Revisiting the COVID-19 vulnerability index in South Africa

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Professor, Department of Economics, University of the Western Cape, Bellville, South Africa

ABSTRACT

This study uses the Census 2011 and Community Survey 2016 data, adopts the Alkire-Foster multidimensional poverty index (MPI) approach and addresses numerous shortcomings of the original Statistics South Africa method by including numerous indicators from four dimensions (socio-economic, demographic, housing and hygiene, health) to derive a revised COVID-19 vulnerability index. The empirical findings indicate the index was relatively higher for African female individuals living in rural areas of the Eastern Cape, KwaZulu-Natal and Limpopo provinces, coming from households headed by elderly aged 55 years or above. Alfred Nzo, Amathole, Harry Gwala, OR Tambo and Umzinyathi are the five district councils that are most vulnerable to COVID-19 (the first four were declared COVID-19 hotspot areas by the South African government in December 2020). The results of the index decomposition found that indicators from the housing and hygiene dimension contributed most to the COVID-19 vulnerability.

1. Introduction

The coronavirus (COVID-19), an infectious disease caused by severe acute respiratory syndrome coronavirus 2 (or SARS-CoV-2), has been spreading fast across the world since November 2019, and was declared a global pandemic by the World Health Organisation on 11 March 2020. In South Africa, the first case of COVID-19 was detected on 1 March, before President Cyril Ramaphosa declared on 15 March that COVID-19 was a national disaster. The country underwent lockdown level 5 on 27 March for five weeks, before dropping to level 4 and level 3 on 1 May and 1 June, respectively. The lockdown level dropped further to level 2 on 17 August and level 1 on 21 September, as the country was open again to inter-provincial and international travel, and more sectors were allowed to operate their businesses under strict health protocols (Republic of South Africa, 2021).

Unfortunately, with the advent of the second wave and identification of the new variant in early December, it was announced that three district councils (DCs) became hotspot areas with stricter lockdown rules, namely Garden Route District, Nelson Mandela Bay Metro and Sarah Baartman District. An additional 23 DCs were included as hotspot areas when Ramaphosa announced the country moved to an adjusted

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lockdown level 3 on 29 December (South African Government, 2020). On 28 February 2021, it was announced that the country would move from level 3 to adjusted level 1. Furthermore, due to surge in infections or the start of the third wave since early May, restrictions were tightened again and the country moved from adjusted lockdown level 1–2 on 31 May 2021.

At the time of writing, more than 170 million people were infected with the virus across the globe, with 3.6 million deaths in total. In South Africa, nearly 1.7 million people were infected, with more than 1.5 million people recovering from the illness but close to 57 000 people passed away (that is, recovery rate is 93.5% while death rate is 3.4%), and there still remains about 50 000 active cases (Republic of South Africa, 2021). It was also announced by the Health Minister Zweli Mkhize that a three-phase distribution process is adopted to roll out the COVID-19 vaccine, with the primary aim of having 40 million (or two-thirds of the national population) to be immunised by the end of February 2022 to achieve herd immunity in order to break the cycle of transmission (Republic of South Africa, 2021).

While South Africans await their turns to receive the vaccines (only one million people were vaccinated at the time of this study), in the meantime, it is important to identify the people and areas most vulnerable to the pandemic to reduce transmission. During 2020, a handful of international studies were conducted to derive a COVID-19 vulnerability index to distinguish these people and areas. Statistics South Africa (StatsSA) also published a report in mid-December 2020 by adopting the Alkire-Foster multidimensional poverty (MPI) approach to derive this index by taking eight indicators from four dimensions into consideration (it will be discussed in greater detail in the next section).

This study aims to develop an improved, revised version of the COVID-19 vulnerability index, before adopting the revised MPI approach to analyse the Census 2011 and Community Survey 2016 data to investigate the areas as well characteristics of people most vulnerable to the pandemic, by considering a wider range of indicators from four dimensions. The empirical analysis also allows for identification of the main indicators or risk factors which contribute most to the pandemic vulnerability by means of conducting index decomposition. It is hoped that the findings and suggestions of this study would help the government in its policy and rules to quicker identify the at-risk people and areas and reduce transmission.

2. Literature review

Poverty is not only about low income and expenditure, but involves numerous non-money-metric dimensions such as health and educational deprivation, lack of asset possession, insufficient access to services, physical and social isolation, as well as feeling helpless, powerless and vulnerable (Woolard & Leibbrandt, 1999; World Bank, 2000; Philip & Rayhan, 2004). Hence, methods such Factor Analysis, Multiple Correspondence Analysis, Principal Components Analysis and the Total Fuzzy Sets approach have been commonly adopted over the years to derive a non-money-metric multidimensional index to examine poverty in South Africa, along with the conventional money-metric approach (which looks at per capita income or expenditure). The MPI method is a relatively new approach in South Africa to examine multidimensional poverty, and at the time of writing, there are numerous local studies using this approach for multidimensional

poverty analysis, such as Finn et al. (2013), StatsSA (2014), Frame et al. (2017), Mushon-gera et al. (2017), Omotoso and Koch (2017), Rogan (2016), Fransman and Yu (2019).[1]

At the time of writing, StatsSA (2020) is the only local study that adopted the MPI approach to derive the COVID-19 vulnerability index. In this study, eight indicators (employment status and car ownership, media access, water access, sanitation source, overcrowding, multigenerational households, presence of elderly household members and receipt of chronic medication) from four dimensions (population dynamics, house-hold service dynamics, household status dynamics and health) were considered before the index was derived to compare the results by DC and municipality. Note that the report did not provide these results in detail, but rather referred the readers to an online dashboard site.[2]

To the author's knowledge, four international studies were released at the time of writing on derivation of the COVID-19 vulnerability index. First, Acharya and Porwal (2020) considered 15 indicators from five dimensions (socio-economic, demographic, housing and hygiene, epidemiological and health system) to derive a composite vulner-ability index at state and district levels in India. The empirical findings indicated that numerous districts in nine large states (Bihar, Gujarat, Jharkhand, Madhya Pradesh, Maharashtra, Odisha, Telangana, Utter Pradesh and West Bengal) were associated with high overall vulnerability with the index exceeding 0.75. Next, the study by Decaprio et al. (2020) considered four risk factors (older adults, individuals with heart disease, people with diabetes and people with lung disease) to derive the vulnerability index in the USA to identify individuals with pre-existing medical conditions who were at the greatest risk for severe COVID-19-related complications.

