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Spatial inequality through the prism of a pandemic: Covid-19 in South Africa

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Abstract
While the global impact of the COVID-19 pandemic made everyone feel very vulnerable, the pandemic has made manifest the significant gaps between individuals in terms of exposure and in terms of the capacities to cope with such a major shock. The onset of the pandemic has seen a very active and promising response from quantitative social scientists attempting to use available household and labour market surveys to assist in framing evidence-informed emergency and longer-run policy responses. This paper implements two basic profiling frameworks in the South African context using the 2018 General Household Survey and the 2016 Community Survey. The first proposes a set of indicators of a household's readiness to cope with a lockdown and then aggregates these into an index of lockdown readiness. The second does the same for COVID vulnerability. We use these indicators and their aggregate indices to profile lockdown readiness and COVID vulnerability at the national, provincial and municipal levels as well providing an urban/rural breakdown. There are stark inequalities across space in lockdown readiness and in COVID vulnerability and disturbingly strong correlations between low readiness and high vulnerability. This has implications for budget allocations in response to the COVID-19 pandemic, especially as some of the government relief funding has been and will be apportioned according to municipal need.

Keywords
Inequality, spatial analysis, vulnerability, Covid-19, South Africa.

Classification JEL
D63, I14, O15

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Résumé

Alors que l'impact mondial de la pandémie COVID-19 a eu pour effet un sentiment partagé de vulnérabilité, la pandémie a mis en évidence les écarts importants entre les individus en termes d'exposition et de capacités à faire face à un choc aussi important. Le début de la pandémie a suscité une réaction très active et prometteuse de la part des spécialistes des sciences sociales quantitatives qui ont tenté d'utiliser les enquêtes disponibles sur les ménages et le marché du travail pour aider à élaborer des réponses d'urgence et des politiques à plus long terme fondées sur des données probantes. Ce document met en œuvre deux cadres de profilage de base dans le contexte sud-africain en utilisant l'enquête générale sur les ménages de 2018 et l'enquête communautaire de 2016. La première propose un ensemble d'indicateurs du degré de préparation d'un ménage à faire face à un confinement, puis les regroupe en un indice de préparation au confinement. La seconde fait de même pour la vulnérabilité à la COVID-19. Nous utilisons ces indicateurs et leurs indices agrégés pour établir un profil de l'état de préparation au confinement et de la vulnérabilité à la COVID-19 aux niveaux national, provincial et municipal, ainsi que pour une désagrégation urbaine/rurale. Il existe des inégalités spatiales flagrantes en ce qui concerne l'état de préparation au confinement et à la vulnérabilité à la COVID-19, ainsi que des corrélations troublantes entre un état de préparation faible et une vulnérabilité élevée. Cela a des implications sur les allocations budgétaires en réponse à la pandémie COVID-19, d'autant plus qu'une partie des fonds d'aide du gouvernement a été et sera répartie en fonction des besoins municipaux.

Mots-clés

Inégalités, analyse spatiale, vulnérabilité, Covid-19, Afrique du Sud.

Introduction

In early April 2020 half of humanity was in lockdown as a response to the COVID-19 pandemic. Faced with such a novel situation, most governments chose to protect their citizens by temporarily imposing strict restrictions on mobility and by appealing to their sense of solidarity. At the beginning of the pandemic and these lockdowns, everyone was confronted with the same limitations in terms of their daily activities, and everyone was considered equally vulnerable to the virus. Indeed, in the early days of the spread of the virus, those infected were international travellers who often represented a privileged segment of the world's population. However, as countries moved beyond this initial spread, the epidemic became a pandemic and the number of cases began to rise. As a result, it became increasingly evident that the virus did not affect everyone equally and not everyone had the means to cope with extended lockdowns (Brown, et al., 2020).

The COVID-19 pandemic exposed and reinforced socio-economic inequalities within and across countries. Poverty is often associated with weaker health, resulting in higher vulnerability to the Covid-19 due to comorbidities. In addition, poor people may be more exposed to the virus because their jobs are often in sectors where remote working is not possible, they have less access to facilities such as water and sanitation, and they live in more populous areas. Thus, the initial level of inequality can determine the level of exposure to the virus and its lethality (Gordon, et al., 2020). It is imperative that this is profiled in the context of each country so that it is considered as part of the discussion of the balance between saving the population and saving the economy.

Across the world, interventions such as social distancing and hand hygiene are recommended to break the virus transmission cycle. However, compliance with these guidelines depends on appropriate home-environment and personal behavioural responses (Brown & Ravallion, 2020; Brown, et al., 2020). Various papers have analysed how vulnerable or, on the contrary, how ready countries are to face a pandemic like the one we have faced in 2020 (Brown, et al., 2020; Egger et al., 2020; Jones et al., 2020; Gordon et al., 2020). But, as it is the case with most aggregated measures, these analyses conceal the heterogeneity of sub-national situations. Some preliminary cross-country and within country level analysis has been conducted in Africa (see e.g. Egger et al., 2020; Danquah & Schotte, 2020), but specific attention has not been given to the way in which pre-existing spatial inequalities shape intra-country inequalities in readiness and vulnerability outcomes. This spatial inequality is one of the factors that increases the vulnerability of a country to a crisis such as COVID-19. While remote and isolated areas may benefit from being less exposed to contagion, the lack of access to basic services and health facilities could actually increase fatalities in these areas as the infection spreads. Inequality also affects government's ability to respond to the pandemic.

High inequality and polarization have been shown to negatively affect political institutions and trust in the government, thus limiting the ability to agree on policies to respond to the pandemic and ensure compliance by citizens without harsh enforcement (Resnick, 2020; Agley, 2020).

The aim of this paper is to build on existing work and extend it by conducting a more geographically disaggregated analysis using data from South Africa, a country that has implemented one of the most stringent lockdowns in the world. Such an analysis could start with inequality in terms of exposure, in asking whether all provinces or municipalities are equally exposed to COVID-19. They are probably not in most contexts and have not been in the South African context. Both the international and national travel hubs have been shown to have higher initial contamination rates and then country-specific socioeconomic circumstances mediate the spatial spread of the contamination. This analysis of initial and ongoing intra-regional exposure is an important part of understanding the inequalities in the transmission of COVID-19 and the evolving spatial context of the disease across the country where individuals live, work and go to school.[1] However, as spelt out by Qiu et al. (2020), detailed demographic and epidemiological data are required to undertake such an analysis adequately. These data are not readily available in South Africa right now and will not be available in many developing country contexts.

This paper therefore goes a different route. It uses survey data that is much more widely available to profile the prevailing circumstances of individuals and households across South Africa who are confronted with the virus. We analyse the vulnerability of provinces and municipalities based on the living conditions of their populations in order to describe the prevailing inequalities in the capacity to respond well to the presence of the virus. We examine whether poorer households /individuals are less ready to comply with strict lockdown policies and more vulnerable to COVID 19 infection due to their living conditions.

Our findings indicate that there are stark spatial inequalities in lockdown readiness and in COVID vulnerabilities in South Africa and disturbingly strong correlations between low readiness and high vulnerability. We also find a strong positive wealth effect in lockdown readiness and vulnerability to COVID-19. Regardless of where poor households live, they are less likely to be able to protect themselves from the virus and to comply with strict lockdowns.

We start with a description of the datasets used in this paper. We then use these data and the emerging 2020 literature measuring the socio-economic realities of readiness and vulnerability to COVID-19 in order to derive lockdown readiness and vulnerability indices. Sections that follow use these indicators and their aggregate indices to profile, consecutively, lockdown readiness and vulnerability to COVID-19

[1] The paper by Qiu et al., 2020 provides a useful framework on how to do this.

at the national, provincial, and municipal levels. We conclude by summing up with a particular focus on the implications for budget allocations in response to the COVID-19 pandemic.

1. Data and measurement

2.1. Data sources

We use data from two surveys: the 2018 General Household Survey (GHS) and the 2016 Community Survey (CS). The GHS is a nationally representative sample of approximately 24,726 households (Stats SA, 2019). The 2018 GHS sample is based on a two-stage stratified sampling method. In the first stage, primary sampling units (i.e. EAs) were sampled using a probability proportional to size (PPS) method. Dwelling Units (DUs) were sampled using systematic sampling at the second level. The 2013 Master Sample was used as a sampling frame that is designed to be representative at the province level and within provinces at the metro / non-metro level. The design weights in the 2018 GHS data were reweighted on the basis of the 2017 Mid-Year Population Series projections.

The sample design of the 2016 CS was based on a stratified single-stage sample design (Stats SA, 2016). All EAs from the 2011 Census were included and within each EA DUs were sampled using a systematic sampling technique. However, EAs with a very small number of DUs were excluded from the sample frame. Although the final sample size is 1 370 809 DUs sampled from a total of 93 427 EAs, the realized sample size is 984,627 DUs. The purpose of such a sampling strategy was for the 2016 CS to provide representative estimates at the local municipality level. Thus, while the 2018 GHS is fairly recent and contains more comprehensive details than the 2016 CS, the CS is useful for providing representative estimates at the local municipality level. In this paper, both data sources are used to generate results at the province level and the CS is used to obtain estimates at the local municipality level.

2.2. Lockdown readiness and vulnerability measurements

The lockdown readiness measure is used to provide an estimate of the population living under conditions that would allow for a strict lockdown in a given country. Jones et al (2020) motivated that five factors should be available in order for people to be able to stay at home during a lockdown: access to clean drinking water, safe sanitation, access to electricity, savings and regular income to buy food, and access to information. We use the following five indicators for calculating the lockdown readiness index for South Africa:

1. Access to electricity
2. Access to safe drinking water
3. Access to a safe toilet
4. Have a TV or radio in the household
5. At least one person in the house employed or the household is food secure

Access to safe drinking water indicates water accessed from piped (tap) water in the dwelling, piped (tap) water on-site, or in the yard. Access to a safe toilet indicates that the household has access to a toilet facility, and it is not shared with other households. The emphasis here is on whether or not the toilet facilities are shared with other households irrespective of the form of the toilet facilities used. So, when calculating the lockdown readiness index, we do not consider whether or not the toilet is improved. Data on all the five indicators are available in the 2018 GHS.

Apart from the employment information, the data is also available in the 2016 CS and we use a food security indicator instead of the employment indicator when calculating the lockdown readiness index based on the CS. The food insecurity indicators are measured based on survey participants responding to the following questions: "In the past 12 months, did this household run out of money to buy food?" and "Has this happened for 5 or more days in the past 30 days?" In view of the fact that, in South Africa, a significant proportion of workers (63%) cannot be regarded as either essential workers nor could they work from home (Kerr & Thornton, 2020), the food security indicator may provide a better indicator of households' access to regular income to purchase food. Based on the GHS data we compared estimates of the lockdown readiness index using the food security indicator with those based on the employment indicator. The results are very similar.

The vulnerability indicators are intended to identify a household that is at a higher risk of contracting Covid-19 infection due to their living conditions. While lockdown and social distancing policies are implemented to minimize the risk of infection outside the household, the secondary attack rate (the proportion of people exposed to an infected person) varies depending on the living circumstances of the individual. Gordon et al. (2020) suggest nine indicators to measure vulnerability to Covid-19 infection. The vulnerability indicators are selected based on how the virus would likely spread. We are restricted to using six of the indicators that can be measured using both the GHS and CS datasets. Table 1 provides the vulnerability indicators and the scientific justification for using each indicator. The lockdown readiness indicators and the vulnerability indicators overlap somewhat with access to safe water, safe toilet, and information being part of both indicators. But even these overlapping indicators have somewhat different conceptual rationales within each indicator. The vulnerability indicators explicitly seek to measure an individual's capacity to follow WHO recommendations on regular hand washing, social distancing, and access to information from trusted sources.

Table 1: Vulnerability to Covid-19 infection indicators
Source: Gordon et al. (2020)

Vulnerability Indicator	Secondary Attack Rate Level	Scientific Reason
Large Household - 6 or more people	Household	An ill person is more likely to infect their household members than friends, neighbours or the wider community. The larger the household the more household members are likely to be infected
People over 60 living in households with two or more younger people	Household	People aged 60 and over are more likely to die or suffer from a severe Covid-19 infection. Older people are more likely to be infected within the households with younger members i.e. they have a higher secondary attack rate within the household.
No refrigerator	Household	Households which do not have a refrigerator will need to leave their homes more frequently to get food and thus be at greater risk of infection.
Sharing a toilet with other households	Neighbours/ Friends	Sharing a toilet increases the risk of catching Covid-19 from infected people in neighbour's households either by faecal/oral transmission or from close contact in or near the shared toilet
Sharing water sources with other households	Neighbours/ Friends Wider community	Sharing a water supply increases the risk of catching Covid-19 from infected people in the neighbour's house-holds. Needing to collect water from a public supply increases the risk of catching Covid-19 from infected people in other households due to close contact while queuing to collect water or touching infected parts the water supply equipment e.g. stand-pipe taps, well buckets, etc.
Have no access to a radio or TV	Household	Effective risk communication and community enga-gement is of key importance to controlling infectious disease epidemics. It is much harder for households without telephones or access to broadcast media to get the correct public health information they need to stay safe as misinformation and rumour during a pandemic can be both extensive and dangerous

2. Results

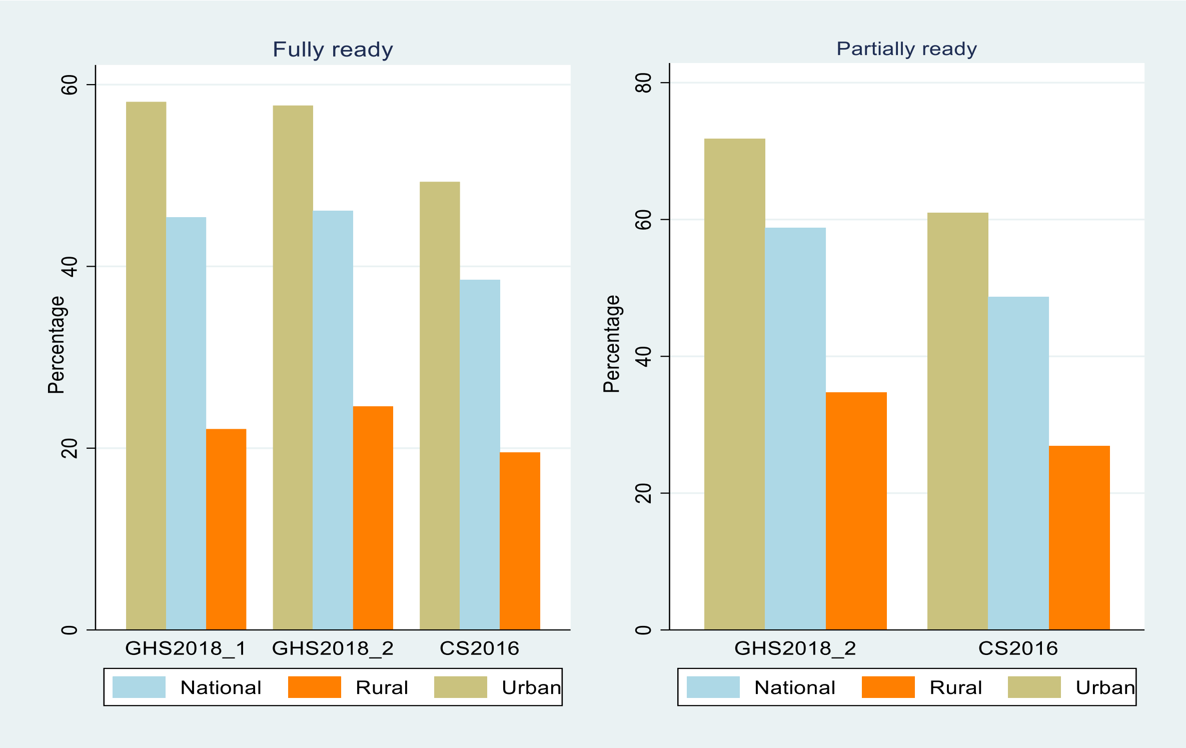
In this section, we provide estimates of the lockdown readiness and vulnerability indicators and indices using data from both the GHS 2018 and CS 2016 datasets. We are restricted to the CS to estimate the lockdown readiness index and the vulnerability indicators at the local municipality levels.

