UNITED NATIONS UNIVERSITY

UNU-WIDER

World Institute for Development Economics Research

Research Paper No. 2008/54

Measuring the Vulnerability of Subnational Regions

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May 2008

Abstract

A small but growing literature has been concerned about the economic (and environmental) vulnerability on the level of countries. Less attention is paid to the economic vulnerability of different regions within countries. By focusing on the vulnerability of subnational regions, our paper contributes to the small literature on the 'vulnerability of place'. We see the vulnerability of place as being due to vulnerability in various domains, such as economic vulnerability, vulnerability of environment, and governance, demographic and health fragilities. We use a subnational dataset on 354 magisterial districts from South Africa, recognize the potential relevance of measuring vulnerability on a subnational level, and construct a *local vulnerability index* (LVI) for the various districts. We condition this index on district per capita income and term this a *vulnerability intervention index* (VII) interpreting this as an indicator of where higher income per capita, often seen in the literature as a measure of resilience, will in itself be unlikely to reduce vulnerability.

Keywords: vulnerability, regional development, decentralization, South Africa

JEL classification: O18, O55, R58

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This is a revised version of a paper originally prepared for the UNU-WIDER conference on Fragile States–Fragile Groups, directed by Mark McGillivray and Wim Naudé. The conference was jointly organized by UNU-WIDER and UN-DESA, with a financial contribution from the Finnish Ministry for Foreign Affairs.

UNU-WIDER gratefully acknowledges the contributions to its project on Fragility and Development from the Australian Agency for International Development (AusAID), the Finnish Ministry for Foreign Affairs, and the UK Department for International Development—DFID. Programme contributions are also received from the governments of Denmark (Royal Ministry of Foreign Affairs), Norway (Royal Ministry of Foreign Affairs) and Sweden (Swedish International Development Cooperation Agency—Sida).

ISSN 1810-2611 ISBN 978-92-9230-102-6

Acronyms

CIFP	country indicators for foreign policy
CSIR	South African Centre for Industrial and Scientific Research
GGP	gross geographic product
HDI	human development index
LVI	local vulnerability index
MDGs	Millennium Development Goals
PCA	principle components analysis
SOPAC	South Pacific Applied Geosciene Commission
VII	vulnerability intervention index

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Typescript prepared by Liisa Roponen at UNU-WIDER

1 Introduction

In economics,[1] vulnerability has often been defined as the risk of households falling in or remaining in poverty because of either idiosyncratic hazards (due to characteristics of the individual household) or covariate/aggregate hazards (external to the household) (e.g., Dercon 2005). More generally, however,[2] vulnerability refers to the risk that a 'system', such as a household, region or country would be negatively affected by 'specific perturbations that impinge on the system' or to the probability of a 'system' undergoing a negative change due to a perturbation (Gallopin 2006: 294). It can be relevant on the level of socioeconomic groups (e.g., households), places (e.g., states, regions and local areas) and across time (Turvey 2007). There is a small but growing number of attempts to measure economic vulnerability on the level of a country (Briguglio 1995, 1997; Briguglio and Galea 2003). One consequence of this literature has been recent attempts to define and measure the 'resilience' of vulnerable countries (Easter 1999; Briguglio et al. 2005), which is defined as the ability of a country to cope with economic vulnerability. Often GDP per capita is seen as a measure of resilience or compensating factor in highly vulnerable countries (Easter 1999).

On a lower level, most analyses of vulnerability have been conducted on the level of the household—as in economics. This, as pointed out by Bird, McKay and Shinyelawa (2007) is a shortcoming as far as understanding spatial poverty traps is concerned. They point to the fact that research on spatial pockets of poverty typically finds that the characteristics of a place 'may explain a significant proportion of poverty once household characteristics have been controlled for' (ibid.: 2). In particular therefore, regional level shocks to income—or regional level government capacity and action—can be a source of covariate risk to household income. Subnational regional factors exist (subnational vulnerability) that can have an impact on household incomes and wellbeing capabilities as well as on the way that they accumulate assets, as described in the framework provided by Dercon (2001). These factors can lead to both transient poverty and the occurrence of geographic poverty traps (Jalan and Ravallion 2002; Carter and Barret 2006)—and suggests that 'vulnerability of place' is distinct from national economic vulnerability or household vulnerability. Turvey (2007: 246) has recently pointed out that in order to understand the 'vulnerability of place', geography and the environment need to be taken into account as one of a number of domains across which a region or place can be seen to be vulnerable. These are typically absent from country-level economic vulnerability indices, which separate economic vulnerability from environmental vulnerability (Briguglio 2001).

