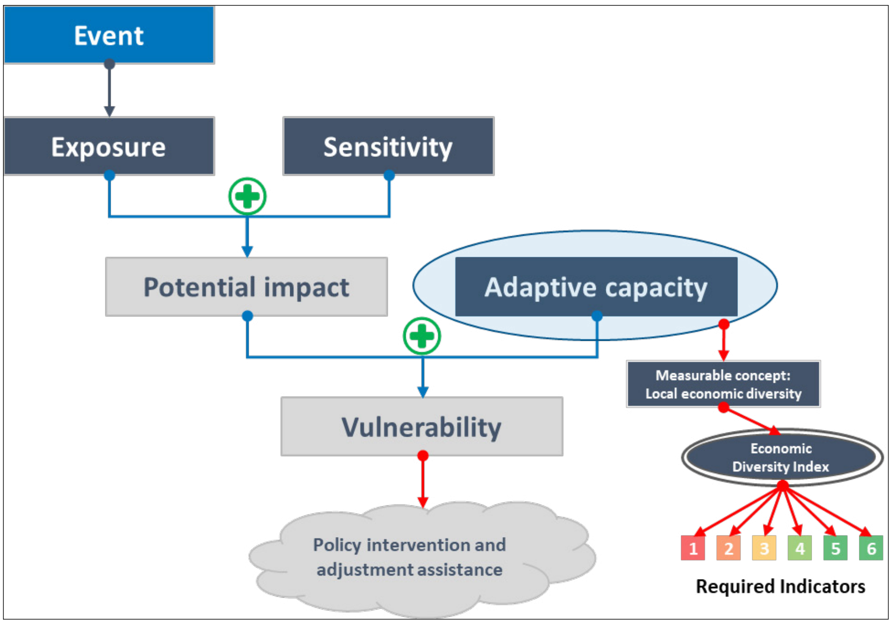

Figure 1: Conceptual framework to understand vulnerability

Source: Adapted from Allen Consulting Group (2005), based on Schröter, Polsky and Patt (2005: 579).

exhibiting higher resilience when confronted with shocks. The paper underscores the significance of the diversity of the local economic base and the diversity of local resources, emphasising their role in enhancing adaptive capacity and lowering vulnerability.

2.4 The Economic Complexity Index framework: Bridging theory and practice

The ECI serves as the theoretical foundation, linking economic diversification to key indicators such as employment levels, exports, and income. The ECI's calculation is grounded in the understanding that knowledge accumulation and diffusion are pivotal drivers of long-term economic growth. It provides a unique indicator that measures the non-observable capabilities or 'know-how' embedded in the production of goods and services (Hidalgo & Hausmann, 2009).

2.5 The relationship between the Economic Complexity Index and existing indices

To understand the structure of regional economies, theories such as economic base theory acknowledge the significant role of export of goods and services to provide income to the region (Poinsot & Ruault, 2019). However, it does not take the diversity and complexity of goods produced into account compared to the ECI.

In examining economic vulnerability in South African municipalities, particularly those reliant on mining, the ECI emerges as a superior tool compared to existing indices. Rooted in the framework developed by Hidalgo and Hausmann (2009), the ECI not only comprehensively understands economic structures, but also excels in predicting growth and income inequality. This aligns with the resilience needed in regions heavily dependent on specific industries such as mining, as emphasised by Folke *et al*. (2002). Siegel, Alwang & Johnson's (1995) advocacy for a structural decomposition model to analyse economic instability in industry-dependent regions further underscores the ECI's significance.

A nuanced evaluation of economic diversity in South African mining-dependent municipalities calls for carefully selecting indices. While Shannon's diversity index and Acar and Sankaran's (1999) insights on the unique decomposability myth are considerations, the ECI stands out with its predictive economic growth and income inequality capabilities. The ECI's suitability in mining-dependent regions is evident, aligning with the emphasis on resilience. This comparison is crucial in light of the limitations of existing indices, as highlighted by Siegel *et al*. (1995), prompting a shift toward more comprehensive tools such as the ECI.

One widely used approach to measuring economic diversity is through indices such as Shannon's diversity index, also known as the Shannon-Wiener index or entropy. These indices, discussed by scholars such as Simpson (1949) and Shannon (1948), provide a mathematical basis for assessing the diversity within a system. On the other hand, absolute specialisation indices reveal the concentration of specific industries in a region, offering insights into its economic structure (Palan, 2010). This idea of industrial concentration echoes McLaughlin's (1930) and Tress' (1938) works in the early 20th century, emphasising the importance of industrial diversification for economic stability. Such measures have been applied to regions (Conroy, 1974; Conroy, 1975) and portfolios (Markowitz, 1959; Sherwood-Call, 1990), illustrating their versatility in analysing economic structures at different scales.