2.1. Lockdown readiness index

Figure 1 presents estimates of the lockdown readiness index based on the GHS and CS datasets. The GHS2018_2 and CS2016 estimates are based on the same indicators (i.e. access to electricity, safe water, safe toile, access to a Tv or radio, and an indicator of food security) while it is the GHS2018_1 estimate that uses the employment indicator instead of the food security indicator.

As can be seen in the figure below, the results based on data from the 2018 GHS (i.e., GHS2018_1 and GHS2018_2) are more or less the same. Thus, the use of the food security indicator instead of the employment indicator does not significantly change the results. However, findings differ when we compare estimates based on the GHS2018_2 and CS2016 datasets even though we use the same indicators. Based on the GHS2018_2 data, about 46 % of the population had access to all the five indicators, with the figure being 25 % in rural areas and 58 % in urban areas. The corresponding figures based on the CS2016 data are 38 % at the national level, 20 % in rural areas, and 49 % for urban areas. Overall, the lockdown readiness index estimates based on data from the CS are lower than the estimates based on data from the GHS. In all cases though, the lockdown readiness index is higher in urban areas compared to rural areas.

Figure 1: Lockdown readiness index, nationally and by rural and urban areas
Source: Own estimates using data from GHS (2018) and CS (2016)



Comparing each lockdown readiness index indicator shows that, except for sanitation, the estimates based on the CS data for all indicators are not substantially different from estimates based on the GHS data (Figure 2). Therefore, the disparity in the lockdown readiness index estimates based on data from the GHS and CS datasets is primarily attributed to the discrepancy in the respective survey estimates of the proportion of the population that used shared toilet facilities. At the national level, the proportion of the population who shared toilet facilities with other households is only 17.3% based in the 2018 GHS data, while the estimate is 31.6% based on the 2016 CS data.[2]

[2] Both the 2016 CS and the 2018 GHS statistical reports do not provide estimates of the proportion of households sharing toilet facilities. However, according to a 2017 report by the parliamentary monitoring group (https://pmg.org.za/committee-meeting/23868/), the percentage of households that shared toilet facilities, or did not have toilet is around 30% in urban areas and 16% in rural areas. These estimates are close to the ones obtained using the 2016 CS than the ones from 2018 GHS.

Figure 2: Lockdown readiness index indicators, nationally and by rural and urban areas
Source: Own estimates using data from GHS (2018) and CS (2016)

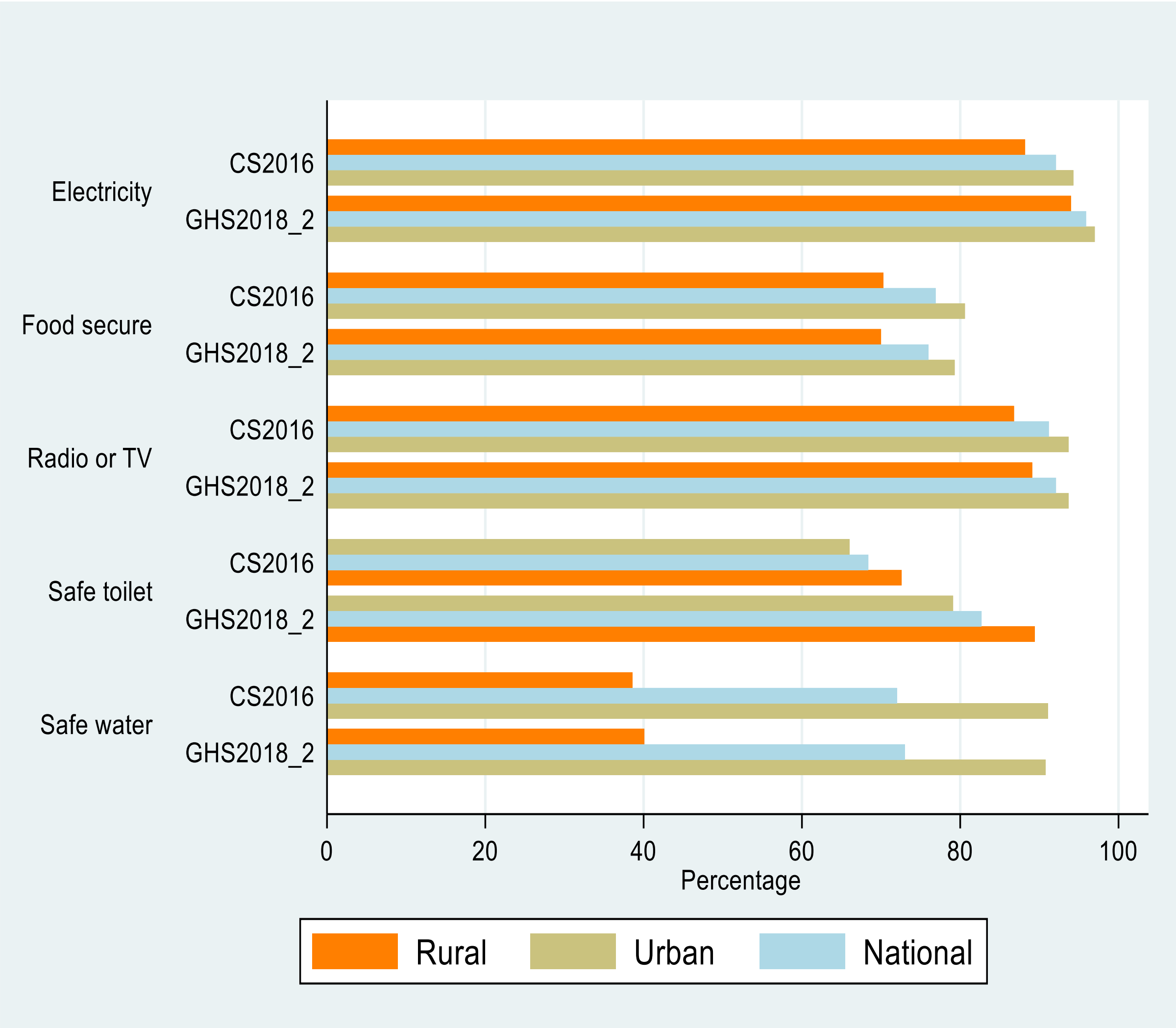


Figure 3 contrasts estimates of the lockdown readiness index by province based on the same set of indicators from GHS and CS datasets (GHS2018_2 and CS2016). When mapping the lockdown readiness index, the brighter colours (e.g. sand) represent low values (i.e. lockdown readiness values), while the darker colours (e.g. red) represent higher values. The two data sets are consistent in showing that the top three provinces with the highest percentage of the population that can be considered fully ready are Western Cape, Gauteng, and Free State, while the bottom three provinces are North West, Limpopo, and Eastern Cape.

Figure 3: Lockdown readiness index by province (CS 2016 and GHS 2018)

Source: Own estimates using data from GHS (2018) and CS (2016)

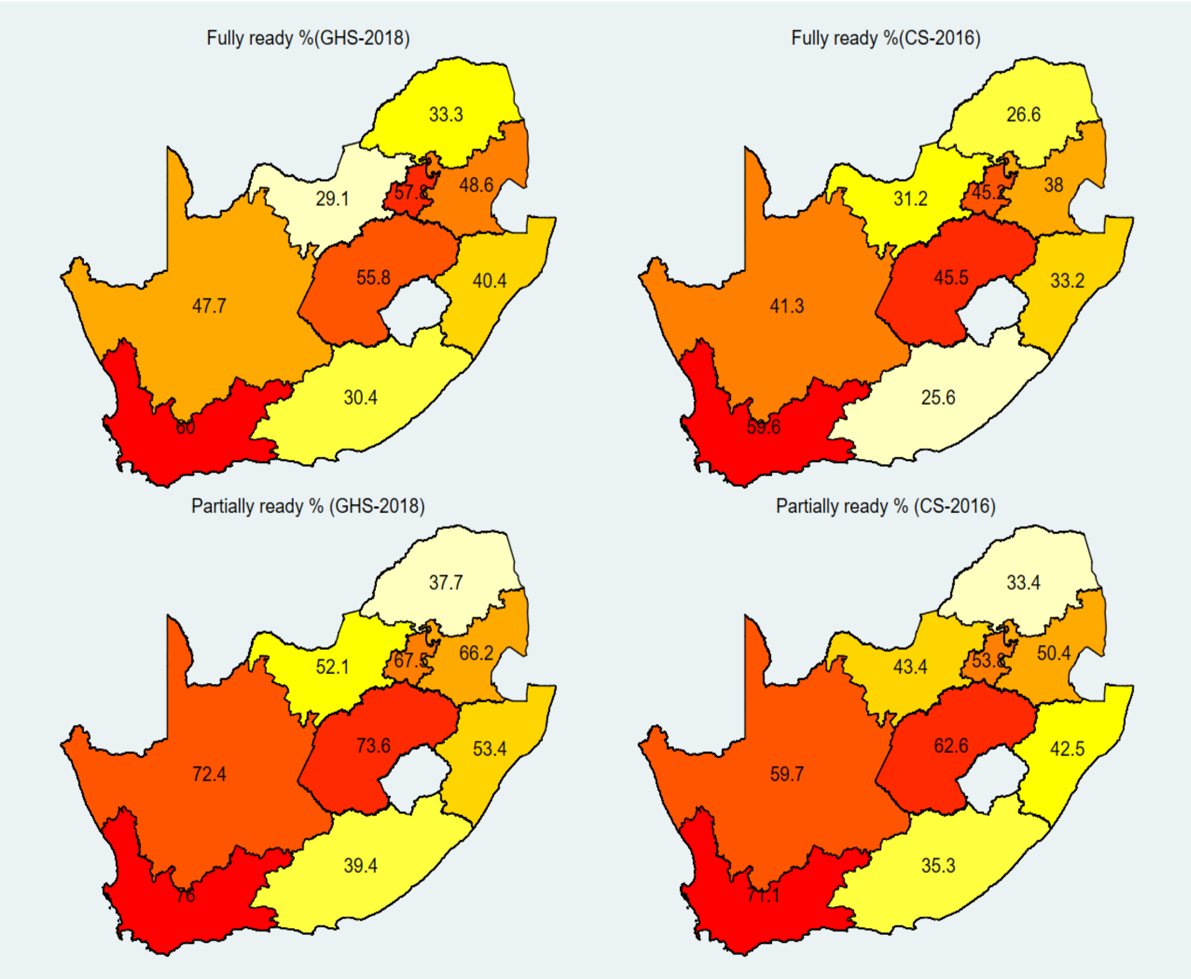
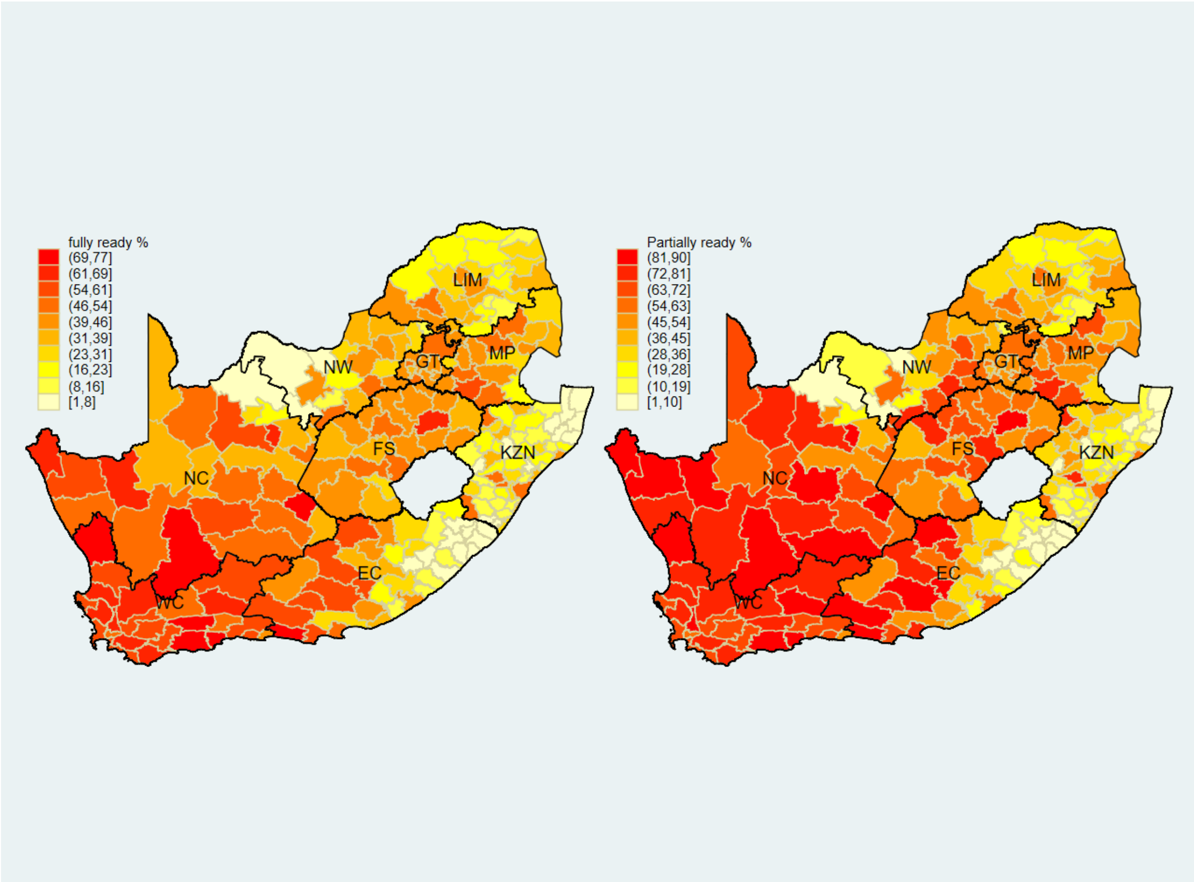


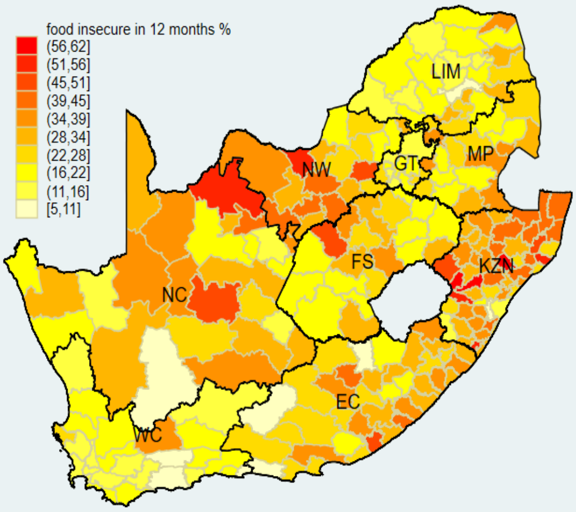
Figure 4 maps the lockdown readiness index estimates by local municipality using CS data. The results show considerable inequality across municipalities and within provinces. The proportion of the population that can be considerd fully ready ranges from 68 % to 77 % in the 10 top fully ready municipalities (Kou-Kamma, Hessequa, Karoo, Hoogland, Matzikama, Renosterberg, Mossel Bay, Kannaland, Kgatelopele, Drakenstein,and Prince Albert), while the figures range from 0.7 % to 4 % in the bottom 10 least ready municipalities (Joe Morolong, Umhlabuyalingana, The Big 5 False Bay, Ntabankulu,Nongoma, Ratlou, Nyandeni, Ngquza Hill, Mbizana, and Mbhashe). With the exception of Kou-Kamma municipality,from the Free State province, the top 10 most fully ready municipalities are located in the Western Cape and Northern Cape provinces. The 10 least ready municipalities are located either in the Eastern Cape or KwaZulu-Natal provinces, with the exceptions of Joe Morolong and Ratlou municipalities, respectively in the Northern Cape and North West provinces.