Thus, while research on vulnerability on country and household level is proceeding, there is a relative lack of study on conceptualizing and measuring vulnerability on the subnational regional level. The present paper therefore aims to make the following threefold contribution to the literature. First, we attempt to fill the gap, by discussing the

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1 De Léon (2006) contains an excellent summary of the development of the concept of vulnerability outside of the field of economics, from the work of Chambers (1989) which focus on sustainable livelihoods of households, to the work sponsored by UN-DESA which focuses on vulnerability of small island states and the work of the United Nations University Institute for Environmental and Human Security (UNU-EHS).

2 Different disciplines have definitions of vulnerability that differ in specifics because they focus on different components of risk (Alwang, Siegel and Jorgensen 2001)

concept and need for measuring subnational vulnerability, and by providing an example of a *local vulnerability index* (LVI) by using data from South Africa. Second, we condition the LVI on income per capita (often considered a measure of resilience) in order define a *vulnerability intervention index* (VII), as it indicates the locations where higher income per capita may be unlikely in itself to reduce vulnerability. Thus, we qualify the extent to which income per capita is useful as a measure of resilience. Third, we include in our LVI environmental and geographical indicators, explicitly taking these into account in a single composite index.

The paper is structured as follows. In section 2, we discuss the concept of vulnerability on a subnational level. In section 3, we refer to the case of South Africa as an illustration of the usefulness of focusing on vulnerability on a subnational level. On a country level, South Africa has a relatively low economic vulnerability index (its score of 76 is comparable to that of France or Poland) but has a relatively lower resilience score, and is judged to be highly vulnerable in terms of SOPAC's[3] environmental vulnerability index (Briguglio and Galea 2003). It has a number of characteristics that, in the absence of strong institutions, could render it more fragile. These include its dependence on commodity exports, high inequality in incomes and wealth—often along ethnic lines, historical grievances, high poverty and unemployment, and rising violent crime. In this paper, we argue that these factors may be more pertinent on a subnational government level. Our contribution is to fill the gap that exists in terms of understanding these factors. We point out that despite the importance of local government in South Africa, and the evident problems that they are currently facing in terms of capacity and legitimacy, there has been little economic analysis of vulnerability on a subnational level.

In section 4 we describe the characteristics of he country's subnational regions, focusing on 354 magisterial districts, and outline our methodology. Section 5 reports on the results from our local economic vulnerability index and vulnerability intervention index for South Africa, and draws out some implications for policy and further research. Section 6 concludes.

2 Vulnerability on a subnational level

Most analyses of vulnerability have been conducted on the level of the household (including dynamic analyses) (Ligon and Schechter 2003; Prowse 2003). Exceptions are Chander (1996) and Briguglio (1997) who approach country vulnerability with small states in mind and see it as the susceptibility of a country to external shocks. In the more voluminous household-level analyses, however, vulnerability refers to the risk that non-poor households will become poor, and that poor households will remain in poverty. It is therefore an ex ante measure of poverty (Holzman and Jorgenson 2000). Günther and Klasen (2007: 2) perceive vulnerability narrowly as transient poverty (as opposed to chronic poverty, or poverty 'traps'). In this paper we take a different view, based on the recognition that vulnerability at the level of a place (as against a household) can influence both transient and chronic poverty (Bird, McKay and Shinyelawa 2007), and that poverty in itself may be a source of vulnerability for a region (Hulme, Moore and