Looking at the other studies, Macharia et al. (2020) included 24 indicators from four dimensions (socio-economic deprivation, population characteristics, access to services and epidemiological background) to derive the COVID-19 vulnerability index in Kenya, and found that 46 sub-counties (which represented 7.0 million people) located around central and south eastern were more vulnerable to the pandemic, whilst 81 sub-counties (14.4 million individuals) were least vulnerable to it. Lastly, Nair (2020) considered 12 indicators from the socio-economic, demographic, transportation and health dimensions to derive the vulnerability index to identify counties that are vulner-able to the pandemic in the USA, with the aid of the Principal Components Analysis stat-istical technique. The empirical findings suggested that counties with high vulnerability index were associated with high COVID-19 case rates.

3. Methodology and data

3.1 Methodology

The original global MPI approach was introduced in 2011 by Alkire and Foster for the purpose of measuring acute multidimensional poverty across countries. This approach comprises 10 indicators from three dimensions, namely health, education and living standard (Santos and Alkire, 2011:5-6). A two-step approach is adopted to derive the MPI index (Alkire and Foster, 2011: 296). First, linked to each indicator is a minimum

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[1]These literatures are not reviewed in detail here, given this study primarily relates to COVID-19 vulnerability.
[2]Link to this online dashboard: http://www.statssa.gov.za/?p=13875

level of satisfaction, namely the deprivation cut-off point (z_i). An individual or household i is deprived in this indicator if his/her achievement in this indicator, x_i, is below the cut-off (i.e. $x_i < z_i$) and hence the dummy variable I_i equals one. Conversely, I_i equals zero if $x_i \geq z_i$. The indicators' weights are then chosen, and these weights sum to 1 ($\sum_{i=1}^{m} w_i = 1$).

Each dimension carries the same weight of one-third, and an equal weighing scheme is applied to the indicators within each dimension. The deprivation score, c_i, is calculated as: $\sum_{i=1}^{m} w_i I_i$, with this score ranging from zero to one.

A specific cut-off point, k, stands for the share of weighted deprivations a person must have before he/she is regarded as multidimensionally poor. Someone is distinguished as poor if $c_i \geq k$. In the MPI, $k = 1/3$, meaning the person's deprivation must be at least a third of the weighted indicators to be distinguished as MPI poor. In addition, $c_i(k)$, the censored deprivation score, is derived as follows: if $c_i \geq k$, $c_i(k) = c_i$; if $c_i < k$, $c_i(k) = 0$ (Santos and Alkire, 2011:11).

The MPI reflects both the percentage of population that is multidimensionally poor (H or the poverty headcount ratio) and average proportion of weighted deprivation the person experiences (A or the intensity of poverty). In equation terms, $H = q/n$, where q and n denote the number of multidimensionally poor and total population respectively. Moreover, $A = \dfrac{\sum_{i=1}^{n} c_{i(k)}}{q}$, which represents the fraction of the m indicators in which the multidimensionally poor individual is deprived. The MPI is calculated as $H \times A$. Lastly, the MPI index can be decomposed by population sub-groups or indicators, in order to find out the demographic characteristics of people as well as indicators that contribute most to the MPI (refer to Santos and Alkire (2011) as well as Fransman and Yu (2019) for detailed mathematical explanation).

This study adopts the MPI approach by revising the indicators, dimensions and cut-off points from the StatsSA 2020 study to re-derive the COVID-19 vulnerability index, as shown in Tables 1 and 2, with the last column of both tables indicating the weight of

Table 1. Dimensions, indicators, deprivation cut-offs and weights for the COVID-19 vulnerability index, Census 2011.

Dimension	Indicator	Deprivation cut-off	Weight
Socio-economic	[A]: Education	None of working-age household member completed Matric	1/16
	[B]: Informal employment	At least one member working in the informal sector	1/16
	[C]: Car ownership	Did not own a motor vehicle	1/16
	[D]: Access to media	Did not own any one of television, radio, cellphone and has no access to internet	1/16
Demographic	[E]: Multigenerational households	Children (0-15 years) and elderly (60+) both present in the household	1/8
	[F]: Overcrowding	More than two people per functional room	1/8
Housing and hygiene	[G]: Dwelling type	Informal dwelling	1/16
	[H]: Refuse removal	Not removed by local authorities at least once a week	1/16
	[I]: Water	Did not have access to water within 200m of the dwelling	1/16
	[J]: Sanitation	Did not have own flush/chemical toilet in dwelling	1/16
Health	[K]: Disability	At least one member with disability problem	1/8
	[L]: Chronic medication	At least one member using chronic medication	1/8

Source: Adapted from Statistics South Africa, 2020.

Table 2. Dimensions, indicators, deprivation cut-offs and weights for the COVID-19 vulnerability index, Community Survey 2016.

Dimension	Indicator	Deprivation cut-off	Weight
Socio-economic	[I]: Education	None of working-age household member completed Matric	1/12
	[II]: Car ownership	Did not own a motor vehicle	1/12
	[III]: Access to media	Did not own any one of television, radio, cellphone and has no access to internet	1/12
Demographic	[IV]: Multigenerational households	Children (0-15 years) and elderly (60+) both present in the household	1/8
	[V]: Overcrowding	More than six people in the household	1/8
Housing and hygiene	[VI]: Dwelling type	Informal dwelling	1/16
	[VII]: Refuse removal	Not removed by local authorities at least once a week	1/16
	[VIII]: Water	Did not have access to water within 200m of the dwelling	1/16
	[IX]: Sanitation	Did not have own flush/chemical toilet in dwelling	1/16
Health	[X]: Disability	At least one member with disability problem	1/12
	[XI]: Malnutrition	Ran out of money to buy food or skipped a meal +5 days in past 30 days	1/12
	[XII]: Public healthcare	Poor quality or no access to public clinic and public hospital	1/12

Source: Adapted from Statistics South Africa, 2020.

each indicator. Note that the indicators are not exactly the same in Census 2011 and Community Survey (CS) 2016, as the questionnaire design was not identical in the two years.

The indicators come from four dimensions (socio-economic, demographic, housing and hygiene, and health), as vulnerable individuals should not be confined to elderly and those with comorbidities and ill health, but also those from certain socio-economic groups who struggle to cope with the pandemic financially, mentally and physically (The Lancet 2020).

With regard to the indicators in the first dimension (socio-economic), educational attainment was not included from the StatsSA approach but is included in this study, as it is an important indicator to reflect the socio-economic conditions of the households. Note that this indicator was also included in the 2020 Acharya and Porwal as well as Macharia et al. studies. Whilst the StatsSA approach included the 'at least one employed household member and the household does not own a motor vehicle' indicator, this study rather treats the two variables separately. In 2011, two different indicators are included, namely 'at least one member working in the informal sector' and 'the household does not own a motor vehicle'. It is important to separate the two variables (this approach was also adopted in the 2020 Macharia et al. study), because household members who rely on public transport for purposes other than work (e.g. shopping for groceries) can also be vulnerable to the pandemic. One drawback is that StatsSA did not release data in connection with the whole labour market section in CS 2016, and thus it is not possible to include the informal sector indicator in 2016. Lastly, the media access indicator is derived in the same way as the StatsSA 2020 study.