Figure 4: Lockdown readiness index by local municipality (CS 2016)
Source: Own estimates using data from CS (2016)



With respect to the distribution of the lockdown readiness indicators by municipality, only estimates for food insecurity measures are discussed here (Figure 5), as the other variables overlap with the vulnerability indicators that we will be discussing later. The percentage of individuals that lived in a household that reported being food insecure ranges from 51 % to 62 % in Ratlou, Joe Morolong, Mfolozi, Impendle, Ezingoleni, Imbabazane, Nkandla, and Mpofana municipalities. In contrast, the figure is less than 10 % in Kou-Kamma, Karoo, Hoogland, Hessequa, Kannaland and Maletswai muncipalites. The proportion of the population that reported that they were food insecure for 5 days or more in the 30 days prior to the survey was 35 % and above in local municipalities such as Imbabazane, Mfolozi, Ratlou, Joe Morolong, Hlabisa, Nkandla, and Mpofana. These are located in KwaZulu-Natal province with the exception of Joe Morolong and Ratlou municipalities which are located in Northern Cape and North West provinces respectively. High-level food insecurity is also reported in some local municipalities located in relatively better off provinces. For example, about 35 % of the population in Laingsburg municipality in the Western Cape province is food insecure. Similarly, the percentage of the population reported food insecurity is between 25-27% in Merafong City and Lesedi municipalities in Gauteng province.

Figure 5: Food insecurity indicators by local municipality (CS 2016)
Source: Own estimates using data from CS (2016)



Note: the brighter colours (e.g. sand) represent low values, while the darker colours (e.g. red) represent higher values.

The pre- COVID-19 figures on food insecurity are alarming. Given that poor households have little or no savings, stricter lockdown policies in response to pandemics like COVID 19 may lead to more hunger and poor nutrition outcomes. More recent evidence from the NIDS-CRAM survey indicates that individuals expressed higher levels of food insecurity during the lockdown period. Among adults interviewed in the survey 47% reported their households face food insecurity problem (Wills et al., 2020).

Overall, the analysis of the lockdown readiness index suggests that, preceding the lock-down, less than half of the national population in South Africa was living under conditions that would allow them to adhere to a strict lockdown policy. Disaggregated level figures show marked differences in the level of readiness across the South African landscape. This is true even within provinces that are most ready on average.

3.2. Vulnerability indicators

In this sub-section, we present estimates of the vulnerability indicators based on the 2018 GHS and 2016 CS datasets. Figure 6 presents the vulnerability indicators nationally and by rural and urban areas. The results indicate that the estimates obtained based on the two datasets are very similar except for the toilet sharing and household size indicators. As was discussed in the readiness section, the CS has consistently higher estimates of toilet sharing than the GHS. On the other hand, it has consistently lower estimates of household size. In both cases, about 21 % of the population resided in households that consist of at least one older adult (age >60) and two younger individuals. Around 15 % of the population did not have access to a refrigerator while 8 % of the population did not have access to a television or radio. The percentage of the population living in a family size of six or more is greater in rural areas compared to urban areas. For instance, based on the 2018 GHS data results show that about 37 % of the population lives in households with six or more household members with the number being higher in rural areas (51 %) than in urban areas (30%).

Figure 6: Vulnerability indicators, nationally and by rural and urban areas (CS 2016 and GHS 2018)

Source: Own estimates using data from GHS (2018) and CS (2016)

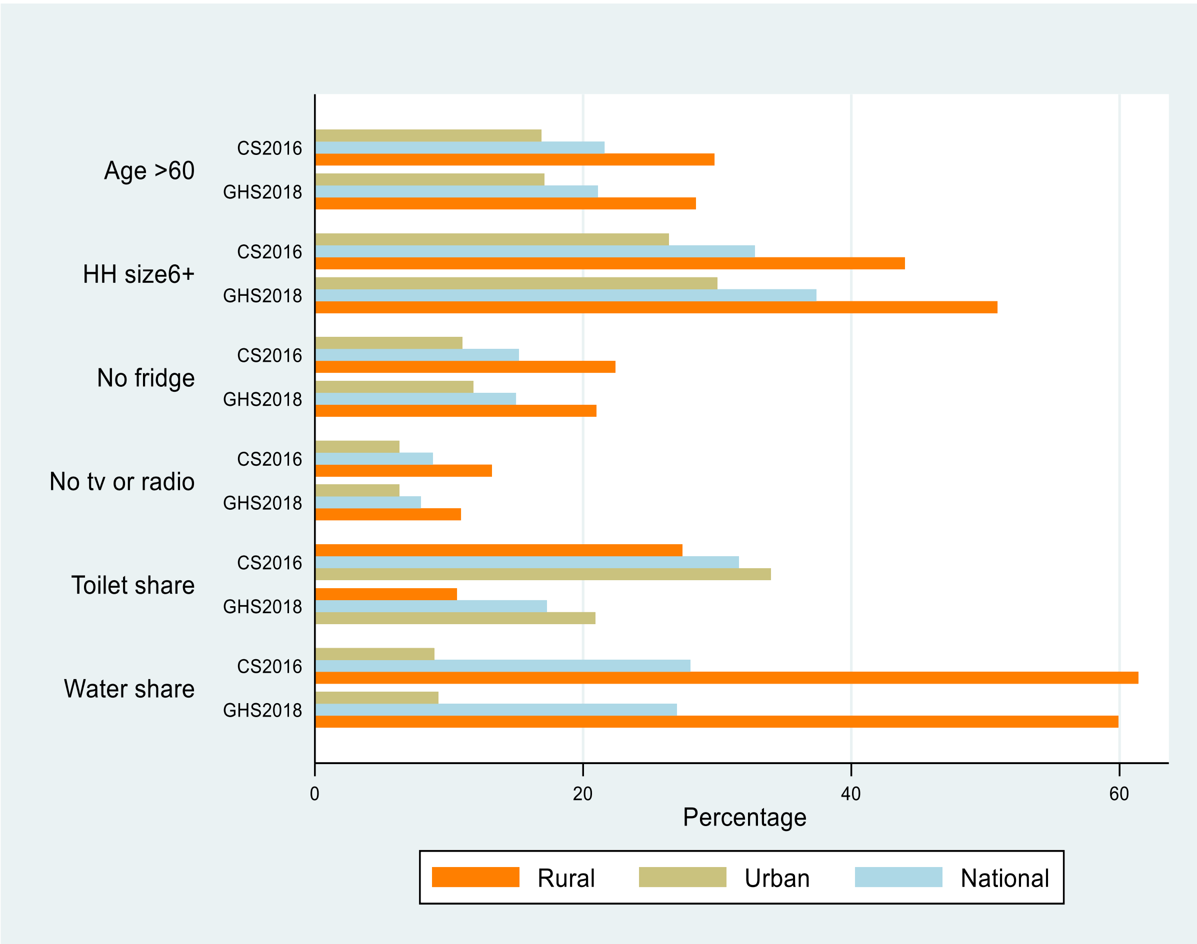
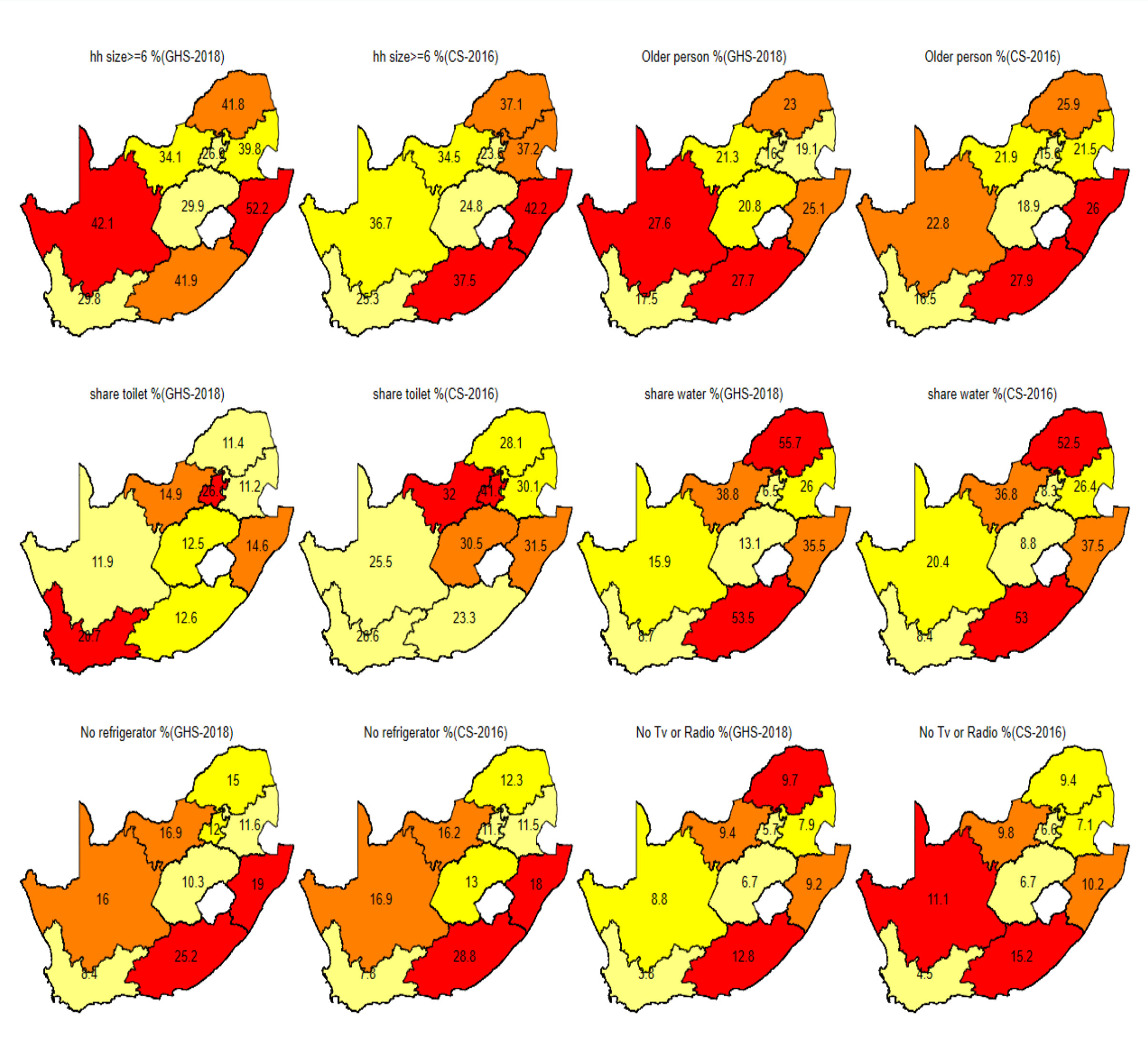


Figure 7 presents vulnerability indicators by province. The findings reveal significant variations across provinces with respect to some of the vulnerability indicators. For instance, the proportion of the population sharing water is less than 10 % in Gauteng and Western Cape, whereas the figure is more than 50 % in Limpopo and Eastern Cape. Likewise, a relatively higher proportion of the population in Eastern Cape had no access to a refrigerator (25-29 %), while the figure is only 8 % in Western Cape. As we have seen before at the national and urban/rural levels, the estimates based on the CS and GHS datasets differ significantly mainly with regard to the toilet sharing indicator.

Figure 7: Vulnerability indicators by province (CS 2016 and GHS 2018)

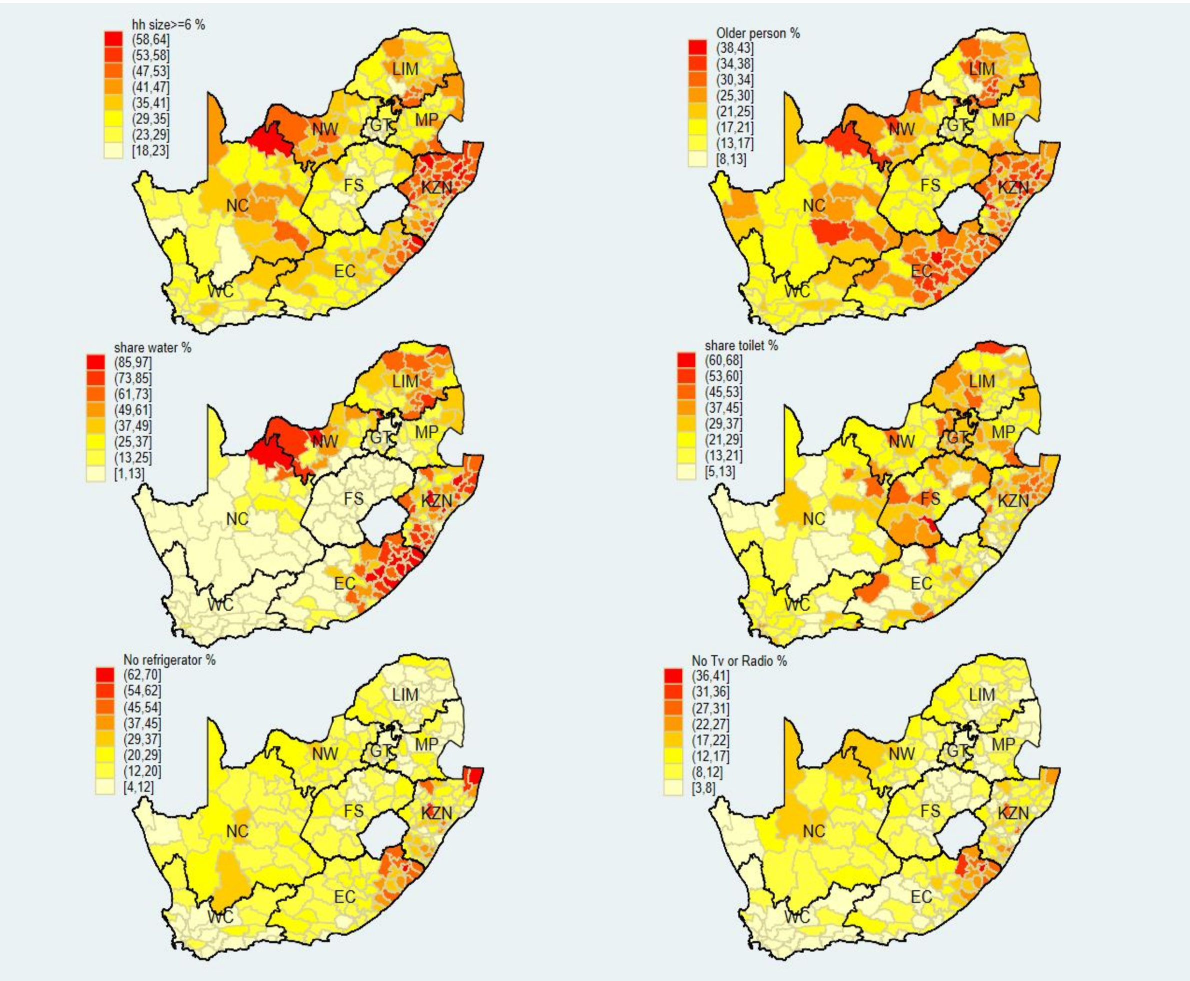
Source: Own estimates using data from GHS (2018) and CS (2016)



Note: the brighter colours (e.g. sand) represent low values, while the darker colours (e.g. red) represent higher values.