3 See South Pacific Applied Geoscience Commission, www.sopac.org.

Shepherd 2001). Fragility, being an aggregate-level phenomenon (Binzel and Brück 2007: 5) can be a source of risk on the place level. One way to explain this is to acknowledge that risks to household income can have different sources. Typically, the literature identifies idiosyncratic risks (on the individual level) and covariate risks (systemic). The latter provides a link with vulnerability on the level of a region or country, since regional level shocks to income, or regional level government capacity and actions, can be a source of covariate risk. In particular, subnational level factors exist (subnational vulnerability) that will have an impact on household incomes, capabilities as well as on the way in which they accumulate assets. These factors can lead to both transient poverty and the occurrence of geographic poverty traps (Jalan and Ravallion 2002; Carter and Barret 2006).

By focusing on the vulnerability of subnational regions, our paper contributes to the small literature on the vulnerability of place. Turvey (2007: 246) describes the concept of 'vulnerability of place' and notes the lack in the literature 'of systematic empirical study that links geographic theory with vulnerability assessment'. She argues that place vulnerability is a function of economic geography and sociopolitical determinants in a given geographical region. Herein vulnerability of place is due to fragility in various domains, such as economic fragility, fragility of ecosystems and fragility related to governance and institutions.

An analysis of the vulnerability of place lends itself perhaps more readily to the consideration of non-income vulnerability (poverty) than to the analysis of household vulnerability. Hulme and McKay (2005) stress the shortcomings of focusing only on incomes in assessing vulnerability, and Günther and Klasen (2007: 3) recognize that one problem is due to the fact that 'equal incomes do not translate into equal outcomes for all ... different people are faced with different environments for translating income gains into non-income wellbeing gains'. In this paper we will attempt to provide a method for measuring the degree to which different geographical environments/regions are more conducive in this regard.

3 Subnational vulnerability in South Africa

Despite its troubled history and economic stagnation during the 1980s and early 1990s, South Africa is not a fragile state nor is it seen as being economically highly vulnerable. Its per capita GDP of US$13,000 places it in the middle-income country category. On a country level, South Africa has a relatively low economic vulnerability index (its score of 76 is comparable to that of France or Poland) but has a relatively lower resilience score, and is judged to be highly vulnerable in terms of SOPAC's[4] environmental vulnerability index (Briguglio and Galea 2003). The country has avoided significant domestic conflict, managed the transition to democratic government in 1994, is characterized by monetary and fiscal stability, and has seen its highest growth of almost a century taking place over the past five years.

Although not a fragile, low-income or economically highly vulnerable state as conventionally defined, South Africa has a number of characteristics that, in the absence

4 See South Pacific Applied Geoscience Commission, www.sopac.org

of strong institutions, could render it more vulnerable. These include as its dependence on commodity exports, high inequality in incomes and wealth—often along ethnic lines, historical grievances, high poverty and unemployment and rising violent crime. In this paper, we take it as a point of departure that these factors may be more pertinent on a subnational government level. This is so for two reasons.

First, the country's high spatial inequality in economic activity will have given rise to significantly different social and economic conditions across space. Naudé and Krugell (2003, 2006) investigate spatial inequalities in incomes and note an absence of convergence in per capita incomes between the country's subnational regions. Rossouw and Naudé (2008) construct indices of the non-income quality of life on a subnational level in South Africa and find significant variation across space in non-income quality of life, including environmental quality.

Second, institutional quality at local level is very uneven across South Africa. Both capacity constraints as well as reduced legitimacy have been noted as factors that compromise the quality of local government institutions in South Africa. In his 2007 state of the nation address, the South Africa State President referred to 'stubborn capacity constraints in local government'. The remark followed the mixed success of a two-year project to provide capacity support to 136 (out of 283) local municipalities that were identified to be failing in critical areas. Furthermore, the very legitimacy of many local governments is in doubt. In a recent review of local governments, Steytler (2005: 208) remarks that 'local government's legitimacy as a sphere of government is not high', pointing to such indicators as the low esteem in which citizens hold councillors, and the low voter turnout in local elections. A further indicator is the rising number of violent protests against local governments: at the time of writing the popular press had documented such uprisings in more than 20 localities over 2004-07 alone.[5]

The upshot of the above is that there is likely to be significantly more variation in the degree of fragility and vulnerability at subnational level in South Africa than would be reflected in the aggregate and national indicators. Weaknesses in capacity and legitimacy at country level are typical of fragile states (Anderson 2005: 2) and the differing economic, non-economic and environment aspects of the quality of life are consistent with the determinants of vulnerability at regional and household levels.