Moving on to the second dimension (demographic), the multigenerational household variable is derived in the same way as StatsSA (2020) did. With regard to the overcrowding indicator, in this study, in Census 2011, the cut-off point is rather changed from 'more than three people per functional room' (the StatsSA approach) to 'more than two people per function room', because it is extremely difficult for self-isolation and

1.5m social distancing to be feasible if there are three people in the same room. In CS 2016, it is unfortunate that the number of rooms question was not asked. However, given the mean number of rooms was about four (4.10) in Census 2011, and it is assumed that we can accommodate two people in the main bedroom for household head and his/her spouse, another two people (e.g. children) in the second bedroom, one person in the living room and one person in the dining room (that is, six people in total for four functional rooms), it is decided to adopt the 'more than six people in the dwelling' cut-off point for the overcrowding indicator in CS 2016.

As far as the housing and hygiene dimension is concerned, in this study, water and sanitation indicators are included and the same cut-offs are adopted as in the StatsSA 2020 study. However, this study includes two additional indicators, namely dwelling type (threshold: informal dwelling) and refuse removal (threshold: refuse is not removed at least once a week), as these two indicators are also important to reflect the housing and hygiene condition of the household. These two indicators were also included in some of the international studies reviewed earlier (Acharya & Porwal, 2020; Macharia et al., 2020).

Finally, for the health dimension, in the 2020 StatsSA study, two indicators – chronic medication and presence of elderly household members – were included. In this study, in Census 2011, the chronic medication indicator is still included (unfortunately the information was no longer captured in CS 2016), but the presence of elderly members indicator is not included. The two main reasons for the exclusion of the latter indicator is that the recent news clearly suggests the youth population are also likely to be infected with the virus upon the identification of the new variant (Kubheka, 2020), and there is a strong correlation between this indicator and the earlier discussed multigenerational households indicator (correlation coefficient between the two indicators is quite high at 0.67).

The disability indicator is included for both years in this study, as people who have a lot of difficulty to perform or cannot perform certain duties at all clearly need assistance from fellow household members, meaning it is relatively more difficult for the members to self-isolate or subsequently they are under greater risk to be transmitted with the virus. Lastly, malnutrition and access to public healthcare are included as additional health-related indicators in 2016 (unfortunately the information was not captured in Census 2011). Note that similar indicators were also included by Acharya and Porwal (2020) as well as Macharia et al. (2020) by rather omitted by StatsSA (2020).

The MPI method discussed at the start of this section is adopted to derive the COVID-19 vulnerability index, before the index estimates are derived and compared by personal, geographical and income characteristics in 2011 and 2016. The index decomposition by these characteristics as well as indicators is also conducted.

3.2 Data

Two StatsSA data sets are used: the original 10% sample of Census 2001 and CS 2016 data that was released by StatsSA. These data sets provide comprehensive personal- and household-level information on demographic characteristics, educational attainment, labour market activities, asset ownership, access to household goods and services, as well as household income in interval terms.

One serious drawback is the non-availability of 2016 CS data on labour market activities, even though the information was captured. In addition, as mentioned earlier, the questions on malnutrition and public healthcare access were not asked in Census 2011, whereas information on number of rooms in the dwelling and receipt of chronic medication was not captured in CS 2016. This explains the indicators included and why the weighting of each indicator are not exactly the same in both years. Therefore, the forthcoming empirical findings need to be interpreted with caution when it comes to comparison of results between the two years.

Another drawback is that StatsSA also did not release household income data in CS 2016. Whilst the information is released in Census 2011, more than 15% of households declared either zero or unspecified income. Therefore, for these households, the sequential regression multivariable imputation (SRMI) approach is adopted to impute the income of these households.[3] The household income variable after SRMI is used to derive the quintile variable (dividing the households into five groups, with an equal 20% share per quintile) which is used for the forthcoming empirical analysis.

4. Empirical findings

4.1 Extent of deprivation per indicator

Figure 1 illustrates that there was generally a continuous downward trend in the proportion of deprived population for the indicators that were captured in both years, with the exception of overcrowding as the proportion increased from 15.6% to 20.3%. In both years, the proportion of deprived population was the greatest for the motor vehicle ownership indicator (nearly 70%), followed by refuse removal (41%) and education (approximately 40%). The deprivation proportion was the lowest for the media access indicator (2011: 3.1%; 2016: 1.8%). The latter result is not anything surprising because cellular telephone ownership has become much more prevalent during the decade of the 2010.

4.2 Vulnerability index by sub-groups

The COVID-19 vulnerability index estimates by numerous characteristics are shown in Table 3. For the overall population, the index hovered around the 0.14-0.15 range, while the poverty headcount estimate was roughly 31% in both years. Table 3 also shows that individuals coming from households headed by elderly female Africans and residing in rural areas of the Eastern Cape, KwaZulu-Natal and Limpopo provinces were more vulnerable to the pandemic, as shown by the relatively higher vulnerability index. For the results by income quintile variable in 2011, as expected, higher income quintiles are associated with lower headcount ratio and lower vulnerability index.

Table A.1 shows what happened in all 52 DCs, whereas Table 4 shows the top 10 and bottom 10 DCs with the lowest and highest index estimates, respectively. Table 4 shows that, for the 10 DCs with the lowest index in 2011, eight of them remained in the top 10 in 2016 (Cape Winelands, City of Cape Town, City of Johannesburg, Ekurhuleni, Nelson

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[3]Detailed mathematical explanation of the SRMI approach falls beyond the scope of this study, but the readers can refer to Raghunathan et al. (2001), Ardington et al. (2006), Lacerda et al. (2008) and Vermaak (2008).
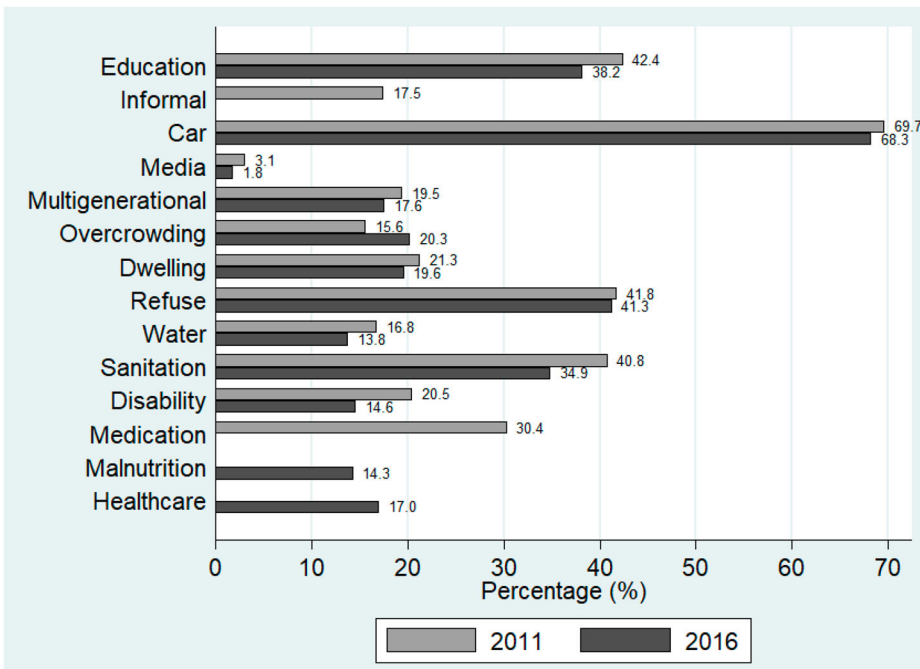
Figure 1. Proportion (%) of population deprived in each indicator. Source: Authors' calculations using Census 2011 and Community Survey 2016 data.