Figure 8 below maps the vulnerability indicators by local municipalities. It shows large differences in the degree of vulnerability across municipalities. The proportion of the population living in a family of six or more members is 60 % or higher in Hlabisa, Nongoma, Indaka and Dannhauser municipalities. The proportion of the population that uses shared toilet facilities is between 50 % and 68 % in seven local municipalities (Naledi-FS, Mandeni, Musina, Camdeboo, Ntambanana, Mookgopong, and Tokologo). This figure is less than 10 % in 11 local municipalities (Tsolwana, Ubuntu, Kareeberg, Kou-Kamma, Nama Khoi, Umuziwabantu, Baviaans, Ezingoleni, Ikwezi, Richtersveld, and Blue Crane Route). The proportion of the population sharing water with other households is 50 % and more in 75 of the municipalities, with the figure being 95 % and more in Mbizana, Ngquza Hill, Mbhashe, Nyandeni, and Port St Johns. More than 25 % of the population did not have access to either TV or radio in nine local municipalities (Ntabankulu, Elundini, Mbizana, Vulamehlo, Port St Johns, Msinga, Umzimvubu, Ndwedwe, and Ubuhlebezwe).

Figure 8: Vulnerability indicators by local municipalities (CS 2016)
Source: Own estimates using data from CS (2016)



Note: the brighter colours (e.g. sand) represent low values, while the darker colours (e.g. red) represent higher values.

Intensity of vulnerability: The vulnerability index

After describing the patterns of each vulnerability indicator across space, the next step is to examine the incidence of multiple vulnerabilities experienced. We expect as the number of vulnerabilities experienced increases, the risk of infection also increases. However, it is important to note that there is not a best way to combine the various indicators into a single vulnerability index, as it is not conceptually clear how the intersections between the indicators work and how each indicator should be weighted. Nonetheless it it important to profile and assess the internsity of vulnerability to the Covid-19 infection. We start by computing a weighted sum of vulnerability scores for each individual with each indicator being equally weighed. The value for the weighted vulnerability scores ranges from 0 (vulnerable in none of the indicators) to 1 (vulnerable in all of the indicators).Then, average values are calculated at province and municipality levels. However, this average can conceal the heterogenous outcomes across indicators and municipalities so we complete the analysis by counting the number of vulnerabiliy indicators for each individual. Then, we examine the proportion of people experiencing multiple sources of vulnerabilities.

Figure 9 shows the average vulnerability score broken down by rural and urban areas. The average vulnerability score in rural areas is higher than urban areas, with the national average lying in between the two as the weighted average. The average vulnerability score for rural areas is around 0.3, which is twice as high as the value of urban areas, regardless of the dataset used.

Figure 9: Average vulnerability scores, nationally and by rural and urban areas (CS 2016 and GHS 2018)
Source: Own estimates using data from GHS (2018) and CS (2016)

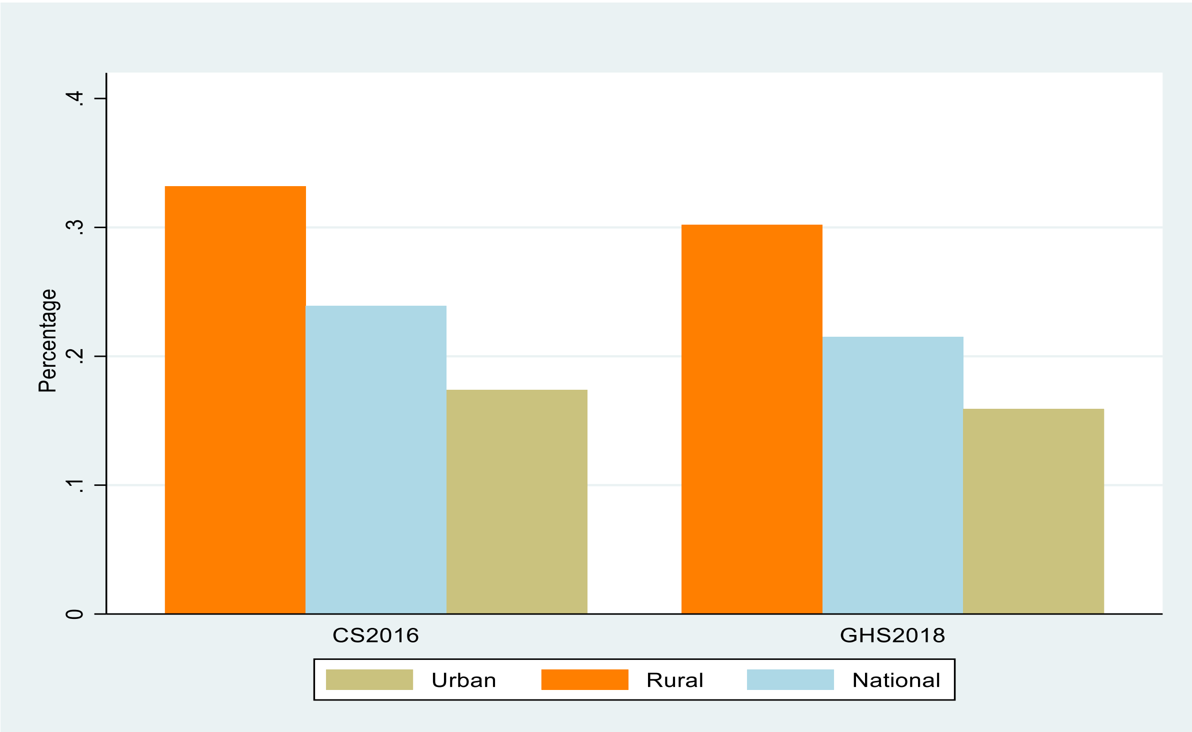
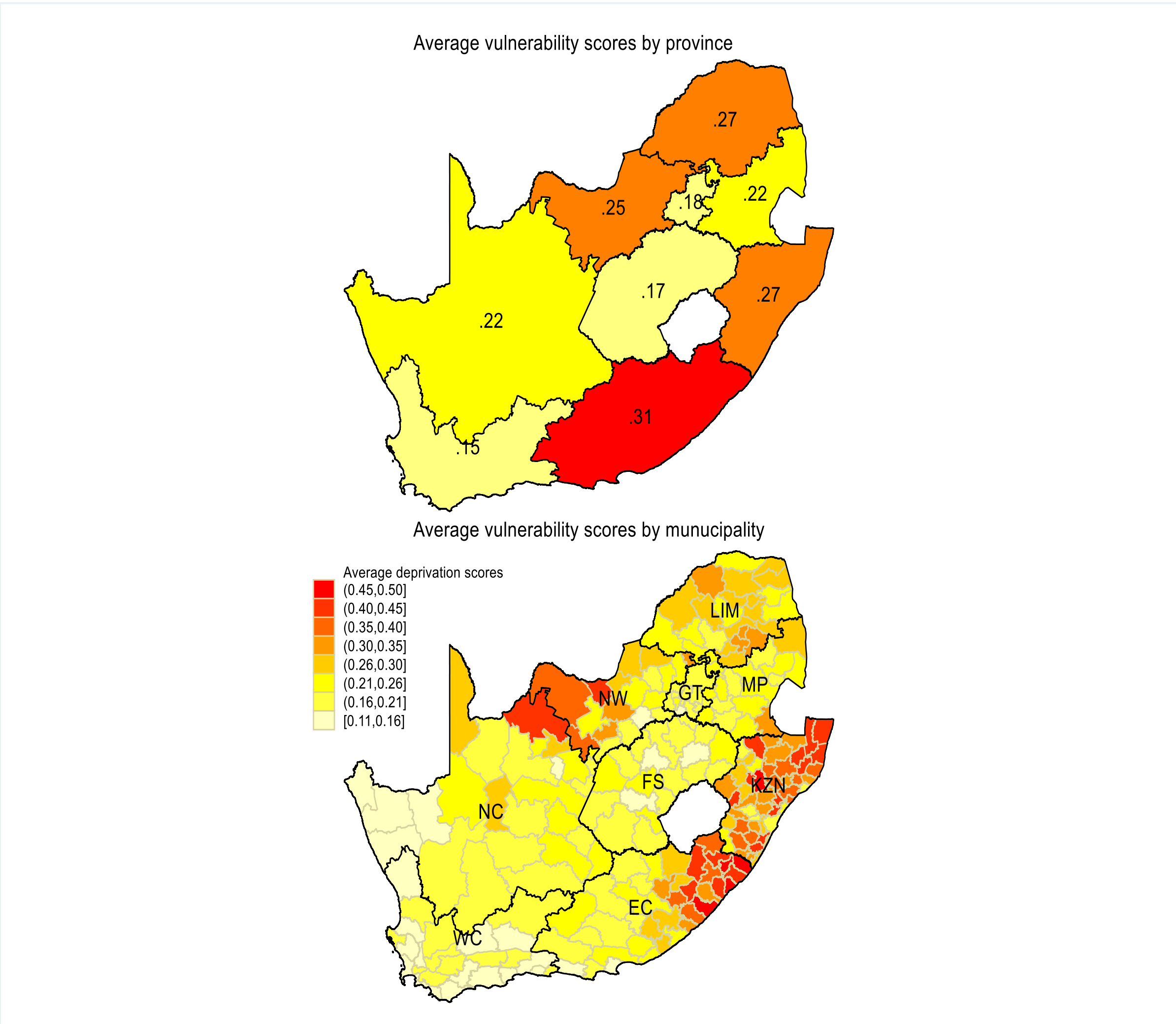


Figure 10 shows the average vulnerability scores by province and municipality. The average vulnerability score is the highest for Eastern Cape province followed by Limpopo and KwaZulu-Natal. The municipality level estimates, however, show significant variations within provinces. Indeed, if the provincial level analysis shows the Eastern Cape province as having the highest vulnerability score, when we look at the level of municipalities we see that municipalities with very high vulnerability scores can also be found in KwaZulu-Natal, North West and Northern Cape.

Figure 10: Average vulnerability scores by Province and Municipality (CS 2016)
Source: Own estimates using data from CS (2016)



We now move to finer grained analysis by adopting a counting approach for the vulnerability indicators. The figure below(Figure 11) shows the percentage of the population by the number of vulnerability indicators. About 30 % of the population is not vulnerabile in any of the indicators. Then, the proportion of the population that are vulnerable to Covid-19 infection in only one indicator is 32 %, while close to 23 % of the population are vulnerable to Covid-19 infection due to two of the vulnerability indicators. The intensity of vulnerability is higher in rural areas compared to urban areas. These estimated shares are similar in the

GHS and CS datasets. The GHS estimates higher shares of the population with no vulnerability indicators and then slightly lower shares when it comes to the proportion of the population that is vulnerable to Covid-19 infection due to three and more indicators.

Figure 11: Intensity of vulnerability to Covid-19 infection, nationally and by rural and urban areas (CS 2016 and GHS 2018)
Source: Own estimates using data from GHS (2018) and CS (2016)

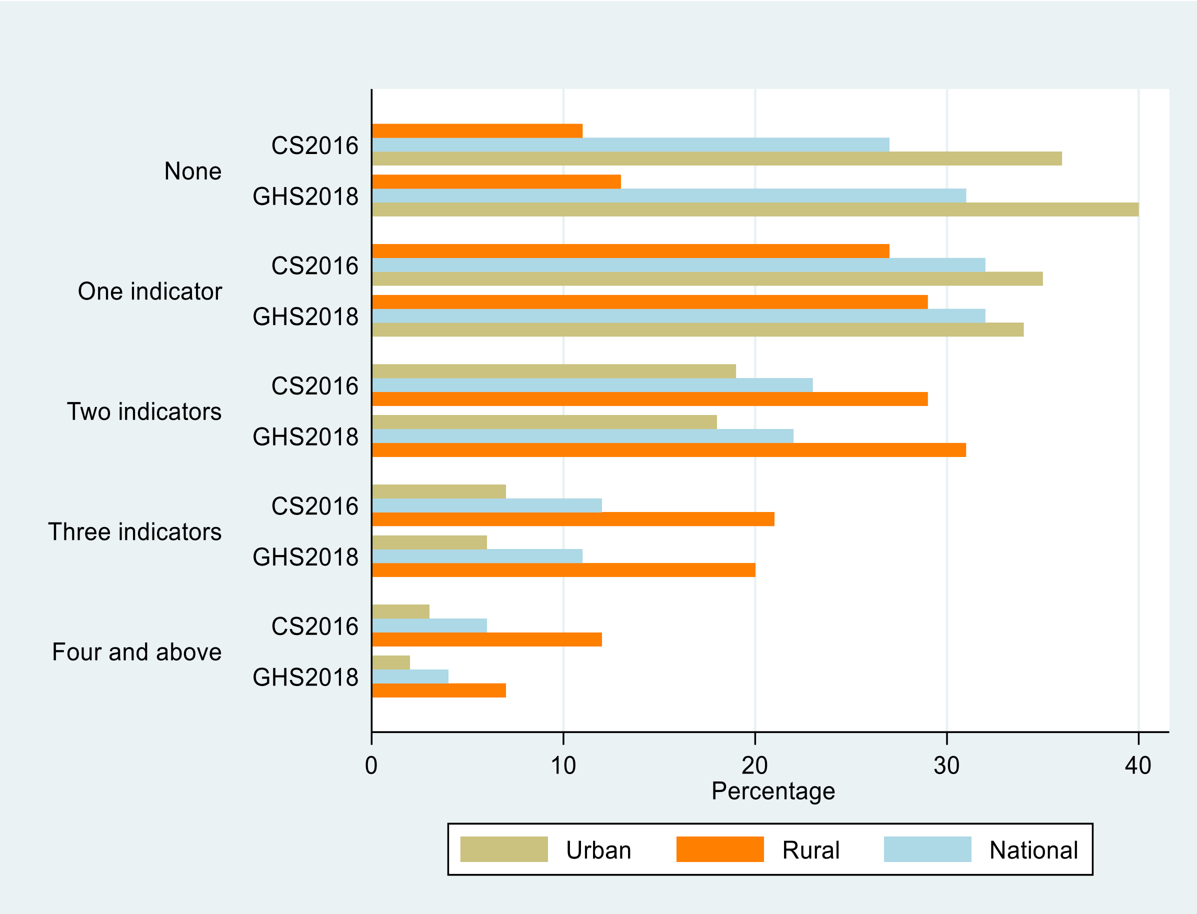
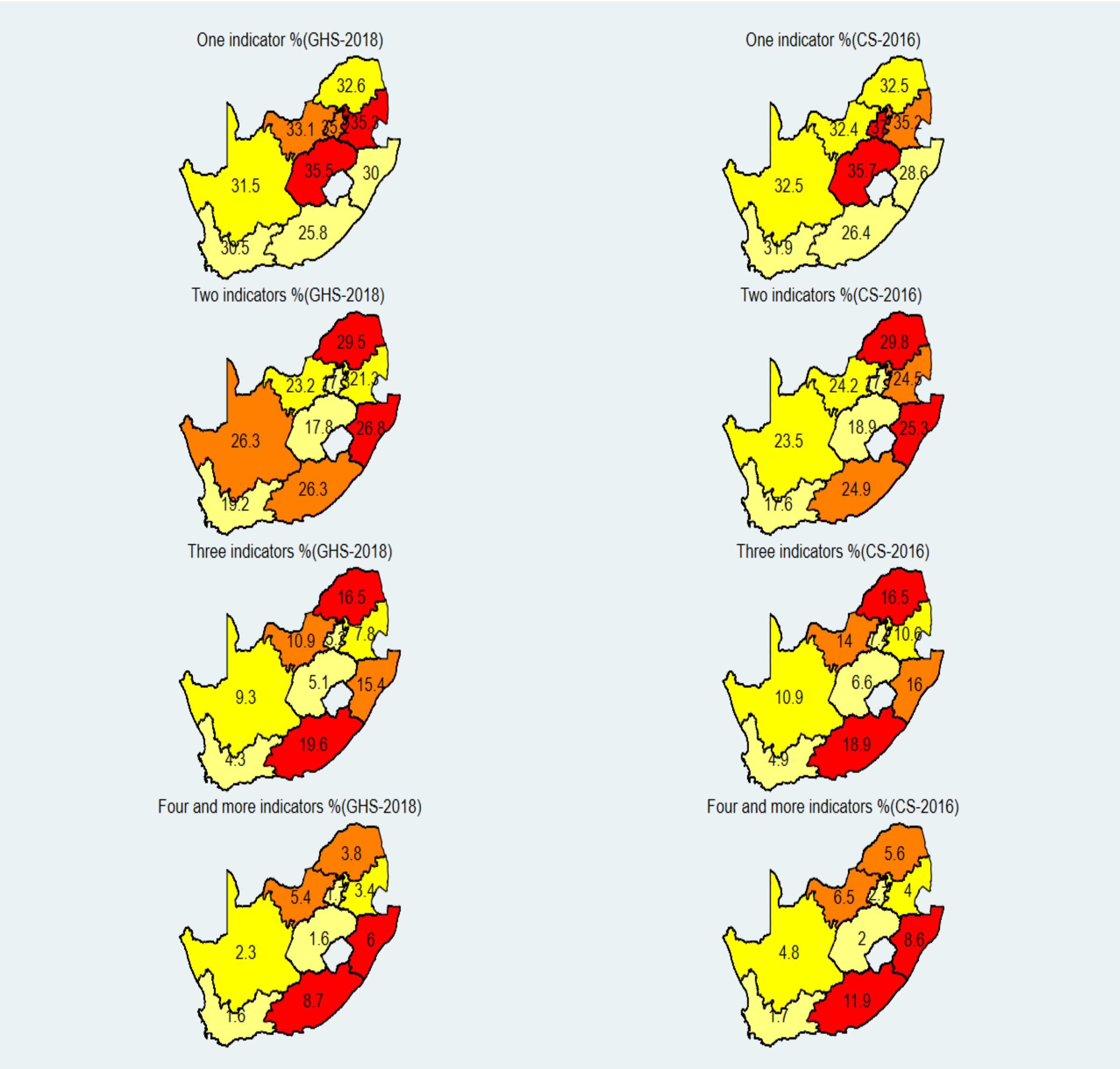