Our concern in this paper is to construct indicators to identify and analyse local vulnerability and its sources. This is important for a number of reasons.

First, objective indicators can be useful to identify municipalities that might require assistance from national government and/or donors. In South Africa, local governments are constitutionally responsible for economic development, and are entitled to an 'equitable' share of taxes raised nationally, in addition to raising their own revenue through property taxes and service charges. As recently stressed by Ahmed, Brosio and Gonzalez (2006: 5), transfers to local governments need to be based on a 'formula-based allocation system reliant on objective, quantifiable indicators'. However, the rules or formulae according to which these equitable shares are currently allocated in South

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5 These places are Cape Town (Langa, Gugulethu, Khayelitsa, Happy Valley, Blackheath, Ocean View), Johannesburg (Diepsloot), Pretoria (Mamelodi, Lotus Gardens), Port Elizabeth, Durban (Cato Manor), Harrismith, Secunda, Potchefstroom, Bloemhof, Khutsong, Matatiele, Bushbuckridge, Henneman, Kgotsong.

Africa make no provision for the vulnerability of a local economy or the fragility of its institutions. Moreover, the extent to which local government can access international aid may inversely depend on its vulnerability. Knowledge of the location and nature of the most vulnerable subnational regions may be important in supporting the call for more aid and the government's own financial resources to fragile regions, as well as the type/mix of aid flowing to subnational governments.

Second, such indicators can inform the monitoring of local government—and even raise attention to vulnerability (Turvey 2007: 255). The case for monitoring needs to be made not merely for determining whether particular subnational regions are becoming more or less vulnerable or fragile, but also for monitoring the spillover effects from a fragile and vulnerable region onto its neighbours. There is a lack of research on the financial costs that these regions impose on their neighbours, and a measurement of vulnerability on a subnational level can be a first step in such an attempt. The South African Constitution makes the provincial governments responsible for the monitoring of local governments, and the national treasury also fulfils an important monitoring role.

Third, if compiled properly, these indicators may provide information on the sources of vulnerability. Different sources of vulnerability (risk) will have different implications for chronic and transient poverty and thus whether structural or short-term actions are required to address the vulnerability (risk).

Fourth, unless vulnerability is addressed on a local (subnational) level, attempts to significantly reduce poverty and attain the Millennium Development Goals (MDGs) may be compromised. Kanbur and Venables (2005) point out that if spatial inequality is on the increase between various regions, as is the case in South Africa, that particular country's inequality as a whole is also likely to increase.

Fifth, given the rising tendency towards decentralization in developing countries, the success of national development increasingly hinges on the performance of subnational governments. Apart from South Africa, developing countries where constitutional changes have decentralized powers and functions to lower spheres of government include Brazil, India and Nigeria (Steytler 2005: i), Sierra Leone (Jackson 2005), Afghanistan (Lister and Wilder 2005), and Zimbabwe (Conyers 2003).

Despite the importance of local government in South Africa, and the evident problems that they are facing in terms of capacity and legitimacy, there is a lack of economic analysis of the fragility and vulnerability on a subnational level. Existing research focuses more on the vulnerability of particular groups and groups of households than on regions. There is, for instance, a growing literature on the vulnerability faced by those with HIV-positive status, by rural women, the unemployed, and those employed in the informal sector. In addition, a number of studies have focused on (income) poverty dynamics in South Africa and have constructed indices of poverty and/or deprivation (Klasen 2000; Mattes et al. 2003) and a service deprivation index (UNDP 2003). There have also been studies within the field of urban and regional planning focusing on central place indices and the potential of certain small towns (see, e.g., Krige, Schur, and Sippel 1998). However, these are all based on household survey data or planning data, covering only limited geographical areas (extending at most to the level of the country's nine provinces) and periods (limited in most cases to the period 1996-2001).