In the context of economic vulnerability, the comparison extends to the widely used Hachmann (1995) Index (HI), emphasising economic diversity and location quotients (LQs) that quantify industry concentration. However, the ECI surpasses these indices in its predictive capacity and nuanced understanding of economic structures. The superiority of the ECI becomes evident, offering a more holistic perspective for policymakers and researchers striving for adaptive capacity and sustainable development in mining-dependent regions.

3. METHODS

This article addresses the scarcity of indicators reflecting the economic vulnerabilities of certain South African mining regions, towns, and municipalities. Making use of an integrated/mixed methods design, this study uses literature reviews combined with GIS for data collection and analysis (Creswell & Plano-Clark, 2018: 8). Integrated research data makes it possible to elaborate on specific findings from the GIS analysis on mining-dependent risk areas and cross-check it against other analysis such as economic complexity levels of these areas, from the ECI analysis.

3.1 Data collection

Although this analysis strongly focuses on mining areas, the data sources covered the country to derive results that depict mining regions and provide complete coverage of South Africa. This article acknowledges the constraint of data available to represent mining geography and related data, especially at a sub-municipal level.

To reflect the main mining regions in South Africa, various data levels such as unique point or polygon-based data, mesozone data, settlement footprints, and local municipal datasets need to be considered. In this instance, the primary focus was to provide a broader regional and national perspective. Two data levels were applied: Data at the *settlement level* was sourced from the CSIR settlement footprint layer, a fine-grained layer depicting settlements and containing downscaled socio-economic data, which includes economic production (Gross Value Added [GVA]) data for the major Standard Industrial Classification (SIC) divisions. Data at the *local municipal level* was sourced from Quantec Easydata (Quantec, 2020) for multiple periods and included demographic, economic production, and employment data. Additional data from the Housing Development Agency (2023) indicated the municipalities with prioritised housing developments. This data was used to indicate areas with significant mining activity. Geospatial data included the local municipal demarcations sourced from the Municipal Demarcation Board. Data was sourced from the Council for Geoscience (2018) to depict mining occurrence and derive mining clusters. This included the last available set of active mines, reflecting the mining type and commodities mined.

The data used for the ECI calculations integrated sub-national economic and trade data. Global ECI computations relied on international trade data sourced from the BACI dataset published by CEPII (*Centre d'Etudes Prospectives et d'Informations Internationales*), which provides bilateral trade flows at the HS 6-digit product level (Gaulier & Zignago, 2010).

The study adhered to complexity indicators from the Atlas of Economic Complexity (The Growth Lab at Harvard University, 2022) for sub-national indicators within South Africa. Utilising international trade data from the South African Revenue Service's (SARS) Department of Customs and Excise merchandise trade database (SARS, 2022), with a high product disaggregation level (at the HS 8-digit level and available monthly), the analysis computed revealed trade advantages (RTAs) for each product, constructing an ECI at the local municipality level.

3.2 Data analysis and interpretation

For the classification of the mining regions and mining-dependent areas in South Africa, the following methods were used.

First, data points for all active mines were extracted from the core mining dataset provided by the Council of Geoscience. A Point Density analysis was applied to derive a high-mining activity heat map. This produced a density surface that, when depicted in formatted colour ranges, clearly illustrates the areas of mining concentration.

The second method used economic production data (gross value added) linked spatially to the settlement and local municipal levels. Economic information used in this analysis was sourced from Quantec, including economic production values and employment statistics (applied for 2011 and 2018). The percentage of the mining sector (production) compared to total economic production was calculated for both the settlement and local municipal levels. These percentage levels were thematically mapped to show levels of increasing mining sector dependence. Where percentage values exceeded 30%, settlement or local municipalities were considered dependent.

By combining both items, several dominant clusters could be visually identified. These clusters were graphically marked, and the dominant mining type and location were used to describe and name several mining clusters.

The ECI calculation, using an iterative process, considers a region's diversity and a product's ubiquity. Higher capabilities in a region result in greater diversity, whereas products requiring advanced capabilities become accessible to fewer countries, reflecting lower ubiquity. This dynamic establishes a positive relationship between a country's capabilities and future economic growth. The Product Complexity Index (PCI), mirroring the ECI, serves as the product equivalent (Hartmann *et al.*, 2017).