Figure 12 provides the intensity of vulnerability to Covid-19 infection by province and the results are similar to those from figure 11 above.The intensity of vulnerability estimates based on the GHS and CS data vary in most provinces when we consider vulnerability to Covid-19 infection due to three or more number of indicators. However, uniformly, the intensity of vulnerability to Covid-19 infection is the highest in Eastern Cape, Limpopo,KwaZulu-Natal and North West provinces regardless of the data sources used.

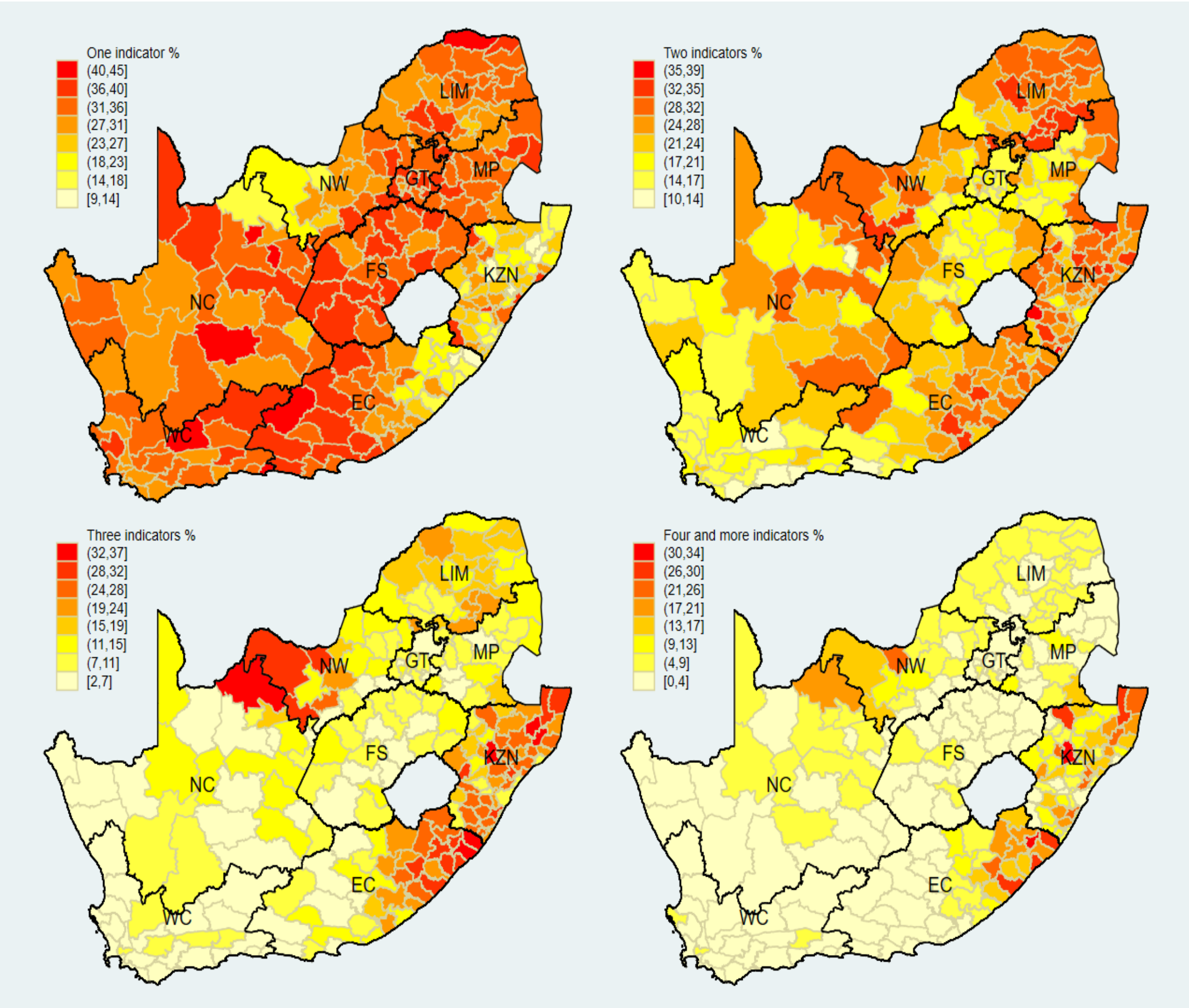
Figure 12: Intensity of vulnerability to Covid-19 infection by province (CS 2016 and GHS 2018

Source: own estimates using data from GHS (2018) and CS (2016)



The municipality level analysis also reveals that the intensity of vulnerability to Covid-19 infection is highest in municipalities located in Eastern Cape, KwaZulu-Natal and North West provinces (Figure 13). The proportion of people who are vulnerable due to three or more indicators is between 30-37% in 17 municipalities, mainly located in KwaZulu-Natal and Eastern Cape. On the other hand, the figure is less than 5% for 19 municipalities largely located in Western Cape and Northern Cape.

Figure 13: Intensity of vulnerability to Covid-19 infection by municipalities (CS 2016)
Source: Own estimates using data from CS (2016)



Provincial vulnerability shares

Our previous analysis shows that there are large differences in levels of vulnerability across the provinces. However, the population size of the provinces also varies (Figure 14). The population share for KwaZulu-Natal and Gauteng is 20% and 24 % respectively, while the figure for Eastern Cape is 13%. On the other hand, the population share for Northern Cape province is only 2%. Thus, it is important to consider the contribution of each province to the overall vulnerability measure in the country.

Figure 15 shows the relative provincial shares of the population that are likely to be vulnerable to Covid-19 infection by a number of intensity indicators. To measure this, for the different intensities that are reflected in figure 11 the number of vulnerable population in each province is divided by the total number of vulnerable population in the country. The shares of the population that are estimated to be vulnerable due to two or more indicators are relatively higher in the Eastern Cape, Limpopo, KwaZulu-Natal and Gauteng provinces.

In the Eastern Cape and KwaZulu-Natal this is due to both high provincial intensity combined with large shares of the national population. Limpopo does not have such a large population share (10%) but the intensity of vulnerability within this population is so high that it still has a high national share.

Figure 14: Provincial population share (CS 2016)
Source: Own estimates using data from CS (2016)

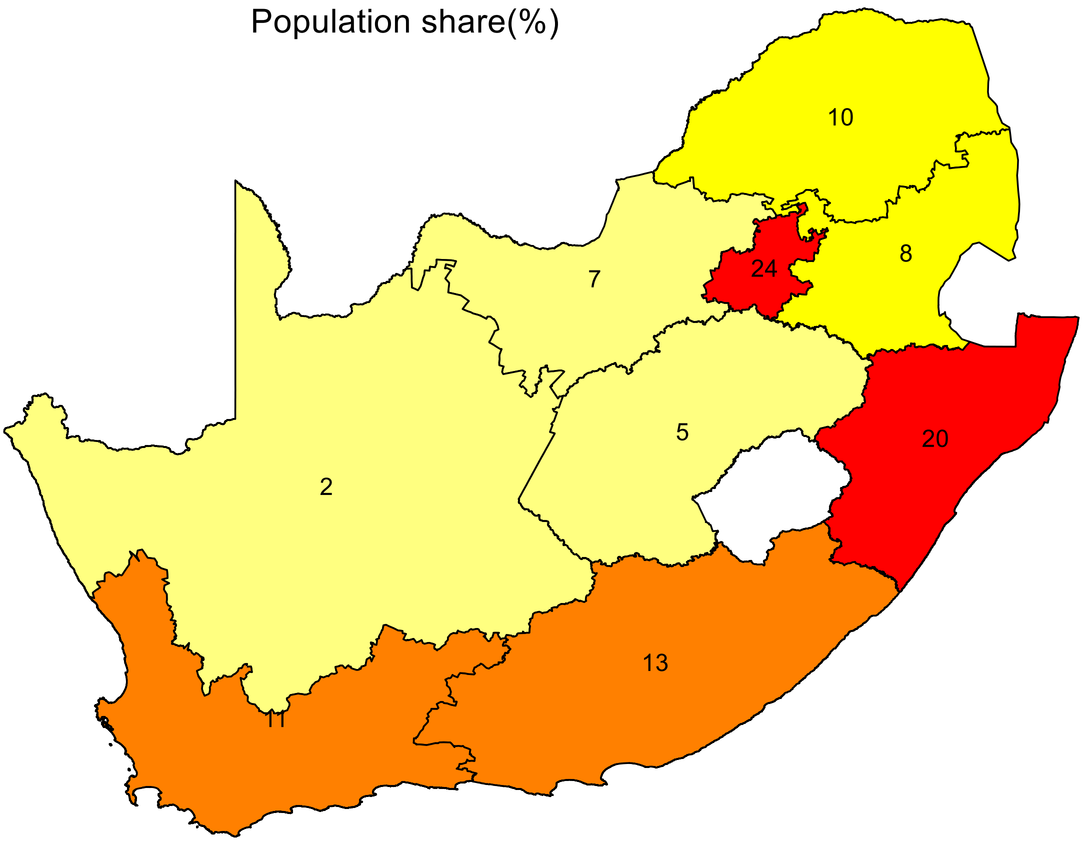
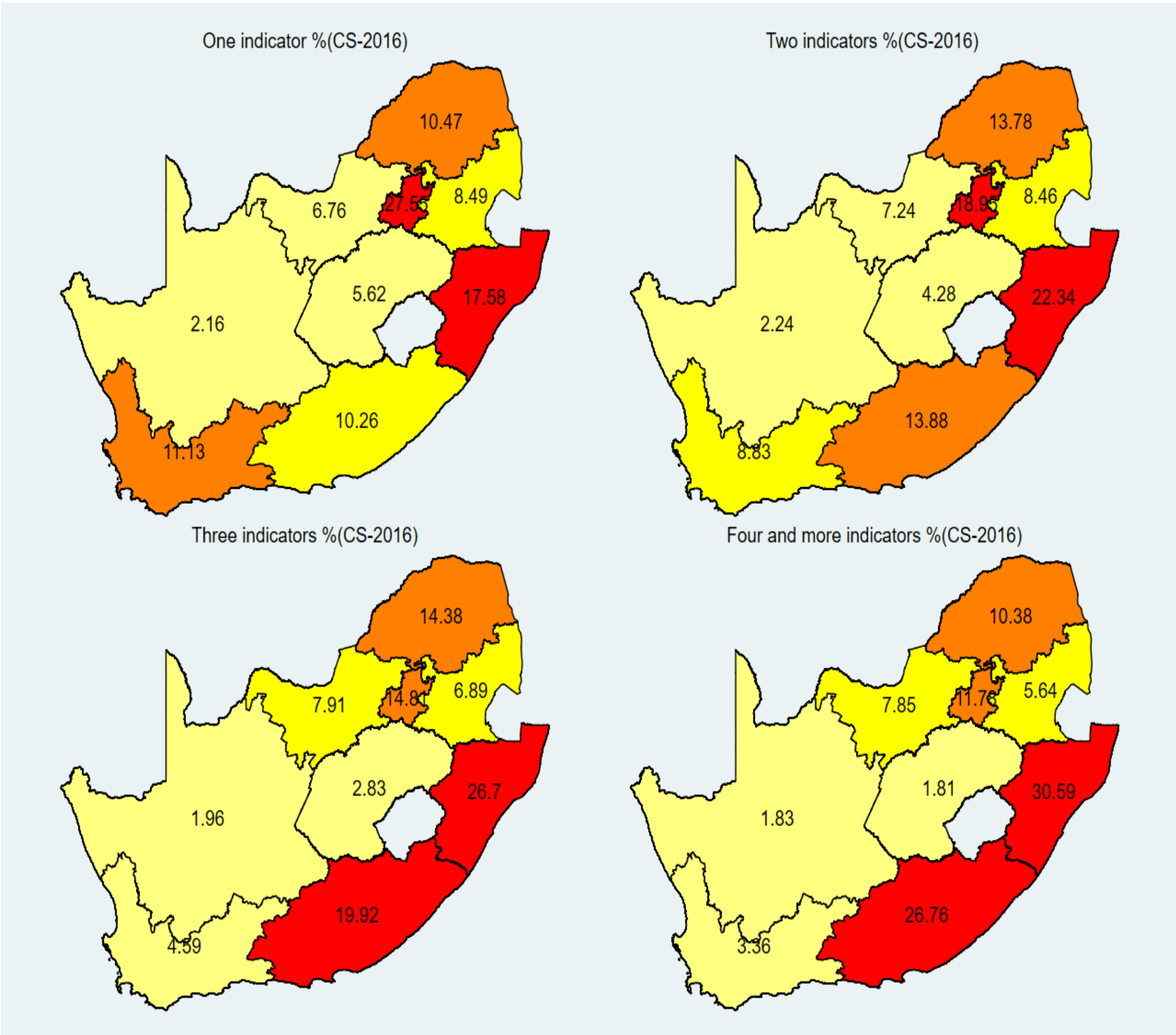