Five studies that come the closest in spirit to our paper are the poverty maps compiled by Alderman et al. (2000), the four deprivation indices at magisterial district level for 1996 by McIntyre (2000), the provincial indices of multiple deprivation[6] for 2001 by Noble et al. (2006), indices of growth potential[7] for the towns in the Western Cape by Zietsman et al. (2006) and an index for the non-economic quality of life at a magisterial district level by Rossouw and Naudé (2008). These studies all concur that South Africa is characterized by significant subnational variation in poverty, deprivation and quality of life. The Eastern Cape and Limpopo Provinces are identified as the provinces with the highest incidences of poverty and deprivation, and the Western Cape and Gauteng are with the least, although even in a relatively prosperous province of Western Cape, significant variation exists in poverty and growth outcomes, with towns with high and very high 'growth potential' predominantly located close to the Cape Town metropolis and along the south Cape coast (Zietsman et al. 2006: 695). While these studies take note of the static spatial inequalities in poverty, deprivation and quality of life in South Africa, Naudé and Krugell (2003, 2006), using panel-data growth regressions, find little evidence of convergence in per capita incomes among the magisterial districts since 1996.

Useful as these studies are to the understanding of the spatial patterns of poverty and deprivation in South Africa, they focus only on poverty outcomes ex post. Furthermore, as we will show, these indices tend to be fairly strongly correlated with per capita income, suggesting their possible redundancy as proper measures of non-income poverty and poverty dynamics. In light of our discussion of the concept vulnerability, they are clearly inadequate, as far as risk to unforeseen events and local capacity to deal with existing and possible future poverty is concerned.

4 Empirical analysis

4.1 Geographic context

South Africa has 283 local governments, which include 234 local municipalities, 6 metropolitan governments and 43 district municipalities. This current municipal demarcation dates back to December 2000 when the country was divided into 354 magisterial districts at the local government level. In this paper, we will focus on the earlier demarcation of 354 magisterial districts for two reasons. First, our dataset, with its basis in the 1996 and 2001 census boundaries, follows the magisterial district boundaries. Second, the pre-December demarcation of 354 districts provides a finer spatial view than the 283 municipalities. A brief overview of the historical patterns that shaped the South African space economy is provided in Naudé and Krugell (2003). Table 1 summarizes the salient socioeconomic features of these districts for the period 1996 to 2005 (see the discussion on the data in the section below). Table 1 was

6 These indices, although reported on the level of magisterial districts, have been compiled on a province by province basis, making comparisons between localities across provinces impossible. Also, these indices fail to distinguish between chronically deprived and partial or non-chronically deprived areas as argued in Anderson (2007). As a result, their usefulness in being used as subnational indicators of vulnerability is limited.

7 Zietsman et al. (2006) compile three composite indices to measure the 'growth potential' of towns in the Western Cape Province: a resource index, an infrastructure index and an economic index.

compiled after the 354 magisterial districts were divided in quintiles based on per capita income. Quintile 1 includes the districts with the highest average per capita income and quintile 5 those with the lowest.

Table 1 illustrates the degree of spatial inequalities that exists in South Africa on subnational (magisterial) level. For one, the average per capita income of the highest earning quintile is almost double that of the next highest quintile, and more than five times that of regions in the bottom quintile. Regions with higher per capita income also experienced, on average, higher economic growth, lower poverty and unemployment, a better human development index (HDI), and less HIV. On average, the richer places in South Africa were also located closer to an export hub (international port), were exporting more of their gross geographic product (GGP), and were spending more government resources per capita on capital goods than the poorer magisterial districts. Also, richer locations were endowed with better educated workers and better access to financial services. Finally we can note that the locations in quintile 1 experienced higher volatility in their GDP growth rates, as measured by the standard deviation of GDP growth rates over the period 1996-2005 than, for instance, poorer areas in quintile 5. One possible explanation could be that the places in quintile 1 are, on average, more open for trade (exporting on average 16 per cent of GDP compared to only 3 per cent of those in quintile 5) and thus more susceptible to changes in the external trade environment (see Briguglio 1995).