Mandela Bay, Overberg, Sedibeng and West Rand). Moreover, for the bottom 10 DCs with the greatest index estimate in 2011, seven of them were also ranked in the bottom 10 in 2016 (Alfred Nzo, Amathole, Harry Gwala, OR Tambo, Ugu, Umkhanya-kude and Umzinyathi). Furthermore, six out of the bottom 10 DCs in 2011 with the highest vulnerability index were declared as COVID-19 hotspot areas by Ramaphosa in December 2020, namely Alfred Nzo, Amathole, Chris Hani, Harry Gwala, OR Tambo and Ugu (Republic of South Africa, 2020).

The cut-off point of 0.25 was adopted in the StatsSA 2020 study to distinguish the COVID-19 vulnerable or 'poor' individuals. This study adopted the more universally adopted threshold of 0.33 as in the 2010 Alkire and Santos original approach, Table A.2 examines the vulnerability estimates and ranking of the DCs by using different thresholds (0.25, 0.33, 0.40 and 0.50), and the results suggest that there are not any drastic changes in the ranking of DCs.

Lastly, Table A3 shows the 30 municipalities with the greatest COVID-19 vulnerability index in each year, and the results indicate that most of them are located in Eastern Cape and KwaZulu-Natal.

4.3 Profile of the vulnerable people and index decomposition

Table 5 shows that, as expected, individuals being vulnerable to the pandemic were pre-dominantly those coming from households headed by females (about 55%), Africans (95%) and older adults aged at least 55 years (about 50%), living in rural areas (two-

Table 3. COVID-19 vulnerability index by demographic, geographical and income characteristics.

		2011			2016		
		H	A	Index	H	A	Index
All	All	0.3105	0.4789	0.1487	0.3190	0.4484	0.1431
Gender	Male	0.2508	0.4735	0.1188	0.2538	0.4405	0.1118
	Female	0.3846	0.4833	0.1859	0.3966	0.4545	0.1803
Race	African	0.3620	0.4817	0.1744	0.3688	0.4504	0.1661
	Coloured	0.2095	0.4488	0.0940	0.1659	0.4145	0.0687
	Indian	0.0549	0.4166	0.0229	0.0368	0.3848	0.0142
	White	0.0258	0.4118	0.0106	0.0145	0.3847	0.0056
Age	0–14 years	0.3014	0.4362	0.1314	0.4811	0.4316	0.2076
	15–24 years	0.2030	0.4379	0.0889	0.3084	0.4217	0.1300
	25–34 years	0.1926	0.4441	0.0855	0.2415	0.4190	0.1012
	35–44 years	0.2130	0.4530	0.0965	0.2261	0.4238	0.0958
	45–54 years	0.2586	0.4620	0.1195	0.2551	0.4312	0.1100
	55–64 years	0.4038	0.4897	0.1977	0.3935	0.4582	0.1803
	65+ years	0.5888	0.5125	0.3017	0.5713	0.4872	0.2783
Area type	Urban	0.1612	0.4457	0.0719	0.1646	0.4126	0.0679
	Rural	0.5622	0.4950	0.2783	0.6197	0.4670	0.2894
Province	Western Cape	0.1596	0.4383	0.0700	0.1328	0.4035	0.0536
	Eastern Cape	0.5188	0.5157	0.2675	0.5069	0.4802	0.2434
	Northern Cape	0.3460	0.4764	0.1648	0.3614	0.4495	0.1624
	Free State	0.2740	0.4588	0.1257	0.2530	0.4244	0.1073
	KwaZulu-Natal	0.4103	0.4943	0.2028	0.4316	0.4648	0.2006
	North West	0.3818	0.4788	0.1828	0.3923	0.4512	0.1770
	Gauteng	0.1239	0.4379	0.0543	0.1479	0.4080	0.0604
	Mpumalanga	0.3193	0.4592	0.1466	0.3806	0.4403	0.1676
	Limpopo	0.4102	0.4588	0.1882	0.5058	0.4441	0.2247
Per capita income quintile	Quintile1	0.6913	0.4816	0.3330		Not applicable	
	Quintile2	0.3701	0.4933	0.1826			
	Quintile3	0.2004	0.4586	0.0919			
	Quintile4	0.1561	0.4432	0.0692			
	Quintile5	0.0384	0.4434	0.0170			

Source: Author's calculations using Census 2011 and Community Survey 2016 data.

Table 4. Topic 10 district councils with the smallest and greatest COVID-19 vulnerability index.

2011		2016	
District council	Index	District council	Index
The 10 district councils with the smallest COVID-19 vulnerability index			
City of Johannesburg	0.0427	Overberg	0.0466
Ekurhuleni	0.0517	Eden (Garden Route)	0.0522
City of Cape Town	0.0580	Sedibeng	0.0523
Sedibeng	0.0619	City of Cape Town	0.0532
City of Tshwane	0.0640	City of Johannesburg	0.0535
Overberg	0.0766	Cape Winelands	0.0544
Nelson Mandela Bay	0.0807	Ekurhuleni	0.0587
West Rand	0.0833	West Coast	0.0591
eThekwini Metropolitan	0.0860	Nelson Mandela Bay	0.0676
Cape Winelands	0.0885	West Rand	0.0690
The 10 district councils with the greatest COVID-19 vulnerability index			
Alfred Nzo	0.3896	Alfred Nzo	0.4168
Amathole	0.3852	OR Tambo	0.3851
OR Tambo	0.3758	Amathole	0.3355
Harry Gwala	0.3331	Umzinyathi	0.3269
Umzinyathi	0.3215	Umkhanyakude	0.3252
Joe Gqabi	0.3102	Zululand	0.3116
Chris Hani	0.3073	Harry Gwala	0.3083
Ugu	0.2894	John Taolo Gaetsewe	0.2987
Umkhanyakude	0.2892	Ugu	0.2827
Zululand	0.2849	Greater Sekhukhune	0.2805

Source: Author's calculations using Census 2011 and Community Survey 2016 data.