The theoretical framework guiding ECI calculations draws from Pérez-Balsalobre, Llano-Verduras and Diaz-Lanchas (2019) and from Fritz and Manduca (2019), involving sub-national ECI estimations in South Africa. First, estimating economic complexity involves assessing the intricacy of both locations (for example, countries, municipalities, cities) and activities (for example, products, sectors, industries). The presence of complex activities in a location and the locations where a complex activity is present offer insights into its economic complexity. This relationship is expressed mathematically through functions *f* and *g* in a circular mapping:

$$K_c = f(K_p)$$
$$K_p = g(K_c)$$

These equations indicate that metrics of economic complexity are solutions to self-consistent equations or linear approximations. The ECI is defined as the average of the PCI for activities in a location and vice versa:

$$ECI_c = \frac{1}{n}\sum_{i=1}^{n} PCI_{p_i}$$
$$PCI_p = \frac{1}{m}\sum_{j=1}^{m} ECI_{c_j}$$

For sub-national data with varying units of observation, sub-national ECIs are defined using a modified version of the Revealed Trade Advantage (RTA), comparing the share of activity in a local unit with its share in the world (Fritz & Manduca, 2019):

$$ECI_{subnational} = \sum_i \left(\frac{PCI_{i,local}}{PCI_{i,world}} \times RTA_{i,local}\right)$$

In this equation, we define $RTA_{i,local}$ using a modified version of the RTA:

$$RTA_{i,local} = \frac{Share\ of\ Activity\ i\ in\ Local\ Unit}{Share\ of\ Activity\ i\ in\ the\ World}$$

This comparison prevents highly developed regions within a country from seeming to have a comparative advantage in every product. In addition, it ensures that the ECI values obtained for sub-national regions are comparable to those of countries in international datasets.

4. FINDINGS

4.1 Geospatial analysis results

Table 1 lists all municipalities that reflect a mining sector (SIC2[1]) economic production presence. It identifies the municipalities that rely on mining and that could be at risk (vulnerable), should their mining futures change (decline). It presents the mining sector percentage per local municipality sorted from large to small. Figure 2 spatially indicates the areas within South Africa where a number of mining town clusters can be identified, all with high levels of economic dependence, due to the lack of economic diversity.

1 *Standard Industrial Classification of all Economic Activities (SIC) - https://www.statssa.gov.za/additional_services/sic/sic.htm*

For both Table 1 and Figure 2, the extent of economic production from mining was categorised into several sector dominance categories, namely

- Mining GVA percentage above 40% – high risk
- Mining GVA Percentage between 30% and 40% – medium risk
- Mining GVA Percentage between 20% and 30% – medium-low risk

The analyses identified 53 municipalities that are reasonably dependent on mining. The remainder would count as low risk, due to below 20% mining sector dominance.

Mining landscape – Table 1 also attempts to distinguish mining areas based on whether they are

Table 1: Municipalities identified due to their relevance (production) in the mining sector. Comparing production and employment in the sector