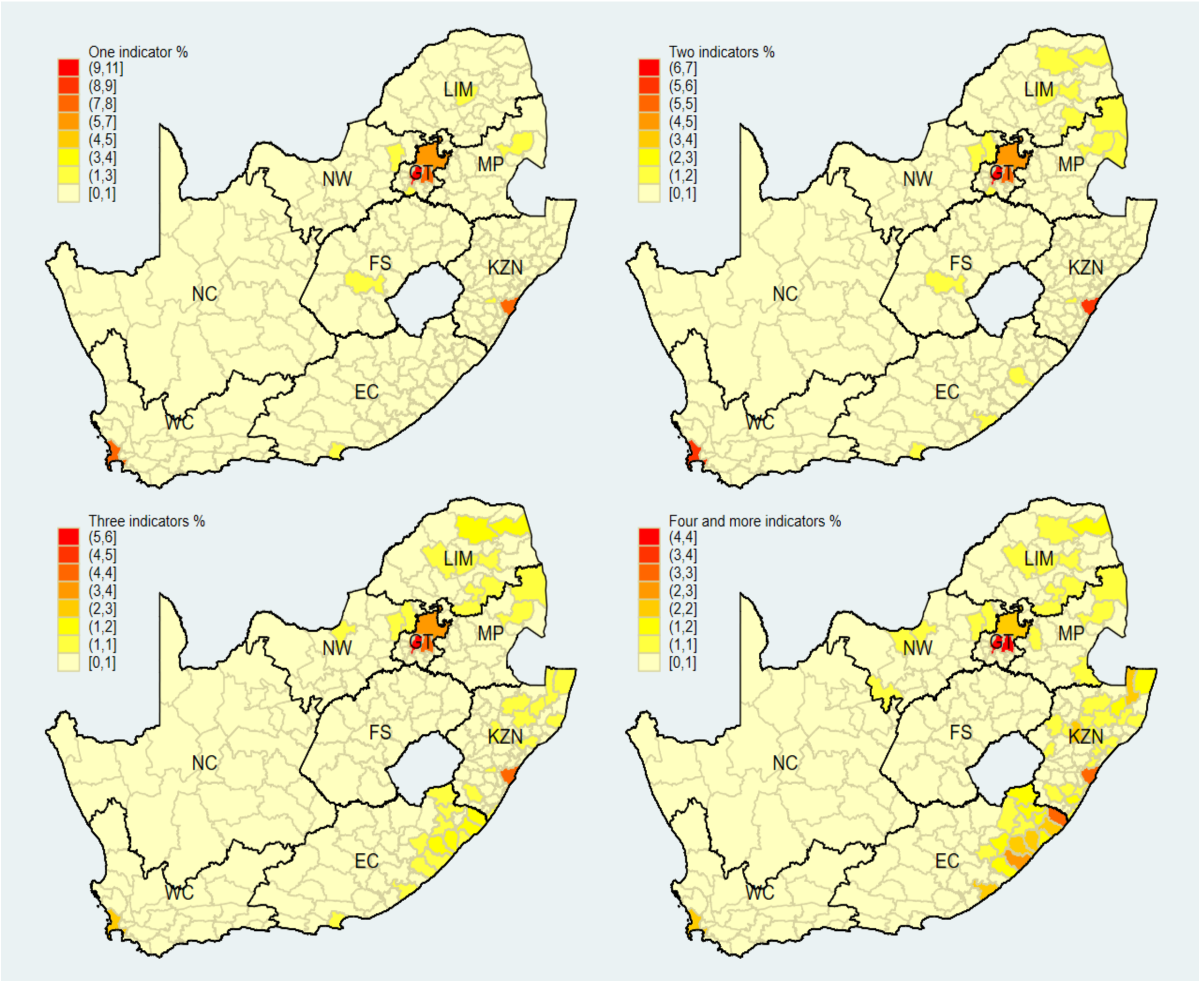
Figure 15: Relative share of the population that likely to be vulnerable to Covid-19 infection by province (CS 2016)

Source: Own estimates using data from CS (2016)



The relative share of the population that is likely to be vulnerable to Covid-19 infection due to two or more indicators is higher in muncipalities located in Gauteng, Eastern Cape, Limpopo, KwaZulu-Natal and Mpumalanga (Figure 16). This map is useful in making two important points. First, even in the least vulnerable provinces, there are local areas that contain sizeable shares of the national population who are highly vulnerable. Second, even in provinces with highly vulnerability, the combination of high vulnerability with large population share is quite localised.

Figure 16: Relative share of the population that likely to be vulnerable to Covid-19 infection by municipality (CS 2016)
Source: Own estimates using data from CS (2016)



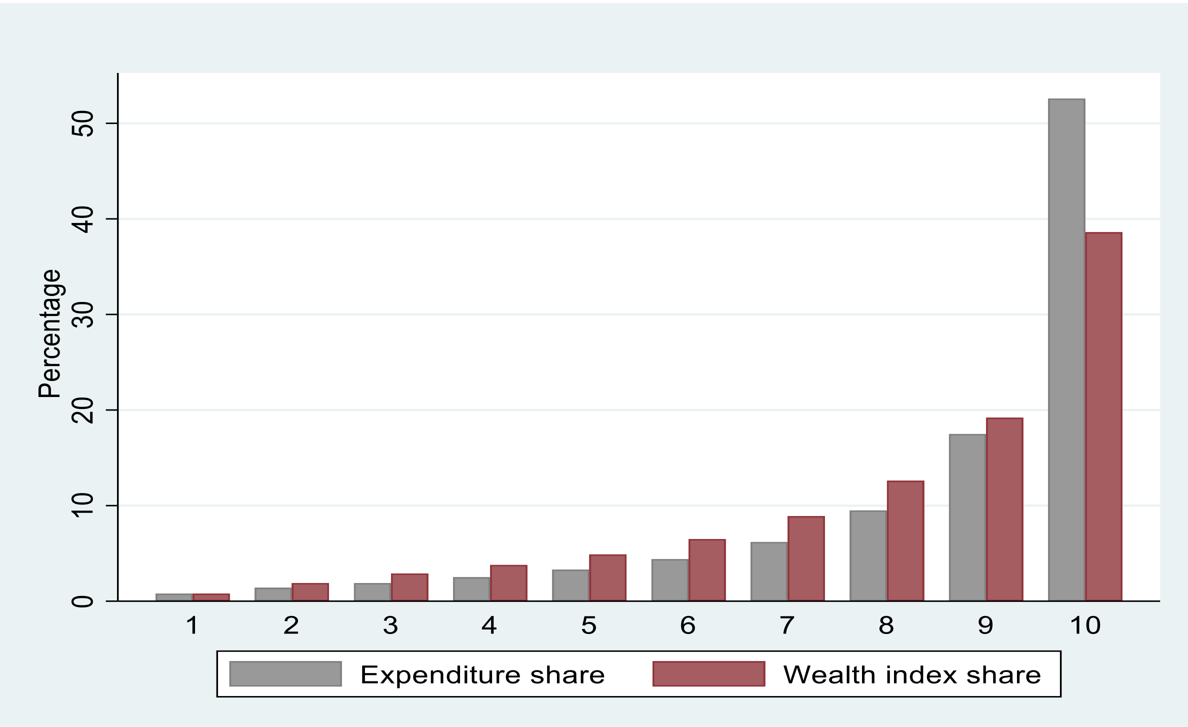
3.3 Is there a wealth effect?

Current socio-economic factors associated with the ability of individuals to protect themselves from infection and deal with severe lockdowns are often a reflection of past wealth-related status, which is unlikely to change quickly in response to pandemics such as COVID-19 (Brown et al,2020). As a result, the lockdown readiness and vulnerability indices are expected to vary with household wealth. In this section, we examine whether asset poor people are more vulnerable to COVID 19 infection and less able to comply with strict lockdown policies due to their living conditions.

To undertake this analysis we construct a wealth/asset index using the list of variables provided in Table 2 in the Annexure. Asset weights are generated using the uncentered PCA (UCPCA) approach (see Banerjee 2010; Wittenberg & Leibbrandt 2017). Although some of the variables included in the wealth index overlap with those used in the lockdown readiness and vulnerability index calculations, in both cases these indicators are not defined in the same way. Also, the wealth index includes 18 additional indicators that are not used in the lockdown readiness and vulnerability indices. As a result, we do not expect the relationship between the wealth index and the vulnerability and readiness indices to be primarily due to this overlap. That said, we check for this by calculate three versions of the wealth index, with and without the variables used in the calculation of the readiness and vulnerability indices. As shown in Table 3 in the Annexure, the rank correlation coefficient between the three wealth indices is very high. In addition, the R^2 for the variance of the overall wealth index on the variance of the vulnerability index is 0.12 while the R^2 of the overall wealth index on the lockdown readiness index is 0.08. Thus, almost 90% of the variance in the overall wealth index is due to variables that are not included in the vulnerability or readiness index calculations. We use the wealth index calculated using all the full set of variables shown in Table 2 in our subsequent work.

Figure 17 shows the distribution of our wealth index along with the distribution of consumption expenditure from Stats SA (Stats SA,2019). The share of the wealth index for the poorest 20 % of the population is less than 3 % while the figure for the richest 10 % of the population is 39 %. The distribution of the wealth index and the distribution of consumption expenditure are closely related. The consumption shares are somewhat lower than the wealth shares in all deciles below the richest decile and then markedly higher than the respective wealth share (53% compared to 39%) in the top decile.

Figure 17: The national distibution of consumption expenditure and wealth index shares by decile
Source: Own estimates using data from CS (2016)

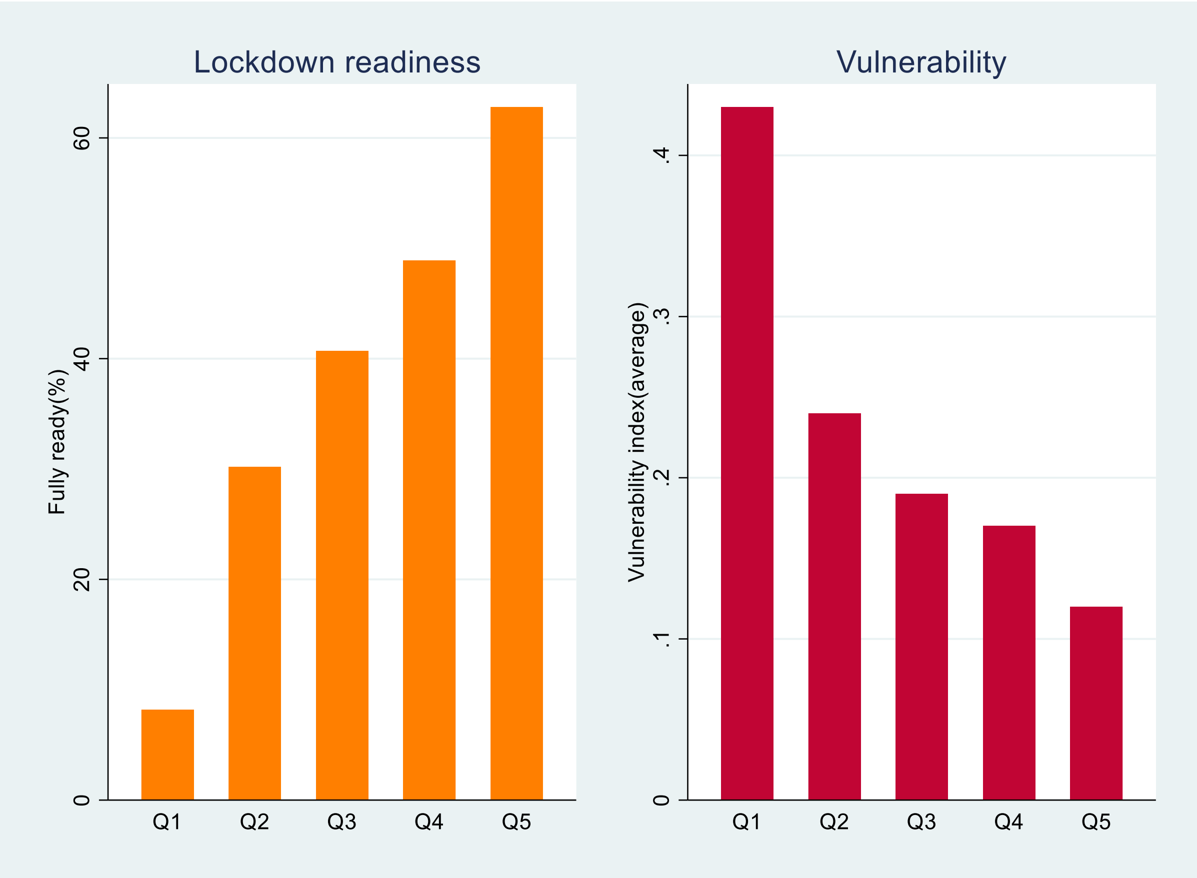


Note: the expenditure shares correspond to the 2015 survey year and are obtained from Stats SA (2019)

In Figure 18 we profile the readiness and vulnerability index values by wealth quintiles at the national level. Only 8 % of the population in the poorest quintile can be considered fully ready while the figure for the richest quintile is 63 %. Likewise, the average vulnerability index is the highest for those in the poorest quintile. A relatively large percentage of the population in the poorest quintile is vulnerable to the virus due to multiple factors (Table 4 in the Annex). For instance, 29% of the population in the poorest quintile are vulnerable to the virus due to three of more vulnerability factors while the corresponding figure for the richest quintile is only 3%. These estimates indicate a strong wealth effect on the lockdown readiness and vulnerability indices.

Figure 18: National lockdown readiness and vulnerability indices by wealth quintile

Source: Own estimates using data from CS (2016)



Provincial-level analysis shown in Table 5 also shows a strong wealth effect in lockdown readiness. For those in the poorest quintile lockdown readiness is significantly lower in all the provinces. The lockdown readiness index for the poorest quintile is the lowest in Eastern Cape (3 % fully ready) followed by Gauteng (4 % fully ready), while the figure is relatively higher in Mpumalanga (15 % fully ready) and Limpopo (14 % fully ready). However, only about 50 % of those in the richest quintile are fully ready in Mpumalanga, Limpopo and North West provinces. The distribution of the population by the wealth quintile shows that the percentage of the population in the richest quintile is the lowest in the Eastern Cape and Limpopo provinces, while a relatively large percentage of the population(about 30 %) in those provinces is concentrated in the poorest quintile (Table 7 in the Annexure). In contrast, only 4 % of the population in Western Cape and 8 % in Gauteng are in the poorest quintile.