Table 5. Profile of COVID-19 vulnerable individuals (%).

		Not vulnerable	Vulnerable	Not vulnerable	Vulnerable
Gender	Male	60.17	44.72	59.53	43.22
	Female	39.83	55.28	40.47	56.78
		100.00	100.00	100.00	100.00
Race	African	73.59	92.72	76.26	95.11
	Coloured	10.09	5.94	10.17	4.32
	Indian	3.42	0.44	2.95	0.24
	White	12.36	0.73	10.61	0.33
	Unspecified	0.54	0.18	0.00	0.00
		100.00	100.00	100.00	100.00
Age	0–14 years	0.16	0.16	0.05	0.09
	15–24 years	5.03	2.84	4.69	4.47
	25–34 years	19.40	10.27	19.26	13.09
	35–44 years	26.31	15.80	26.22	16.35
	45–54 years	25.12	19.46	25.13	18.37
	55–64 years	14.80	22.25	15.42	21.35
	65+ years	9.19	29.22	9.23	26.27
		100.00	100.00	100.00	100.00
Area type	Urban	76.35	32.58	81.05	34.08
	Rural	23.65	67.42	18.95	65.92
		100.00	100.00	100.00	100.00
Province	Western Cape	13.63	5.75	14.30	4.68
	Eastern Cape	8.79	21.05	7.62	16.72
	Northern Cape	2.09	2.46	2.16	2.61
	Free State	5.82	4.88	6.03	4.36
	KwaZulu-Natal	16.66	25.74	15.25	24.73
	North West	6.24	8.56	6.55	9.03
	Gauteng	29.91	9.39	33.59	12.45
	Mpumalanga	7.66	7.98	7.15	9.37
	Limpopo	9.19	14.19	7.35	16.06
		100.00	100.00	100.00	100.00
Per capita income quintile	Quintile1	23.42	40.24	Not applicable	
	Quintile2	18.29	35.80		
	Quintile3	17.60	15.05		
	Quintile4	20.61	7.13		
	Quintile5	20.09	1.78		
		100.00	100.00		

Source: Author's calculations using Census 2011 and Community Survey 2016 data.

thirds share), in Eastern Cape, KwaZulu-Natal or Limpopo, and coming from income quintiles 1 and 2 (75% share). In contrast, those who were classified as not vulnerable to the pandemic were those coming from households headed by males (60%), Africans (about three quarters) and relatively younger adults aged 25–54 years (approximately 70% share), living in urban areas (more than three quarters' share) in Gauteng, Western Cape and KwaZulu-Natal.

It can be seen from Table 6 that in both years, the relative contribution by individuals from African, female- and elderly-headed households was more dominant. The relative contribution of the rural population (about two-thirds) greatly exceeded its population share (around 35%). Lastly, Eastern Cape, KwaZulu-Natal and Limpopo were the provinces with the largest index contributions; they accounted for about 60% share of COVID-19 vulnerability, despite only accounting for about 40% of the population. In addition, the 2011 decomposition results by income quintile indicate that individuals from the two poorest quintiles contributed more than three quarters towards the pandemic vulnerability.

Table 6. COVID-19 vulnerability index decomposition by demographic, geographical and income characteristics (%).

		Population share	Contribution share	Population share	Contribution share
Gender	Male	55.37	44.22	54.33	42.45
	Female	44.63	55.78	45.67	57.55
		100.00	100.00	100.00	100.00
Race	African	79.53	93.26	82.27	95.52
	Coloured	8.80	5.56	8.30	3.99
	Indian	2.50	0.38	2.09	0.21
	White	8.75	0.62	7.33	0.29
	Unspecified	0.43	0.17	0.00	0.00
		100.00	100.00	100.00	100.00
Age	0–14 years	0.16	0.14	0.06	0.09
	15–24 years	4.35	2.60	4.62	4.20
	25–34 years	16.56	9.52	17.29	12.23
	35–44 years	23.05	14.95	23.07	15.46
	45–54 years	23.36	18.77	22.97	17.67
	55–64 years	17.11	22.75	17.31	21.82
	65+ years	15.41	31.26	14.67	28.54
		100.00	100.00	100.00	100.00
Area type	Urban	62.76	30.32	66.07	31.36
	Rural	37.24	69.68	33.93	68.64
		100.00	100.00	100.00	100.00
Province	Western Cape	11.18	5.26	11.23	4.21
	Eastern Cape	12.60	22.67	10.52	17.91
	Northern Cape	2.21	2.45	2.31	2.62
	Free State	5.53	4.67	5.50	4.12
	KwaZulu-Natal	19.48	26.56	18.28	25.63
	North West	6.96	8.56	7.34	9.08
	Gauteng	23.54	8.59	26.85	11.33
	Mpumalanga	7.76	7.65	7.86	9.20
	Limpopo	10.74	13.59	10.13	15.90
		100.00	100.00	100.00	100.00
Per capita income quintile	Quintile1	28.64	40.47	Not applicable	
	Quintile2	23.72	36.87		
	Quintile3	16.81	14.41		
	Quintile4	16.42	6.60		
	Quintile5	14.40	1.65		
		100.00	100.00		

Source: Author's calculations using Census 2011 and Community Survey 2016 data.

Moving on to decomposition by indicators, Table 7 shows that in 2011, chronic medication (12.74%), car ownership (11.87%), disability (11.85%) and multigenerational households (11.36%) were the four indicators contributing most to the vulnerability index. On the other hand, when it comes to CS 2016, the top indicators contributing most to the pandemic vulnerability were car ownership (16.88%), overcrowding (12.51%), multigenerational households (11.36%) and educational attainment (11.22%). In addition, Figure 2 shows that the housing and hygiene dimension contributed most to the vulnerability index (2011: 30.56%: 2016: 36.57%).

5. Conclusion

This study analysed the Census 2011 and CS 2016 data to derive the COVID-19 vulnerability index by revising the original StatsSA 2020 approach. Additional indicators were

Table 7. COVID-19 vulnerability index decomposition by indicators (%).