Municipality	Categories (sector dominance)	Housing agency	Percentage mining GVA 2018	Percentage mining GVA change 2011-2018	Percentage mining employment 2018	Change in mining sector employment 2011-2018	Mining landscape New or established
Thabazimbi	High risk	Additional	88.39	-2.25	49.83	-6.6	Established mining
Greater Tubatse	High risk	Prioritised towns LM	69.62	-3.04	24.49	-4.21	New mining
Joe Morolong	High risk	Not identified LM	65.87	-4.65	28.27	-5.01	Established mining
Ba-Phalaborwa	High risk	Not identified LM	62.84	-4.42	18.37	-4.09	Established mining
Rustenburg	High risk	Prioritised towns LM	60.47	-6.23	47.22	-7.9	Established mining
Gamagara	High risk	Additional	57.84	-13.35	19.89	-9.68	Established mining
Lephalale	High risk	Prioritised towns LM	55.59	0.17	11.27	-1.34	New mining
Dannhauser	High risk	Not identified LM	53.42	-1.85	17.86	1.33	Established mining
Kgatelopele	High risk	Not identified LM	51.3	-4.51	9.66	-1.51	Established mining
Moses Kotane	High risk	Prioritised towns LM	50.89	-3.11	36.33	-4.37	Established mining
Tsantsabane	High risk	Additional	49.81	-4.52	12.9	-2.9	Established mining
Fetakgomo	High risk	Prioritised towns LM	47.65	-4.36	9.28	-1.97	New mining
Richtersveld	High risk	Not identified LM	46.97	-6.54	10.66	-1.97	Established mining/declining
Emalahleni	High risk	Prioritised towns LM	46.23	-5.3	27.46	-1.33	Established mining
Nama Khoi	High risk	Not identified LM	45.93	-6.89	16.29	-3.49	
Khâi-Ma	Medium risk	Not identified LM	39.92	-1.87	5.32	-0.48	
Merafong City	Medium risk	Prioritised towns LM	38.99	-13.38	22.18	-14.02	Established mining/declining
Kamiesberg	Medium risk	Not identified LM	38.95	-5.84	6.94	-1.74	
Steve Tshwete	Medium risk	Prioritised towns LM	36.86	-4.99	17.91	-1.18	Established mining
Madibeng	Medium risk	Prioritised towns LM	36.64	-3.17	20.51	-4.38	Established mining
Matjhabeng	Medium risk	Prioritised towns LM	36.62	-7.75	22.51	-8.24	Established mining/declining
Westonaria	Medium risk	Not identified LM	35.3	-14.71	19.98	-13.91	Established mining/declining
Msukaligwa	Medium risk	Not identified LM	34.12	-1.55	14.62	0.49	Established mining
Masilonyana	Medium risk	Not identified LM	33.6	-8.22	16.23	-7.55	Established mining/declining
Dikgatlong	Medium-low risk	Not identified LM	25.96	-2.23	4.36	-0.93	Established mining
Govan Mbeki	Medium-low risk	Not identified LM	25.82	-7.63	15.73	-4.13	Established mining/declining
Victor Khanye	Medium-low risk	Not identified LM	25.43	-3.07	9.87	-0.39	
City of Matlosana	Medium-low risk	Prioritised towns LM	25.08	-3.23	19.1	-8.4	Established mining/declining
Mkhondo	Medium-low risk	Not identified LM	24.54	1.59	6.92	0.81	
Emakhazeni	Medium-low risk	Not identified LM	22.63	-5.37	7.6	-0.82	Established mining
Mutale	Medium-low risk	Not identified LM	22.39	-2.69	2.7	-0.31	
Ga-Segonyana	Medium-low risk	Prioritised towns LM	22.07	-5.78	5.63	-2.36	Established mining
Emadlangeni	Medium-low risk	Not identified LM	21.89	-2.82	5.1	0.03	Established mining
Abaqulusi	Other	Labour sending areas	15.98	-1.12	4.69	0.04	NA
Ulundi	Other	Labour sending areas	12.86	-3	3.67	-0.28	NA
Mogalakwena	Other	Additional	10.99	-0.54	1.07	-0.12	
Sol Plaatjie	Other	Additional	8.4	-0.84	1.32	-0.18	Established mining
Elias Motsoaledi	Other	Prioritised towns LM	8.27	-0.52	1.12	-0.26	
Uphongolo	Other	Labour sending areas	3.36	-2	1.1	-0.62	NA
Mogale City	Other	Prioritised towns LM	3.3	-0.81	1.1	-0.43	
Nongoma	Other	Labour sending areas	2.8	-1.47	0.69	-0.13	NA
eDumbe	Other	Labour sending areas	1.76	-0.56	0.41	-0.03	NA
Ephraim Mogale	Other	Additional	1.53	-0.05	0.14	-0.01	
Ntabankulu	Other	Labour sending areas	1.51	-2.1	1.22	-0.22	NA
Makhado	Other	Additional	1.24	0.14	0.13	0	
Port St Johns	Other	Labour sending areas	1.13	-1.38	0.98	-0.1	NA
Nyandeni	Other	Labour sending areas	1.02	-1.34	0.87	-0.13	NA
Ngquza Hill	Other	Labour sending areas	0.77	-0.9	0.65	-0.05	NA
Maluti a Phofung	Other	Additional	0.69	-0.15	0.17	-0.01	
//Khara Hais	Other	Additional	0.68	-0.04	0.11	-0.02	
Mbizana	Other	Labour sending areas	0.66	-0.97	0.55	-0.13	NA
Mhlontlo	Other	Labour sending areas	0.56	-0.64	0.4	-0.04	NA
King Sabata Dalindyebo	Other	Labour sending areas	0.18	-0.23	0.18	-0.02	NA

Source: Maritz, 2018

established mining, new mining and, where possible, if areas are declining mining areas. Not all areas are covered, and not all mining labour-sending areas are considered.

Comparing GVA values from 2011 to 2018, there appears to be an overall decline in the contribution of mining to total production in many mining municipalities. Employment figures also reflect a decline when comparing these periods. Therefore, it was essential to consider municipalities' mining sector employment numbers. If a municipality reflects a high level of sector dependence but has a low mining sector employment number, this is less critical than a similar municipality with higher employment numbers. Table 1 indicates that Rustenburg is highly dependent on mining (its share of 60.4% of total economic contribution, 2018). However, it has a much larger mining sector employment than most of the other municipalities. Other municipalities with a high mining prominence (>40%) and the next biggest mining employment numbers are Thabazimbi, Moses Kotane, and Emalahleni. When considering municipalities with a lower mining sector prominence (<40%) and higher sector employment numbers, Merafong City, Madibeng, Matjhabeng, and the City of Matlosana can be identified as more prominent municipalities.