Table 5: Lockdown readiness index by wealth quintile and province
Source: Own estimates using data from CS (2016)

		Wealth quintile				
Province	Average wealth index	Q1	Q2	Q3	Q4	Q5
Western Cape	6.4	5.0	36.9	54.0	64.5	77.5
Eastern Cape	3.0	3.1	24.8	37.7	45.5	59.7
Northern Cape	5.1	5.0	30.3	44.1	51.6	60.2
Free State	4.8	12.1	38.4	46.1	50.9	61.2
KwaZulu-Natal	4.1	9.1	30.0	39.0	47.1	63.5
North West	4.1	7.3	27.0	34.7	41.4	49.6
Gauteng	6.2	4.0	31.0	39.5	49.4	63.3
Mpumalanga	4.2	14.8	34.2	41.6	46.2	55.4
Limpopo	3.6	14.1	25.6	29.3	33.4	42.6

A similar pattern is observed when we look at the vulnerability index. Table 6 shows that the average vulnerability index is relatively higher for those in the poorest quintile in all the provinces. The average vulnerability index in the poorest quintile of each province is relatively lower in Mpumalanga, Limpopo and Free State. Looking at the distribution of the population by the number of vulnerability indicators also shows a large wealth effect within all the provinces (Table 8 in the Annexure). For those in the first wealth quintile, the percentage of the population who is vulnerable to the virus due to four or more vulnerability factors is 34 % and 30 % in Western Cape and Gauteng, respectively. These figures dropped to 0.1 % for those in the richest quintiles in both provinces. These are the two wealthiest provinces.

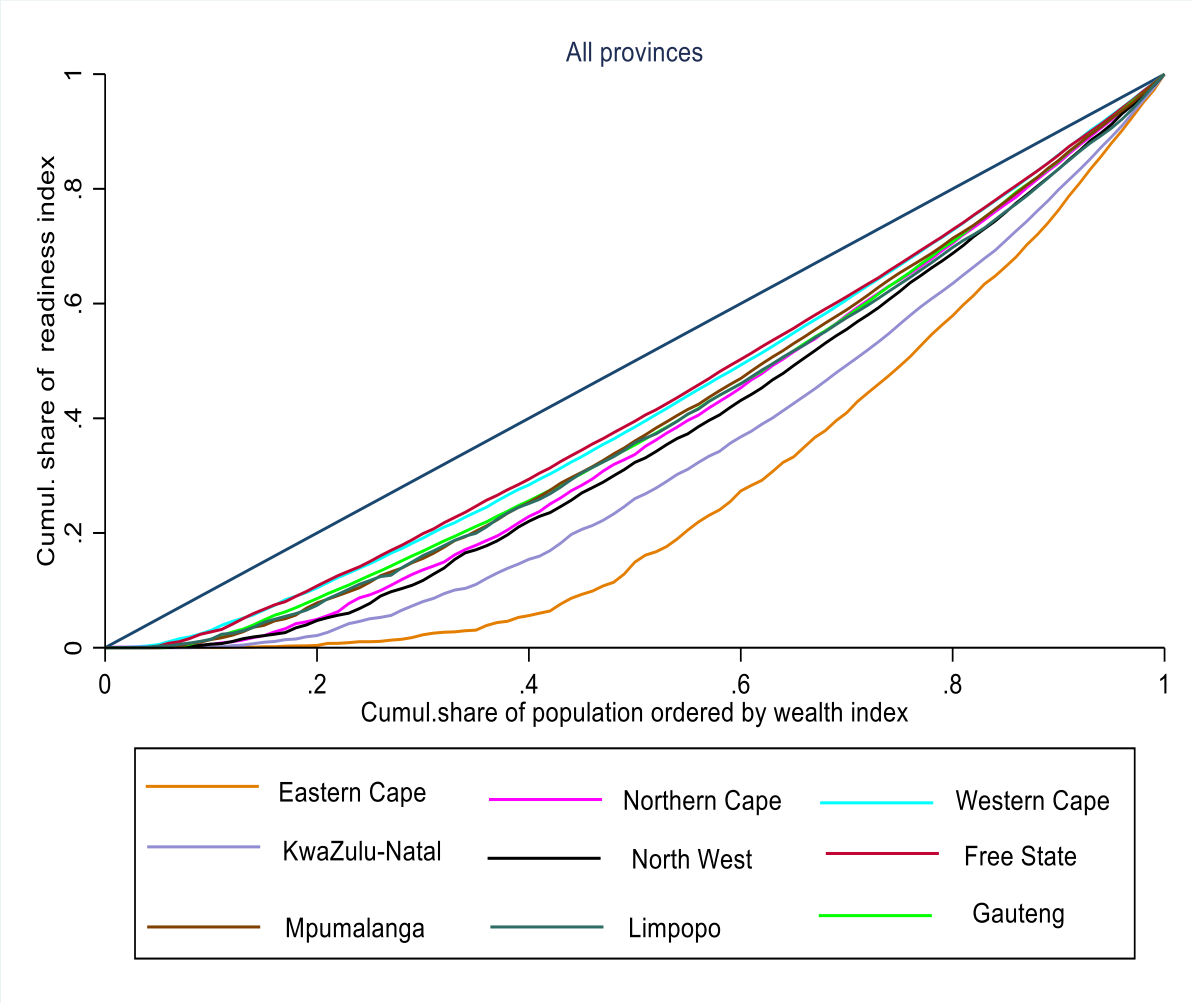
Table 6: Vulnerabiliy index by wealth quintile and province
Source: Own estimates using data from CS (2016)

Province	Wealth quintile				
	Q1	Q2	Q3	Q4	Q5
Western Cape	0.49	0.23	0.15	0.13	0.08
Eastern Cape	0.48	0.27	0.20	0.19	0.13
Northern Cape	0.46	0.25	0.19	0.17	0.13
Free State	0.39	0.19	0.15	0.14	0.11
KwaZulu-Natal	0.44	0.26	0.22	0.20	0.13
North West	0.44	0.25	0.21	0.19	0.15
Gauteng	0.48	0.21	0.17	0.15	0.11
Mpumalanga	0.37	0.22	0.19	0.18	0.14
Limpopo	0.36	0.26	0.25	0.23	0.19

Based on the quintile ratio (quintile 5/quintile 1), the wealth effect is relatively large in the Western Cape province. For instance, for the poorest quintile the percentage of the population that is likely to be vulnerable to the virus due to three of the indicators is 34% declining to 1.1% in the richest quintile (Table 8 in the Annexure). Likewise, following Eastern Cape, the quintile ratio (quintile 5/quintile 1) of the readiness index is relatively higher in Western Cape. However, this ranking is driven by the fact that further analysis of within province inequalities using concentration curves shows that within province inequity in lockdown readiness is the highest in the Eastern Cape, followed by KwaZulu-Natal and North West provinces (Figure 19).[3] In contrast, within province inequality in lockdown readiness is relatively lower in the Free State and Western Cape provinces.

[3] Figure 21 and Figure 22 in the Annexure provide the concentration curves of the vulnerability and readiness indices for each province.

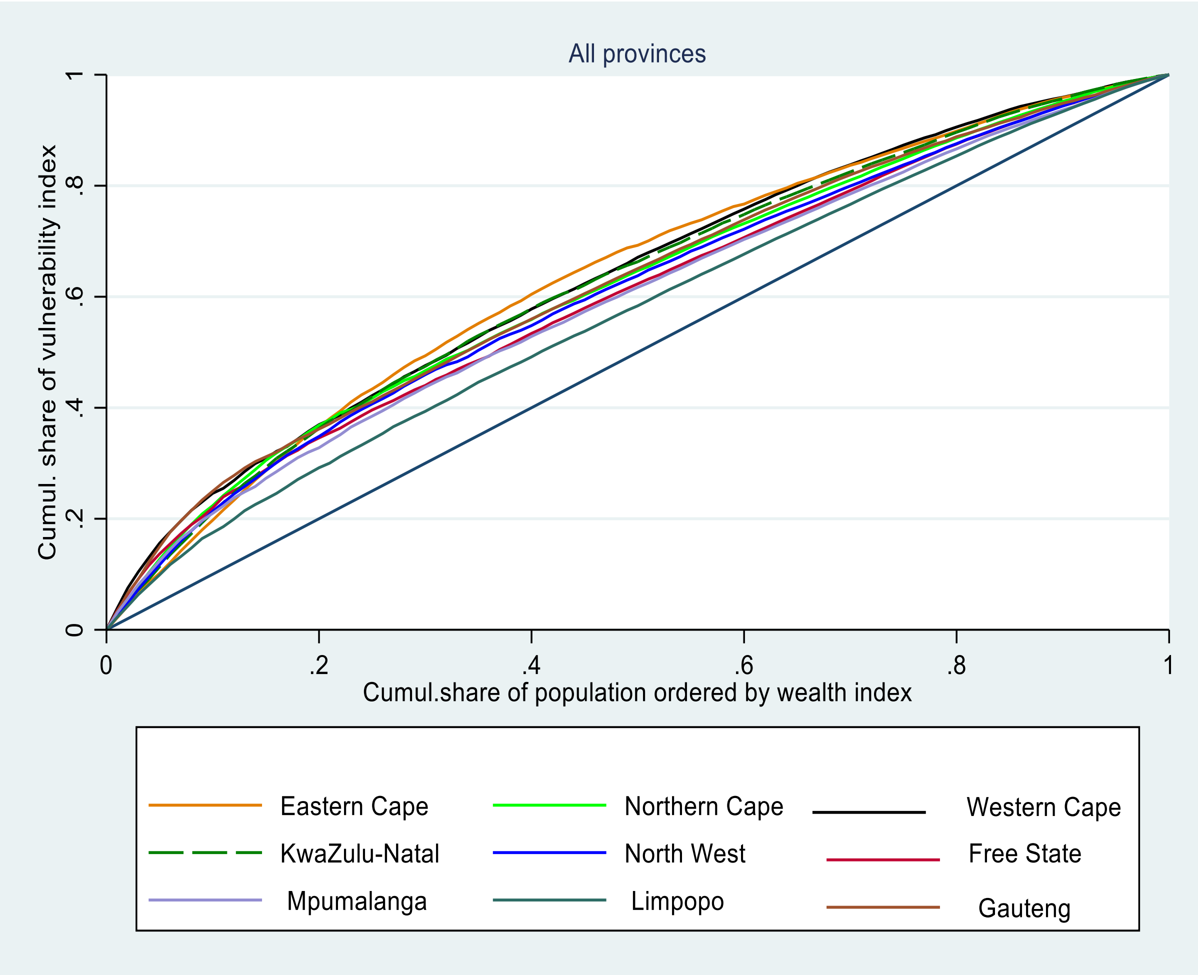
Figure 19: Concentration curves of the lockdown readiness index by province
Source: Own estimates using data from CS (2016)



With respect to the vulnerability index, Eastern Cape, KwaZulu-Natal and Western Cape are among those with relatively higher levels of inequality. In contrast, inequality in vulnerability to the virus is the lowest in Limpopo followed by Mpumalanga and Free State (Figure 20). Interestingly, Eastern Cape is also the province with the highest consumption inequality levels.

Figure 20: Concentration curves of the vulnerability index by province

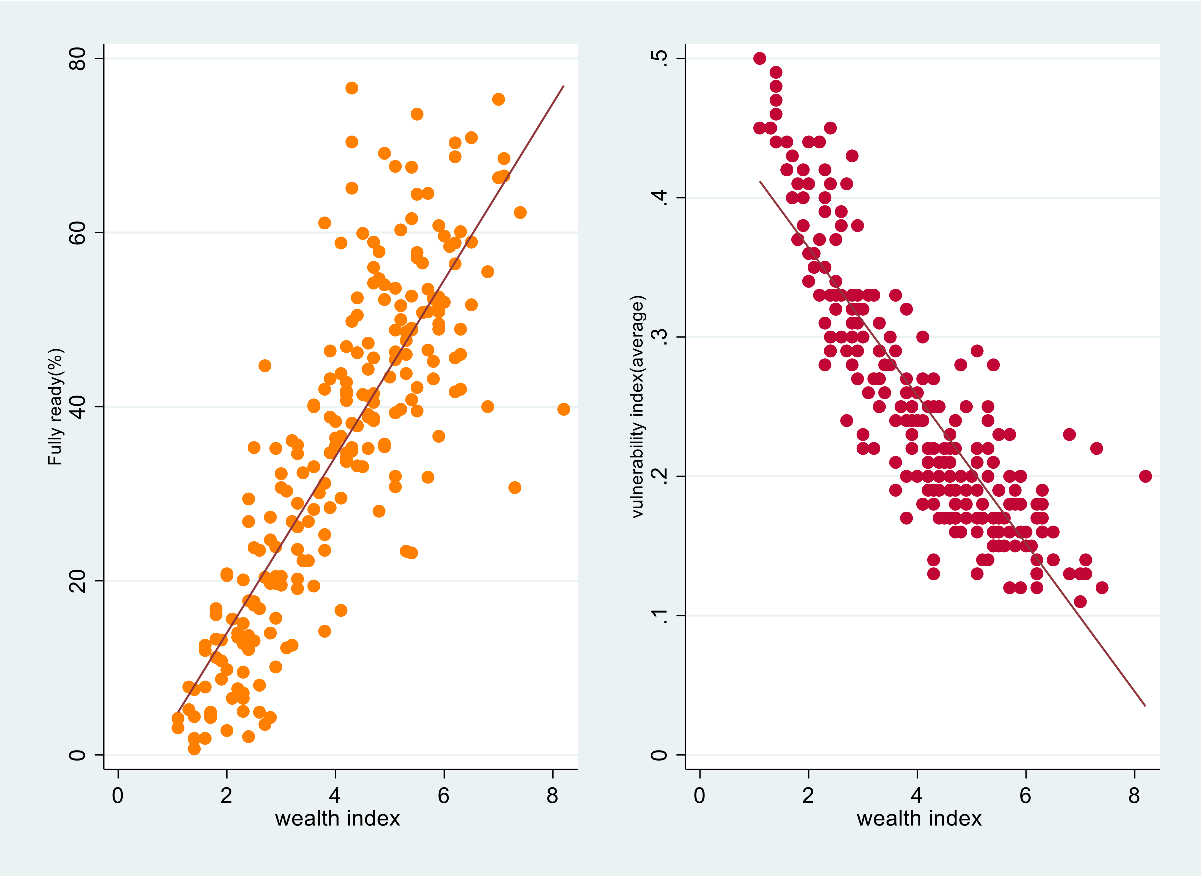
Source: Own estimates using data from CS (2016)



We also find a significant wealth effect across municipalities. Figure 23 shows the relationship between the average wealth index and the lockdown readiness and vulnerability indices by municipality. A simple linear regression of the readiness index on the wealth index indicates a positive and significant relationship (Coef=10.112, se=0.4469, t=22.26) between the lockdown readiness index and the wealth index. On the other hand, we find a negative and significant relationship between the vulnerability index and average wealth index (Coef=-0.05299, se=0.01939, t=-27.32).

Overall, the findings in this sub-section indicate that the living conditions of poorer households make them more vulnerable to COVID-19 infection through their exposure to an infected person. Poorer households are also less ready to be able to cope with strict lockdown policy.

Figure 23: Vulnerability and lockdown readiness indicies by average wealth index (municipality level)
Source: Own estimates using data from CS (2016)



3. Conclusion

In this paper we draw on an international literature profiling lockdown readiness and COVID vulnerability across countries to look, within the South African context, at differences in readiness and vulnerability across space. We select individual indicators of readiness and vulnerability that make sense in the South African context.