Dimension	Indicator	Weight	Contribution
2011			
Socio-economic	[A]: Education	6.25	8.56
	[B]: Informal employment	6.25	2.55
	[C]: Car ownership	6.25	11.87
	[D]: Access to media	6.25	0.95
Demographic	[E]: Multigenerational households	12.50	11.36
	[F]: Overcrowding	12.50	9.55
Housing and hygiene	[G]: Dwelling type	6.25	5.57
	[H]: Refuse removal	6.25	9.93
	[I]: Water	6.25	5.14
	[J]: Sanitation	6.25	9.91
Health	[K]: Disability	12.50	11.85
	[L]: Chronic medication	12.50	12.74
		100.00	100.00
2016			
Socio-economic	[I]: Education	8.33	11.22
	[II]: Car ownership	8.33	16.88
	[III]: Access to media	8.33	0.77
Demographic	[IV]: Multigenerational households	12.50	11.36
	[V]: Overcrowding	12.50	12.51
Housing and hygiene	[VI]: Dwelling type	6.25	5.62
	[VII]: Refuse removal	6.25	10.81
	[VIII]: Water	6.25	4.76
	[IX]: Sanitation	6.25	10.04
Health	[X]: Disability	8.33	5.37
	[XI]: Malnutrition	8.33	5.59
	[XII]: Public healthcare	8.33	5.06
		100.00	100.00

Source: Author's calculations using Census 2011 and Community Survey 2016 data.
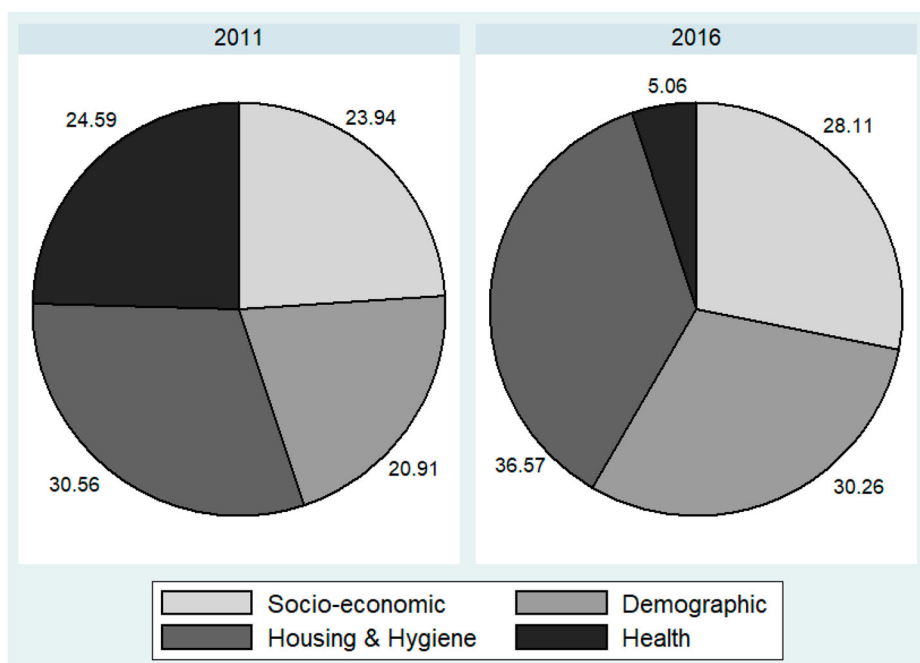

Figure 2. COVID-19 vulnerability index decomposition by dimensions. Source: Authors' calculations using Census 2011 and Community Survey 2016 data.

included to derive this index, after considering the approach adopted in the recent international studies. The empirical findings of this study indicated that individuals coming from female-, African- and elderly-headed households living in rural areas in Eastern Cape, KwaZulu-Natal and Limpopo provinces were relatively more vulnerable to the pandemic. In addition, residents from the Alfred Nzo, Amathole, Harry Gwala, OR Tambo and Umzinyathi DCs as well as individuals living in numerous municipalities from the Eastern Cape and KwaZulu-Natal provinces were identified as most vulnerable to the pandemic. Furthermore, motor vehicle ownership and multigenerational households were the indicators contributing most to the vulnerability index estimate in both years.

It is hoped that the findings of this study would help prioritise regions and people for resource allocation and adopt risk mitigation strategies to better prepare and response to the COVID-19 pandemic for the remainder of 2021 and even early 2022, before the full South African population would receive the vaccination. Numerous suggestions are raised here. First, for people who do not have their own motor vehicles, the government, in cooperation with the private sector businesses, can consider better promotion of online shopping and delivery of items at their residences by, for example, making certain online shopping websites zero-rated.[4] Nonetheless, it is important to ensure such initiative will not unfairly knockout small businesses. Hence, there can be additional support to the small firms to help them convert online and even develop a system of home delivery of shopping items.

There can also be greater initiatives on forming a community neighbourhood group to encourage the residents with motor vehicles to have bulk purchases before delivering some of the essential items to fellow neighbours who do not have their own motor vehicles. These initiatives could reduce the likelihood of the less privileged people from going out with public transport and subsequently the probability of exposure to big crowds.

For areas with a high proportion of multigenerational and/or overcrowded households, they can be targeted as hotspot areas with more public tests being conducted, and more hotels can be used as designated quarantine venues for self-isolation purposes (providing the cost is affordable, especially to those coming from the poorer income quintiles), as a way to indirectly help these hotels to operate to close to full capacity. In addition, vulnerable people who need chronic medication should be discouraged from visiting healthcare facilities if possible, but the medication can be delivered directly to their residences (e.g. 3-month supply of medication being delivered to their doors), so as to reduce their chance to go out and possibly get infected with the virus.

Lastly, since the COVID Alert South Africa mobile app has been available from September 2020, there have not been any updates which indicate how effective this app is in contact tracing, if not helping reduce transmission. Hence, it is important for such information to be released before we will know better how to make better use of this app, and whether there is a need to further upgrade some of the features of this app. For example, in Singapore, it is required that everyone who enters places such as shopping malls, schools and banks must first scan the QR codes with their smartphones and input

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[4]At the time of writing, a total of 1 068 websites are zero-rated, as released by Internet Service Providers' Association (2020). However, these websites are almost all related to education and learning.

their personal information, and similarly 'check out' when they leave these places (Nikkei Asia, 2020). On the other hand, Malaysia's contact tracing app not only includes the above-mentioned QR-code scanning feature, but also allows the users to complete a basic survey on travel history, symptoms and recent contact with a confirmed case, before they are automatically classified into different risk categories and informed of the next steps to take (GovInsider, 2020). Hence, the South African governments may consider including these additional features when they plan to upgrade the COVID Alert app in the near future.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix

Table A1. COVID-19 vulnerability index by district councils.