Table 1 also reflects municipalities viewed as labour-sending areas (notably in the Eastern Cape and KwaZulu-Natal). These were not considered, as the exact numbers of where these workers are employed were not available. However, it is important to consider such areas, especially when a decline in mining employment occurs. This would have significant economic impacts on the labour-sending areas.[2]

In some instances, a single mine can dominate the economy of a local municipality such as Lephalale.

2 Only two districts featured as labour sending areas, it is likely that the mining labour sending is not restricted to these two districts. Mining companies however do have information of the 'home' location of the labour they employ. This was, however, not sourced in this project.

On the other hand, a cluster of mining activity can be found in other areas such as in the Bojanala and Sekhukhune districts. A local municipality, where the mining sector dominates the region's economy, also points to the specific demands and implications on towns in the area. Note that this does not disregard other areas where mining occurs – it simply focuses on areas where mining dominates. Drawing on the preceding analysis indicating the areas where mining occurs (Figure 2), as well as municipalities where mining is economically highly relevant, Figure 2 indicates the areas within South Africa where a number of mining town clusters can be identified:

- Platinum Western Limb – this area reflects several settlements where platinum group metals are predominantly mined. It is also large mining towns where mining employment is substantial.
- Nkangala Coal – Several towns are located in a prominent coalfield known for stainless steel production.
- West Rand Old Gold is part of the Witwatersrand (West Rand group) goldfield, an old mining region that has been part of the mining landscape for over 100 years. Mining in these areas, although still present, is declining.
- Welkom Gold – is also part of the southern extent of the Witwatersrand goldfield (goldfield group), with gold mining as the focus.
- Francis Baard Diamonds and Iron is an old mining region known for mining diamonds, limestone, and cement. Areas to the west include iron ore mining – Kuruman and Kathu.
- Motlasana Gold – is located on the west Rand group goldfields. This area is experiencing a decline in gold mining.
- Sekhukhune Platinum (Eastern Limb) focuses on the areas around Steelpoort and Burgersfort, where chrome, magnetite, and platinum are the main commodities. As a result, much new mining growth has occurred in this cluster.
- The third platinum limb is located in Limpopo near Mogalakwena.

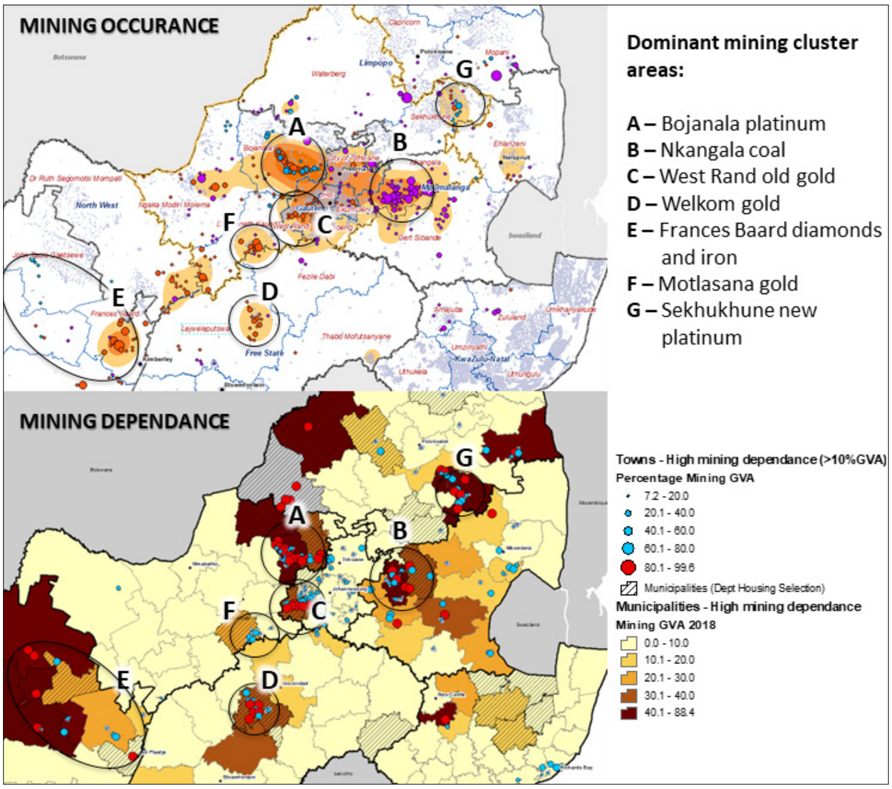

Figure 2: Mining occurrence versus mining dependence
Source: Maritz, 2018

It is known as the northern platinum limb (not part of a cluster in Figure 2).