Table 1
Socioeconomic features of South African magisterial districts (Average over the period 1996-2005)

Socioeconomic variable	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Avg per capita income	R 27,229	R 14,076	R 9,758	R 7,131	R 5,183
Avg GDP growth rate (%)	3.30	2.00	1.20	1.10	0.90
Avg total population	188,832	87,600	110,597	133,301	116,982
Avg HDI	0.66	0.56	0.51	0.47	0.42
People in poverty, avg no.	45,330	34,856	49,049	85,205	78,480
People in poverty, as (%) of total population	25.10	44.20	53.10	65.20	69.80
Avg exports as (%) of GDP	16	9	2	2	3
Avg no. of people HIV+	5324	8251	12445	13311	17201
Avg export diversity index (1-not diverse; 0-very diverse manufacturing sector)	0.55	0.64	0.76	0.73	0.8
Avg total degraded land as (%) of total area	6.87	6.87	6.87	6.88	6.95
Avg no. of people per ABSA bank branch	61,907	64,985	94,751	111,803	133,739
Avg distance from closest export hub/market (km)	157.91	223.25	256.46	274.38	218.44
Avg total land covered by waterbodies, wetlands and forest (km^2)	44.504	40.504	43.241	27.43	44.139
Avg per capita capital expenditure by local government (R'000)	R 938.43	R 307.69	R 357.10	R 161.31	R 173.88
Local financial sector's share (%) of national financial sector	1.78	0.45	0.25	0.1	0.05
Avg no. of adults with no schooling	7,182	5,816	6,942	13,134	12,604
Avg unemployment rate (%)	22	30	36	53	61
Avg income volatility (std dev. in GDP growth over the period 1996-2005)	0.0359	0.0326	0.0296	0.0282	0.0284

Sources: See Table 2.

4.2 Methodology

Outline of approach

Our methodology consists of two steps. First, we construct a *local vulnerability index* (LVI) for each of the 354 magisterial districts in South Africa. We follow the methodologies of CIFP (2006) and Liou and Ding (2004): these and the resulting index are discussed below. Second, we run a regression of the LVI on per capita income, with the resulting residuals being interpreted as a measure to inform interventions aimed at reducing vulnerability. We call this measure the *vulnerability intervention index* (VII). This exercise follows from the fact that the LVI is, as in the case of other fragility or vulnerability indices, significantly correlated with per capita income. For instance the CIFP (2006) itself is highly correlated with the HDI (with a correlation coefficient of 0.9), which in turn is known to be highly correlated with per capita income (McGillivray 2005).

Measuring vulnerability

In constructing the LVI for subnational areas in South Africa, we take into consideration the various approaches currently being used to measure the vulnerability of countries and to construct vulnerability indices. The basic reason for constructing these indices is to identify the basic economic and environmental susceptibility of a country.

An early economic vulnerability index was prepared by Briguglio in 1992 for UNCTAD, and was further developed in 1994 for the UN Global Conference on the Sustainable Development of Small Island Developing States (Briguglio 2001). Subsequently, economic vulnerability indices have been constructed for UN-DESA and by the Commonwealth Secretariat (Easter 1999). As Briguglio notes (2001), there are basic methods for compiling a vulnerability index. One method used by Briguglio (1997) is to normalize the variables selected to take their averages. The second procedure, used by CIFP in measuring country fragility or the SOPAC for their environmental vulnerability index, is to map variables on a categorical scale (e.g., 1 to 9). The third option is to use regression based methods to estimate predicted values for an index, as is done by the Commonwealth Secretariat. In this paper we utilize the latter two methods.

What type of indicators should be used in the compilation of the index? Liou and Ding (2004) use factor analysis to construct a vulnerability index from a set of six indicators, namely, domestic economic scale, international trade capacity, development level, degree of output volatility, inflow of external resources, and institutional capacity. Easter (1998) compiles a vulnerability index for small states that consists of three indicators: export dependency ratio, merchandise export diversification and susceptibility to natural disasters.