	2011				2016			
	H	A	Index	Rank	H	A	Index	Rank
Alfred Nzo	0.7478	0.5210	0.3896	52	0.8239	0.5058	0.4168	52
Amajuba	0.3658	0.4826	0.1766	32	0.4140	0.4470	0.1851	31
Amathole	0.7115	0.5414	0.3852	51	0.6918	0.4849	0.3355	50
Bojanala	0.3346	0.4592	0.1536	27	0.3632	0.4351	0.1580	28
Buffalo City	0.2757	0.4808	0.1326	20	0.2971	0.4438	0.1319	22
Cape Winelands	0.1993	0.4443	0.0885	10	0.1364	0.3988	0.0544	6
Capricorn	0.3700	0.4567	0.1690	31	0.4429	0.4419	0.1957	32
Central Karoo	0.2289	0.4351	0.0996	14	0.1831	0.4032	0.0738	12
Chris Hani	0.5850	0.5253	0.3073	46	0.5805	0.4706	0.2732	42
City of Cape Town	0.1343	0.4319	0.0580	3	0.1318	0.4034	0.0532	4
City of Johannesburg	0.0988	0.4316	0.0427	1	0.1332	0.4014	0.0535	5
City of Tshwane	0.1443	0.4434	0.0640	5	0.1742	0.4195	0.0731	11
Dr Kenneth Kaunda	0.2401	0.4637	0.1113	16	0.2165	0.4272	0.0925	18
Dr Ruth Segomotsi Mompati	0.5187	0.4950	0.2568	40	0.5504	0.4735	0.2606	40
Eden (Garden Route)	0.2168	0.4522	0.0980	12	0.1276	0.4094	0.0522	2
Ehlanzeni	0.3493	0.4536	0.1584	28	0.4506	0.4373	0.1971	33
Ekurhuleni	0.1190	0.4349	0.0517	2	0.1458	0.4028	0.0587	7
eThekwini	0.1887	0.4557	0.0860	9	0.1992	0.4234	0.0844	15
Fezile Dabi	0.2135	0.4448	0.0950	11	0.1927	0.4121	0.0794	13
Frances Baard	0.2639	0.4654	0.1228	18	0.2912	0.4217	0.1228	21
Gert Sibande	0.3061	0.4742	0.1452	24	0.3278	0.4506	0.1477	26
Harry Gwala	0.6523	0.5106	0.3331	49	0.6377	0.4834	0.3083	46
iLembe	0.5059	0.4990	0.2525	38	0.5125	0.4738	0.2428	38
Joe Gqabi	0.6068	0.5112	0.3102	47	0.5232	0.4623	0.2419	36
John Taolo Gaetsewe	0.5087	0.4962	0.2524	37	0.6096	0.4900	0.2987	45
King Cetshwayo	0.5211	0.5119	0.2668	42	0.5170	0.4805	0.2484	39
Lejweleputswa	0.2545	0.4593	0.1169	17	0.2469	0.4241	0.1047	20
Mangaung	0.2416	0.4539	0.1097	15	0.2046	0.4175	0.0854	16
Mopani	0.4184	0.4585	0.1919	35	0.5319	0.4419	0.2350	35
Namakwa	0.2993	0.4550	0.1362	22	0.1932	0.4118	0.0796	14
Nelson Mandela Bay	0.1809	0.4461	0.0807	7	0.1641	0.4119	0.0676	9
Ngaka Modiri Molema	0.5073	0.4985	0.2529	39	0.5163	0.4695	0.2424	37
Nkangala	0.2899	0.4559	0.1322	19	0.3365	0.4371	0.1471	25
OR Tambo	0.7181	0.5233	0.3758	50	0.7721	0.4988	0.3851	51
Overberg	0.1736	0.4413	0.0766	6	0.1156	0.4034	0.0466	1
Pixley ka Seme	0.3178	0.4730	0.1503	25	0.3211	0.4331	0.1391	24
Sarah Baartman	0.2922	0.4556	0.1332	21	0.2266	0.4225	0.0957	19
Sedibeng	0.1412	0.4380	0.0619	4	0.1289	0.4056	0.0523	3
Sekhukhune	0.4852	0.4629	0.2246	36	0.6153	0.4558	0.2805	43
Thabo Mofutsanyane	0.3538	0.4679	0.1655	29	0.3537	0.4345	0.1537	27
Ugu	0.5663	0.5111	0.2894	45	0.5996	0.4715	0.2827	44
uMgungundlovu	0.3834	0.4828	0.1851	33	0.3671	0.4412	0.1620	29
uMkhanyakude	0.5826	0.4964	0.2892	44	0.6868	0.4736	0.3252	48
uMzinyathi	0.6325	0.5083	0.3215	48	0.6831	0.4786	0.3269	49
Uthukela	0.5255	0.4982	0.2618	41	0.5709	0.4716	0.2692	41
Vhembe	0.4152	0.4567	0.1897	34	0.5080	0.4366	0.2218	34
Waterberg	0.3344	0.4588	0.1534	26	0.3983	0.4439	0.1768	30
West Coast	0.2237	0.4440	0.0994	13	0.1457	0.4056	0.0591	8
West Rand	0.1862	0.4475	0.0833	8	0.1668	0.4136	0.0690	10
Xhariep	0.3124	0.4542	0.1419	23	0.2223	0.4120	0.0916	17
ZF Mgcawu	0.3557	0.4719	0.1678	30	0.3110	0.4281	0.1331	23
Zululand	0.5683	0.5013	0.2849	43	0.6386	0.4879	0.3116	47

Source: Author's calculations using Census 2011 and Community Survey 2016 data.

Table A2. COVID-19 vulnerability index in 2011 by district councils at different thresholds.