Table 1 and Figure 2 considered vulnerability by measuring the economic dominance in a municipality and mining towns (points). There was a strong focus on mining as the dominant activity, considering the importance of the future of mining towns in the local context. However, recent mine closures also indicated that neighbouring communities are unprepared (at risk) when other economic activities are not strengthened. Seven mining clusters can be identified, all with high levels of economic dependence, due to the lack of economic diversity. An alternative measure – Economic Complexity (measured by the ECI) – followed a different approach where economic and trade data was used to determine the complexity of the economies in municipalities to derive those most at risk.

4.2 ECI results

The ECI calculations spanning 2011-2018 provided a nuanced understanding of economic resilience in various South African municipalities, particularly those associated with mining activities. The objective was to assess the economic complexity levels of these regions, compare them to the national average ECI, and track changes in resilience from 2011 to 2018, in order to identify economically vulnerable areas in South Africa.

Table 2 presents a comprehensive overview of economic complexity, showing the ECI scores for selected mining-related municipalities and categorising them based on their complexity levels. In 2018, only a select few municipalities, including Rustenburg, Gamagara, Dannhauser, Kamiesberg, Steve Tshwete, Westonaria, Collins Chabane (Mutale), and Mogalakwena, exhibited above-average economic complexity. Identifying these municipalities as highly complex implies their ability to engage in diverse and intricate economic activities beyond the national average. Moreover, their improved ECI scores between 2011 and 2018 underscore their increased resilience during this period.

The municipalities identified as high-risk in Table 1 correlate with those having below-average economic complexity in Table 2. This alignment reveals a compelling interplay between economic vulnerability and complexity, shedding light on the intricate dynamics of regional resilience. High-risk municipalities consistently display a pattern of lower economic complexity, indicating a heightened susceptibility to external shocks and economic downturns. This correlation underscores the pivotal role of economic diversification as a strategic imperative in mitigating risks faced by these regions.

Conversely, the vast majority of listed municipalities, totalling 45, had below-average ECI scores in 2018. Despite this, some showcased improved resilience during the same period, indicating a capacity for economic adaptation and complexity growth. Notably, the low economic complexity levels observed in remote mining regions, particularly in the Northern Cape, Mpumalanga, and parts of KwaZulu-Natal and Limpopo, highlight the challenges faced by these areas in diversifying their economic activities.

Delving deeper into this relationship, the municipalities categorised as high-risk often rely on a limited set of economic activities, rendering them more vulnerable to fluctuations in global and domestic markets. The lack of economic diversification amplifies the impact of adverse events, as these regions are disproportionately affected when their primary industries experience downturns. Moreover, the correlation between high-risk classifications and below-average economic complexity suggests a dual challenge for these regions. Not only do they face immediate risks due to economic concentration, but their long-term resilience is compromised by a lack of diverse economic activities. Economic complexity, as measured by the ECI, becomes a critical lens whereby policymakers can identify areas ripe for intervention. By fostering economic complexity in these high-risk municipalities, policymakers can simultaneously address short-term vulnerabilities and lay the foundation for sustained, diversified economic growth.

Furthermore, the intricate relationship between economic vulnerability and complexity extends beyond the immediate economic considerations. It has broader implications for social and infrastructural development in these regions. High-risk municipalities with lower economic complexity may struggle to invest in education, healthcare, and infrastructure, due to their limited resource base. Therefore, enhancing economic complexity becomes an economic necessity and a pathway to comprehensive and sustainable development.

The alignment observed between high-risk classifications and below-average economic complexity serves as a clarion call for targeted interventions. Strategies aimed at diversifying the economic base of these vulnerable regions can pave the way for increased resilience, not only shielding them from immediate risks, but also fostering enduring development that encompasses social and infrastructural dimensions.

The temporal dynamics of economic complexity, as evidenced in Table 2, reveal intriguing patterns. Municipalities such as Matjhabeng, Westonaria, and Msukaligwa exhibited relative stability in their ECI scores over the years, indicating a consistent level of resilience. In contrast, municipalities such as Greater Tubatse, Rustenburg, Gamagara, and Dannhauser experienced substantial volatility in their ECI scores. This volatility underscores the susceptibility of these regions to economic shocks, emphasising the need for targeted interventions to enhance their economic stability and complexity.