The analysis indicates strong correlations between low access to assets, low readiness and high vulnerability. Thus, those with the least general material resources to draw on enter into this specific COVID pandemic as the least COVID-ready but the most COVID-vulnerable. This is particularly disturbing. Going forward we will seek to explore and explain policy-actionable implications of these correlations further.[4] Of course, COVID-readiness and COVID-vulnerability become binding considerations at the point at which COVID enters the specific areas within which people work and live. The usefulness of this profiling of households will be greatly enhanced by giving more specific recognition to the fact that the epidemic has spread across South Africa in uneven ways and to twin the analysis of readiness and vulnerability to the arrival and spread of COVID-19 into different parts of the country. As mentioned in the introduction, this requires combining the analysis of these indices with fine-grained epidemiological data. Qiu et al. (2020) offers a very promising approach based on Chinese data. With dynamic municipal COVID-19 prevalence data very interesting work is possible and we are exploring the possibility of this twinning.

The analysis of individual indicators and their aggregate indices show stark inequalities across space in lockdown readiness and in COVID vulnerabilities. The municipal analysis shows that this is true even within provinces that have high aggregate readiness and low aggregate vulnerability. Thus, this paper raises the importance of explicitly including a spatial conceptualisation in designing the targeting of COVID policy responses. It also provides initial evidence to inform this thinking. As they stand therefore, the indices in this paper have useful implications for policy.

At face value, "different indicators of vulnerability to COVID-19 infection require different policy solutions, e.g. providing a household with soap and providing an infected person from an overcrowded household somewhere isolated and safe to recover require different kinds of public service interventions" (Gordon et al., 2020). But, the inequalities across space that we profile in each of our individual indicators makes a strong case for the need for spatial targeting, even if policy is implemented as a set of focussed interventions by a number of difference ministries..

We go on to show strong correlations and interactions between our indicators. This too is relevant to policy given that the budget allocation stages of policy implementation often operate at a higher level of aggregation than the indicator-by-indicator approach. Thus

[4] Oronce et al. (2020) and Qiu et al. (2020) offer promising approaches to this work.

there is both a conceptual and a policy case for transparently developing well designed aggregate indices. In this paper we illustrate this approach using simple counts of individual indicators and are careful to test for the sensitivity of our spatial analysis to a range of count cut-offs. Having made the case, the international literature has more sophisticated approaches to explore in taking this further.

Certainly this is not an academic curiosity in South Africa. It resonates with the prevailing approach to anti-poverty budget allocations. Policy takes place via initial national line ministry budgets being disbursed to provinces and then municipalities based on aggregate indices of need. The municipal equitable share formula includes:

> "A basic services component that helps municipalities provide free basic water, sanitation, electricity and refuse removal services to households that fall below an affordability threshold. ... A monthly household income of R2300 per month (in 2011) has been used to define the formula's affordability threshold. Statistics South Africa has calculated that 59 percent of all households in South Africa fall below this income threshold."(National Treasury, 2016)

On 24 June 2020 the South African Minister of Finance read a COVID emergency budget. It was needed in order to tighten up the fiscal thinking on the stimulus package and the COVID relief measures. In it he says:

> "Local government is at the heart of our response to the pandemic. Accordingly, an additional R11 billion is allocated to local government through the equitable share." (p. 12).

The use of the equitable share formula in allocating budget to local government for COVID relief makes a policy case for the kind of indicator development that is our focus in this paper. The free basic services that are considered in the equitable share formula are closely aligned to the indictors we has used to ascertain COVID readiness and vulnerability. At the least, our work on readiness and vulnerability shares could be used to cross check the standard equitable share allocations against their direct COVID related values.

Recently government has spoken frequently of a direct district development approach to policy. Our indicators have shown that within all provices, from the most ready and least vulnerable to the least ready and most vulnerable, there are municipalities with intense vulnerabilities some of which contain large populations. Our local-area work allows us to explore the different rankings of need implicit in a direct targetting of policies at municipalities versus rules that target provinces and then municipalities. Indeed, the municipal work makes a start of the kind of data analysis that will be required to back up a district development approach. Perhaps the strongest example in this paper is our derivation of asset indices and our profiling of the pernicious correlations between prevailing inequalities in acces to assets, COVID readiness and COVID vulberability across the length and breadth of this country.

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Appendix

Table 2: List of variables used to caclulate the wealth indices
Source: Own estimates using data from CS (2016)

	All variables (Wealth index1)	Excluding readiness index vars (Wealth index2)	Excluding vulnerability index vars (Wealth index3)
	Weights	Weights	Weights
Piped water	0.101		
Flush toilet	0.143		
Electricity	0.097		0.093
TV or radio	0.098		
Refrigerator	0.104	0.101	
Post service	0.119	0.115	0.115
Cooking fuel	0.105	0.101	0.101
Refuse removal	0.134	0.130	0.130
Stove	0.101	0.097	0.097
Vacuum cleaner	0.344	0.354	0.354
Washing machines	0.172	0.172	0.172
Phone	0.093	0.089	0.089
Table	0.234	0.238	0.238
Personal computer	0.252	0.257	0.257
Satellite dish	0.160	0.160	0.160
Car	0.209	0.211	0.211
DVD player	0.122	0.119	0.119
Home theatre	0.188	0.189	0.189
Microwave	0.141	0.139	0.139
Geyser	0.259	0.262	0.262
Aircon	0.514	0.543	0.544
Internet	0.375	0.390	0.390

Table 3: Rank correlation coefficients
Source: Own estimates using data from CS (2016)

	Wealth index1	Wealth index2	Wealth index3
Wealth index1	1		
Wealth index2	0.996	1	
Wealth index3	0.996	0.999	1

Table 4: Number of vulnerability indicators by wealth quintile
Source: Own estimates using data from CS (2016)

Number of vulnerability indicators	Wealth quintile				
	Q1	Q2	Q3	Q4	Q5
None	3.9	19.1	28.3	34.7	50.1
One indicator	16.1	36.2	38.9	37.4	33.1
Two indicators	27.2	29	23.4	20.1	13
Three indicators	28.9	12.8	8.2	6.7	3.4
Four indicators & more	24	2.9	1.3	1.1	0.4

Table 7: Population distribution by wealth quintile and province
Source: Own estimates using data from CS (2016)

	Wealth quintile					
Province	Q1	Q2	Q3	Q4	Q5	Total
Western Cape	4	16	25	25	31	100
Eastern Cape	38	21	17	14	11	100
Northern Cape	13	20	26	21	21	100
Free State	9	24	26	21	20	100
KwaZulu-Natal	31	22	17	16	15	100
North West	20	24	22	19	15	100
Gauteng	8	15	21	27	29	100
Mpumalanga	20	22	21	21	16	100
Limpopo	30	24	18	15	13	100
Total	**20**	**20**	**20**	**20**	**20**	**100**

Table 8: Number of vulnerability indicators by wealth quintile and province
Source: Own estimates using data from CS (2016)

	Wealth quintile (quintile 1)			Wealth quintile (quintile 5)		
Province	Two indicators	Three indicators	Four indicators+	Two indicators	Three indicators	Four indicators+
Western Cape	23.3	34.0	33.8	9.1	1.1	0.1
Eastern Cape	26.0	31.1	29.8	14.7	4.4	0.6
Northern Cape	26.5	33.0	26.4	15.2	3.1	0.4
Free State	30.8	25.9	17.0	11.6	2.4	0.2
KwaZulu-Natal	27.0	28.6	24.3	14.5	4.5	0.8
North West	26.1	29.5	25.5	16.9	5.7	1.1
Gauteng	23.2	35.2	30.1	11.1	2.6	0.1
Mpumalanga	28.8	23.0	16.3	17.1	4.3	0.6
Limpopo	31.5	24.2	13.7	21.9	8.1	1.5
Total	27.2	28.9	24.0	13.0	3.4	0.4

Figure 21: Concentration curves of the lockdown readiness index for each province

Source: Own estimates using data from CS (2016)

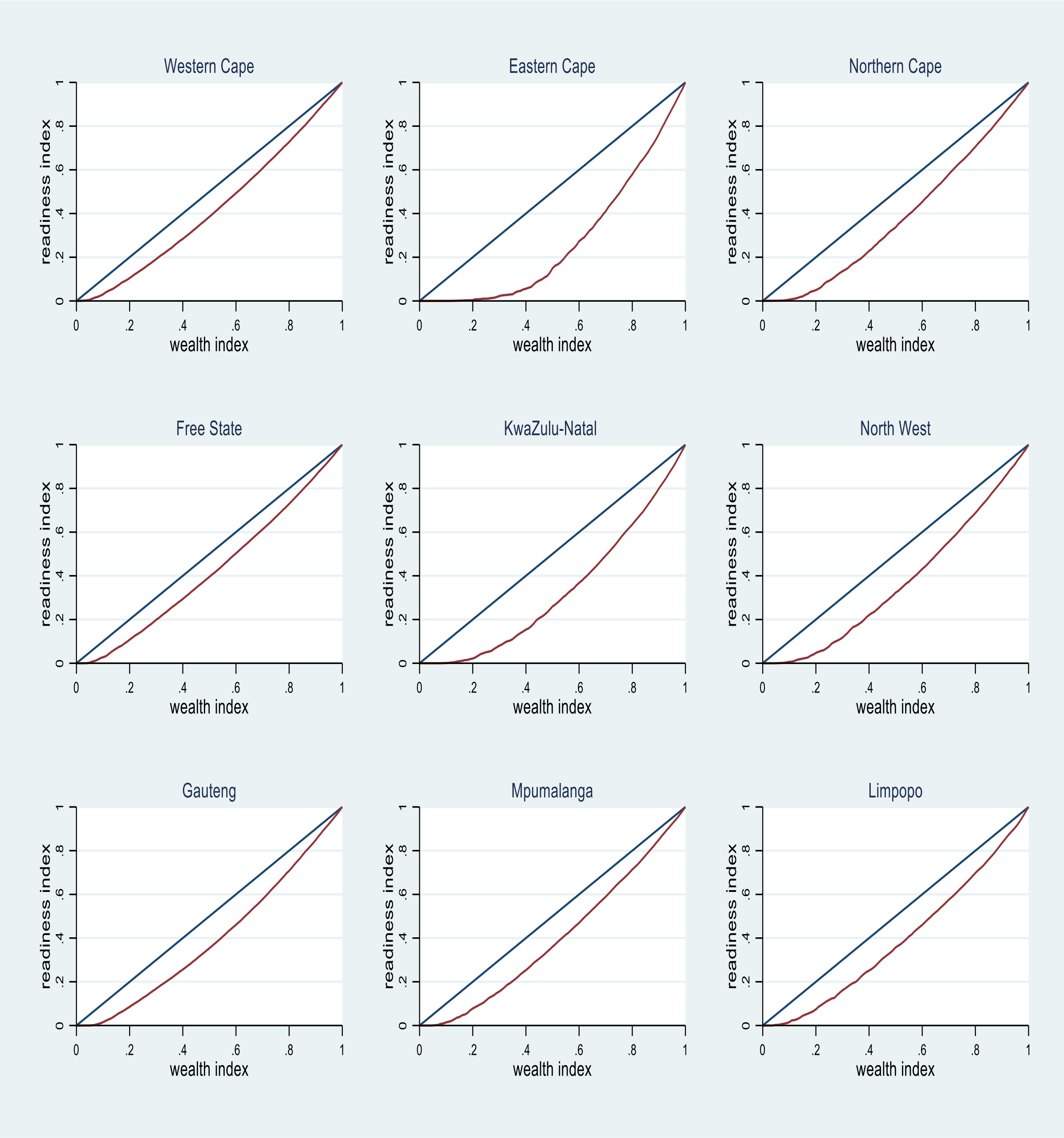
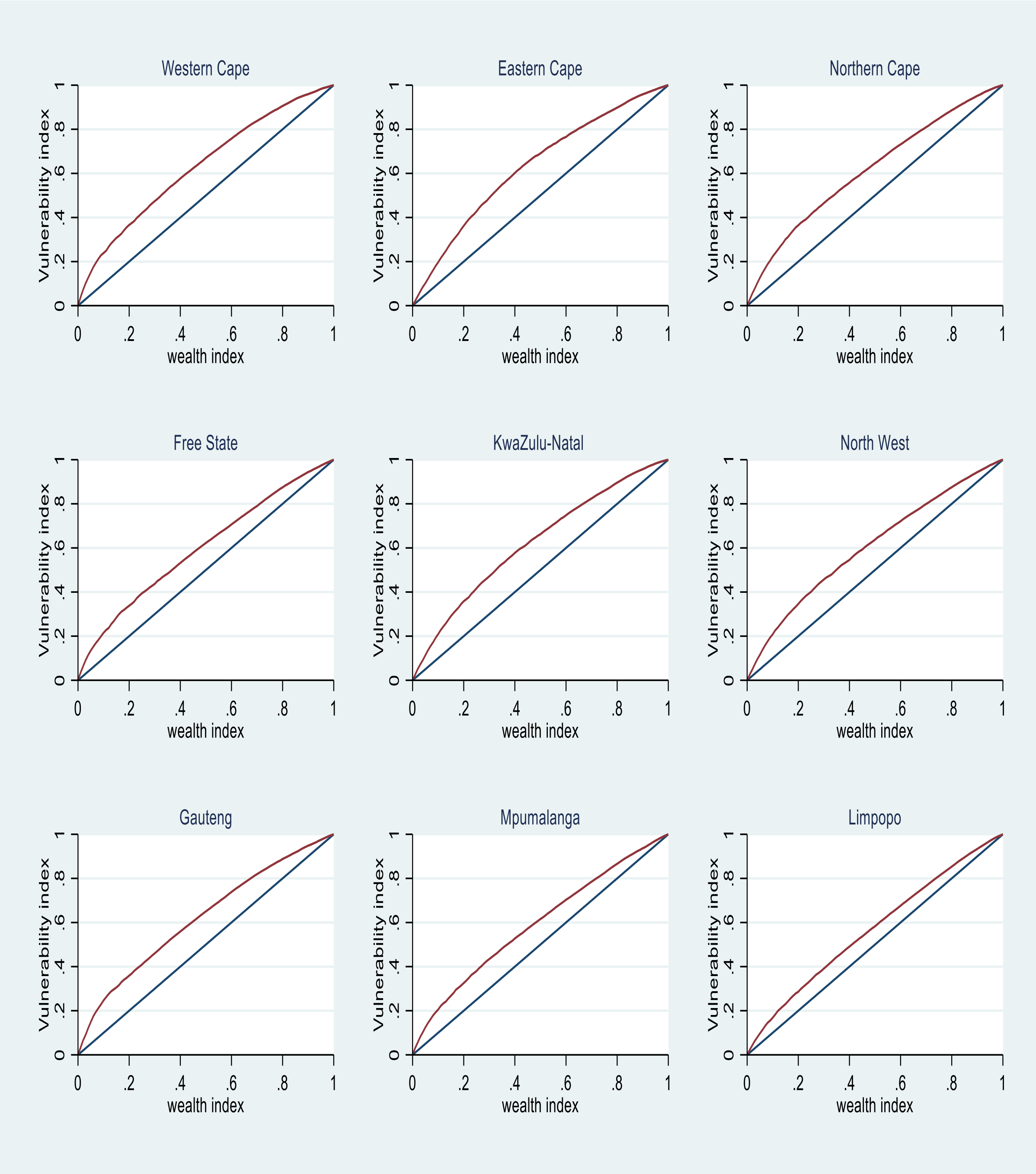


Figure 22: Concentration curves of the vulnerability index for each province
Source: Own estimates using data from CS (2016)



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The Agence Française de Développement (AFD) Group is a public entity which finances, supports and expedites transitions toward a more just and sustainable world. As a French overseas aid platform for sustainable development and investment, we and our partners create shared solutions, with and for the people of the global South.
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It's our way of honoring the commitment France and the French people have made to fulfill the Sustainable Development Goals.
Towards a world in common.

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