	Threshold: 0.25		Threshold: 0.33		Threshold: 0.40		Threshold: 0.50	
	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Alfred Nzo	0.4452	52	0.3896	52	0.3304	51	0.2686	51
Amajuba	0.2481	30	0.1766	32	0.1367	34	0.0970	34
Amathole	0.4353	51	0.3852	51	0.3391	52	0.2852	52
Bojanala	0.2364	27	0.1536	27	0.1068	24	0.0694	24
Buffalo City	0.1973	19	0.1326	20	0.1001	23	0.0703	25
Cape Winelands	0.1667	10	0.0885	10	0.0559	9	0.0333	9
Capricorn	0.2603	33	0.1690	31	0.1169	29	0.0767	29
Central Karoo	0.1840	16	0.0996	14	0.0583	10	0.0336	10
Chris Hani	0.3660	45	0.3073	46	0.2616	47	0.2145	48
City of Cape Town	0.1214	3	0.0580	3	0.0334	3	0.0178	3
City of Johannesburg	0.0983	1	0.0427	1	0.0252	1	0.0127	1
City of Tshwane	0.1223	4	0.0640	5	0.0403	5	0.0235	5
Dr Kenneth Kaunda	0.1832	15	0.1113	16	0.0780	16	0.0502	16
Dr Ruth Segomotsi Mompati	0.3334	42	0.2568	40	0.2065	40	0.1565	40
Eden (Garden Route)	0.1693	11	0.0980	12	0.0652	14	0.0415	14
Ehlanzeni	0.2575	32	0.1584	28	0.1084	27	0.0668	23
Ekurhuleni	0.1096	2	0.0517	2	0.0306	2	0.0168	2
eThekwini	0.1523	9	0.0860	9	0.0586	11	0.0366	12
Fezile Dabi	0.1703	12	0.0950	11	0.0609	12	0.0359	11
Frances Baard	0.1958	18	0.1228	18	0.0879	18	0.0581	19
Gert Sibande	0.2150	22	0.1452	24	0.1076	26	0.0759	28
Harry Gwala	0.3935	49	0.3331	49	0.2766	49	0.2197	49
iLembe	0.3253	39	0.2525	38	0.2042	37	0.1554	39
Joe Gqabi	0.3727	47	0.3102	47	0.2568	46	0.2045	46
John Taolo Gaetsewe	0.3248	37	0.2524	37	0.2048	38	0.1519	37
King Cetshwayo	0.3303	40	0.2668	42	0.2223	42	0.1748	42
Lejweleputswa	0.1916	17	0.1169	17	0.0805	17	0.0526	17
Mangaung	0.1815	14	0.1097	15	0.0751	15	0.0461	15
Mopani	0.2920	35	0.1919	35	0.1347	33	0.0860	33
Namakwa	0.2177	23	0.1362	22	0.0955	21	0.0580	18
Nelson Mandela Bay	0.1442	6	0.0807	7	0.0519	7	0.0307	7
Ngaka Modiri Molema	0.3251	38	0.2529	39	0.2059	39	0.1545	38
Nkangala	0.2121	21	0.1322	19	0.0909	19	0.0583	22
OR Tambo	0.4298	50	0.3758	50	0.3195	50	0.2639	50
Overberg	0.1491	8	0.0766	6	0.0466	6	0.0287	6
Pixley ka Seme	0.2330	25	0.1503	25	0.1110	28	0.0752	27
Sarah Baartman	0.2101	20	0.1332	21	0.0915	20	0.0581	20
Sedibeng	0.1260	5	0.0619	4	0.0368	4	0.0215	4
Sekhukhune	0.3237	36	0.2246	36	0.1623	36	0.1061	36
Thabo Mofutsanyane	0.2471	29	0.1655	29	0.1212	30	0.0824	30
Ugu	0.3569	44	0.2894	45	0.2397	45	0.1897	45
uMgungundlovu	0.2560	31	0.1851	33	0.1434	35	0.1017	35
uMkhanyakude	0.3674	46	0.2892	44	0.2318	43	0.1769	43
uMzinyathi	0.3842	48	0.3215	48	0.2676	48	0.2084	47
Uthukela	0.3310	41	0.2618	41	0.2135	41	0.1606	41
Vhembe	0.2917	34	0.1897	34	0.1321	32	0.0836	31
Waterberg	0.2351	26	0.1534	26	0.1069	25	0.0706	26
West Coast	0.1724	13	0.0994	13	0.0627	13	0.0381	13
West Rand	0.1462	7	0.0833	8	0.0542	8	0.0317	8
Xhariep	0.2250	24	0.1419	23	0.0979	22	0.0582	21
ZF Mgcawu	0.2399	28	0.1678	30	0.1226	31	0.0845	32
Zululand	0.3535	43	0.2849	43	0.2342	44	0.1795	44

Source: Author's calculations using Census 2011 and Community Survey 2016 data.

Table A3. The 30 municipalities with the greatest COVID-19 vulnerability index.

Municipality	Province	Index	Municipality	Province	Index
Mbhashe	Eastern Cape	0.4742	Mbizana	Eastern Cape	0.4755
Intsika Yethu	Eastern Cape	0.4606	Ntabankulu	Eastern Cape	0.4568
Mbizana	Eastern Cape	0.4384	Ngquza Hill	Eastern Cape	0.4403
Engcobo	Eastern Cape	0.4372	Ratlou	North West	0.4362
Ntabankulu	Eastern Cape	0.4213	Nkandla	KwaZulu-Natal	0.4346
Nyandeni	Eastern Cape	0.4188	Port St Johns	Eastern Cape	0.4297
Ingwe	KwaZulu-Natal	0.4114	Joe Morolong	Northern Cape	0.4253
Umzumbe	KwaZulu-Natal	0.4086	Mbhashe	Eastern Cape	0.4220
Mnquma	Eastern Cape	0.3976	Engcobo	Eastern Cape	0.4166
Port St Johns	Eastern Cape	0.3974	Msinga	KwaZulu-Natal	0.4155
Ngquza Hill	Eastern Cape	0.3905	Intsika Yethu	Eastern Cape	0.4071
Ntambanana	KwaZulu-Natal	0.3900	Nyandeni	Eastern Cape	0.4071
Ezingoleni	KwaZulu-Natal	0.3896	Nongoma	KwaZulu-Natal	0.4038
Msinga	KwaZulu-Natal	0.3886	Mhlontlo	Eastern Cape	0.3960
Elundini	Eastern Cape	0.3874	Umzumbe	KwaZulu-Natal	0.3947
Mhlontlo	Eastern Cape	0.3839	Ubuhlebezwe	KwaZulu-Natal	0.3846
Vulamehlo	KwaZulu-Natal	0.3809	Ndwedwe	KwaZulu-Natal	0.3808
Nkandla	KwaZulu-Natal	0.3718	Maphumulo	KwaZulu-Natal	0.3800
Ubuhlebezwe	KwaZulu-Natal	0.3692	Umzimvubu	Eastern Cape	0.3721
Maphumulo	KwaZulu-Natal	0.3637	Emalahleni	Eastern Cape	0.3583
Umlalazi	KwaZulu-Natal	0.3615	Dr Nkosazana Dlamini Zuma	KwaZulu-Natal	0.3578
Mkhambathini	KwaZulu-Natal	0.3583	Mnquma	Eastern Cape	0.3563
Amahlathi	Eastern Cape	0.3533	Greater Taung	North West	0.3507
Umzimkhulu	KwaZulu-Natal	0.3521	Emadlangeni	KwaZulu-Natal	0.3492
Joe Morolong	Northern Cape	0.3501	Matatiele	Eastern Cape	0.3485
Matatiele	Eastern Cape	0.3494	Big Five Hlabisa	KwaZulu-Natal	0.3450
Nongoma	KwaZulu-Natal	0.3489	Umzimkhulu	KwaZulu-Natal	0.3419
Umzimvubu	Eastern Cape	0.3472	Nqutu	KwaZulu-Natal	0.3417
Ratlou	North West	0.3451	Umuziwabantu	KwaZulu-Natal	0.3387
Ngqushwa	Eastern Cape	0.3448	Kagisano/Molopo	North West	0.3384

Source: Author's calculations using Census 2011 and Community Survey 2016 data.