The identified fluctuations in economic complexity also raise questions about the factors contributing to such variability. This invites further investigation into the specific economic activities and

Table 2: ECI by mining municipality, 2011-2018

Municipality	Code	ECI score			Compared to national ECI [0.52], 2018	Comparative resilience (2018 vs 2011)
		2011	2015	2018		
Thabazimbi	LIM361	0.41	0.27 ▼	0.27 ▼	Below average	Less resilient
Greater Tubatse	LIM475	0.35	0.38 ●	0.31 ▲	Below average	Less resilient
Joe Morolong	NC451	0.01	0.01 ▼	0.01 ●	Below average	More resilient
Ba-Phalaborwa	LIM334	0.37	0.29 ▼	0.32 ▲	Below average	Less resilient
Rustenburg	NW373	0.34	0.44 ▲	0.45 ▲	Below average	More resilient
Gamagara	NC453	0.11	0.16 ▼	0.78 ●	Above average	More resilient
Lephalale	LIM362	0.41	0.40 ▲	0.39 ▲	Below average	Less resilient
Dannhauser	KZN254	0.46	0.60 ▲	0.13 ●	Below average	Less resilient
Kgatelopele	NC086	0.21	0.14 ▼	0.19 ▲	Below average	Less resilient
Moses Kotane	NW375	0.25	0.29 ▼	0.39 ▲	Below average	More resilient
Tsantsabane	NC085	0.37	0.37 ▲	0.39 ▼	Below average	More resilient
Fetakgomo	LIM474	0.37	0.35 ▲	0.58 ▲	Above average	More resilient
Richtersveld	NC061	0.32	0.33 ▼	0.27 ▼	Below average	Less resilient
Emalahleni	MP312	0.21	0.49 ▼	0.44 ▲	Below average	More resilient
Nama Khoi	NC062	0.50	0.43 ▼	0.40 ▼	Below average	Less resilient
Khâi-Ma	NC067	0.41	0.17 ▼	0.17 ●	Below average	Less resilient
Merafong City	GT484	0.36	0.38 ▲	0.41 ▲	Below average	More resilient
Kamiesberg	NC064	0.60	0.43 ▲	0.70 ▲	Above average	More resilient
Steve Tshwete	MP313	0.36	0.43 ▲	0.50 ▲	Below average	More resilient
Madibeng	NW372	0.40	0.32 ▼	0.35 ▼	Below average	Less resilient
Matjhabeng	FS184	0.51	0.37 ▼	0.31 ▼	Below average	Less resilient
Westonaria	GT483	0.39	0.40 ▼	0.45 ▲	Below average	More resilient
Msukaligwa	MP302	0.40	0.36 ▼	0.39 ▲	Below average	Less resilient
Masilonyana	FS181	0.35	0.43 ▼	0.39 ▲	Below average	More resilient
Dikgatlong	NC092	0.24	0.16 ▲	0.18 ▼	Below average	Less resilient
Govan Mbeki	MP307	0.35	0.26 ▼	0.37 ▼	Below average	More resilient
Victor Khanye	MP311	0.46	0.38 ▼	0.42 ▲	Below average	Less resilient
City of Matlosana	NW403	0.42	0.40 ▲	0.44 ▼	Below average	More resilient
Mkhondo	MP303	0.54	0.50 ▼	0.45 ▲	Below average	Less resilient
Emakhazeni	MP314	0.33	0.26 ▲	0.26 ▲	Below average	Less resilient
Collins Chabane	LIM342	0.38	0.45 ▼	0.75 ▲	Above average	More resilient
Ga-Segonyana	NC452	0.31	0.21 ▲	0.44 ▲	Below average	More resilient
Emadlangeni	KZN253	0.45	0.19 ▼	0.19 ▼	Below average	Less resilient
Abaqulusi	KZN263	0.39	0.32 ▼	0.23 ▼	Below average	Less resilient
Ulundi	KZN266	0.25	0.28 ▲	0.28 ●	Below average	More resilient
Mogalakwena	LIM367	0.37	0.39 ▲	0.60 ▲	Above average	More resilient
Sol Plaatje	NC091	0.32	0.33 ▼	0.35 ▼	Below average	More resilient
Elias Motsoaledi	LIM472	0.44	0.41 ▼	0.40 ▼	Below average	Less resilient
Uphongolo	KZN262	0.39	0.38 ▲	0.40 ▲	Below average	More resilient
Mogale City	GT481	0.51	0.51 ▲	0.50 ▼	Below average	Less resilient
Nongoma	KZN265	0.16	0.17 ●	0.17 ●	Below average	More resilient
eDumbe	KZN261	0.05	0.15 ▼	0.38 ▲	Below average	More resilient
Ephraim Mogale	LIM471	0.37	0.35 ▲	0.58 ▲	Above average	More resilient
Ntabankulu	EC444	0.25	0.33 ▲	0.35 ▼	Below average	More resilient
Makhado	LIM344	0.31	0.32 ▲	0.38 ▲	Below average	More resilient
Port St Johns	EC154	0.29	0.29 ●	0.29 ●	Below average	More resilient
Nyandeni	EC155	0.03	0.42 ●	0.17 ▼	Below average	More resilient
Ngquza Hill	EC153	0.15	0.15 ●	0.36 ●	Below average	More resilient
Maluti a Phofung	FS194	0.55	0.30 ▲	0.26 ▼	Below average	Less resilient
//Khara Hais	NC083	0.36	0.29 ▼	0.26 ▼	Below average	Less resilient
Mbizana	EC443	0.41	0.57 ▼	0.40 ▼	Below average	Less resilient
Mhlontlo	EC156	0.27	0.98 ▲	0.03 ●	Below average	Less resilient
King Sabata Dalindyebo	EC157	0.07	0.38 ▲	0.33 ▼	Below average	More resilient

Notes: The table shows ECI scores for municipalities (2011-2018), reflecting economic complexity and connectivity. “Comparative resilience” indicates resilience change with arrows (▲ increase, ▼ decrease, ● no change). It classifies municipalities as “More resilient” or “Less resilient” compared to the national average. “Above average” or “Below average” denotes resilience status relative to the national average.

Source: Rossouw, 2020

external influences that may have influenced these municipalities’ ECI trajectories. Understanding these dynamics is crucial for devising tailored policy measures to enhance economic resilience.

5. RECOMMENDATIONS

Using spatial data reveals the regions where mining activity is prominent and when linked to economic production (GVA) emphasises the municipalities that are vulnerable, given their reliance on mining. The ECI goes further and draws on detailed economic data to consider a region’s diversity and a product’s ubiquity. It is recommended that the ECI be applied and incorporated in regional planning frameworks such as SDFs as well as in other development and sector plans, in order to highlight vulnerable areas. The analysis that is part of the ECI calculation also provides value such as understanding a region’s diversity and products.

Considering this, future research should delve into specific regional dynamics, explore trade exposures, and analyse historical ECI data.

The ECI featured in this article has been developed for the local municipal scale. However, more value can be derived if a sub-municipal ECI could be developed, as this would significantly improve the grain of data to enable better targeting of areas. The CSIR’s Settlement Footprint Mesozone spatial data framework introduces a compelling avenue, enabling a more comprehensive evaluation of economic dominance.

Given the relative unfamiliarity of the ECI, it is recommended that it be published through various platforms, in order to make more users aware of its value.

6. CONCLUDING REMARKS

In light of the critical role mining plays in employment and local economies, urgent consideration must be given to the state of mining in its regional contexts. The viability and growth of areas heavily reliant on mining demand a thorough examination of the industry’s future.

The potential or ongoing decline in mining-dependent regions could severely affect the local population and economy. While the government has acknowledged issues in mining towns, its focus appears reactive, addressing concerns such as wages, labourer housing, and the mines' contributions to nearby communities. Persistent protest events in many mining regions, exemplified by the incident in Marikana, underscore the urgency of addressing the futures of these areas, not only for their local impact, but also considering their national significance.

This analysis underscores the immediate need to address economic vulnerabilities in crucial South African regions, particularly those dominated by mining. Following the overarching methodology, which explores economic complexity and connectivity in the context of regional diversification, the study seamlessly weaves in valuable insights.

Economically vulnerable areas, particularly mining towns, present both challenges and opportunities. Their heavy reliance on a specific sector renders them susceptible to shocks. Yet, their existing skills and infrastructure create a foundation for diversification. Leveraging these assets becomes essential for formulating practical and effective strategies that align with the historical significance of mining towns in South Africa.

The ECI emerges as a linchpin for policymakers. Still, its application needs to be more granular, extending the analysis to a sub-municipal level. This precision is crucial for capturing nuanced economic dynamics, aligning with the study's methodology.

In conclusion, this study enhances understanding and lays the groundwork for future research and policymaking. The study takes a pioneering stance in academic exploration, by integrating economic complexity analysis, regional diversification, and spatial data frameworks, providing indispensable tools for evidence-based policies in South Africa's economic development journey.

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