Turvey (2007), focusing only on small island developing states, constructs a composite vulnerability index (CVI) using four broad groups of indicators: coastal indicators, peripherality indicators, urbanization indicators, and indicators of the vulnerability to natural disasters.

A local vulnerability index

Following Liou and Ding (2004), CIFP (2006) and Turvey (2007) we first use a principal components analysis to extract the common factors from a number of domains

influencing the vulnerability of a place. These domains (or sub-indices) are:

- Size of the local economy. The larger an economy, the less vulnerable or fragile it is considered to be (Liou and Ding 2004). This dimension is measured on the basis of population, GDP, population density and THE urbanization rate of the magisterial district.
- Structure of the local economy. Economies relying on a single economic sector or resource are more vulnerable than the more diversified ones. Here we use the share of primary production (consisting of the contributions of mining and agriculture) as an indicator of the local economy's structure.
- International trade capacity. Risk factors to local incomes include not only factors that may adversely affect local production, but also those that may affect local trade ability. Open economies, and economies exporting a variety of goods rather than a single product can be seen as less vulnerable than the more closed, specialized economies. For this domain, we use the ratio of exports and imports to local GDP (as in Briguglio 1995) as well as a measure of export diversification constructed by Matthee and Naudé (2007), whereas a value close to 0 refers to a diverse exporting manufacturing sector, and a value close to 1 refers to only one exporting manufacturing sector in the particular magisterial district.
- Peripherality, or remoteness is noted by Turvey (2007) to be positively related to fragility. Here, following Briguglio 1995), we measure remoteness by the distance from market, i.e., the kilometre distance from the magisterial district to its closest export hub/market; this is derived from Naudé and Matthee (2007).
- The development level of a district is inversely related to vulnerability. We measure this domain through the HDI, the percentage of total population in poverty and the unemployment rate in a particular magisterial district.
- Income volatility is often seen as a direct measure of an area's income 'riskiness' (Liou and Ding 2004). We measure this as the standard deviation of GDP growth in a particular magisterial district over the period 1996 to 2005.
- Demography and health affect vulnerability through the ability of households in a region to withstand or avoid negative future shocks. This is measured through the population growth rate and the incidence of HIV/AIDS in a district. The incidence of HIV/AIDS can be seen as a proxy for the pressure on health services and average life expectancy in a region.
- Governance refers to the willingness and capability of local governments to enact and implement pro-poor policies. There is no single, generally accepted measure of governance. In the international literature a whole range of indicators are available, unfortunately none of which exists at a subnational level. Here, we measure governance through the degree to which a local government allocates financial resources to long-term development, as reflected in the per capita capital budget expenditure of a magisterial district. In districts where there is less capital expenditure per capita, it is assumed that households would be more vulnerable than in areas where higher capital expenditure per capita results in local roads, shelter and sanitation. In terms of the South African fiscal system, these categories, with few exceptions, are the sole responsibility of local government.

- Environment and geography matter for vulnerability. They affect households' transaction and trade costs (through topography and environmental fragility) as well as household incomes (in deciding, for instance, agricultural production and crops) and quality of life (through environmental quality). To measure this domain we use a number of variables calculated from the South African Centre for Industrial and Scientific Research's (CSIR) satellite imagery and aerial photography of the country as well as information obtained from the South African Meteorological Services. These include total degraded land (per cent of size of area), proportion of forest-covered land, waterbodies and wetlands and rainfall (annual average in mm).
- The financial system can be an important mechanism for managing and reducing vulnerability and for ex post management of adverse income shocks. Households with little or no access to the formal financial system can be regarded as being more vulnerable than those with better access. We measure the access to financial systems on a regional level through the number of people per bank branch[8] per magisterial district. We also measure it by the ratio of the percentage share of the country's financial sector in a particular magisterial district to the percentage share of the country's population residing in the said magisterial district.

In the each of the above domains where multiple indicators were possible, the principal components analysis is used to simplify the selection. The resulting first component of each of the domains is then reserved as the indicator for that specific domain/sub-index. This method can be justified in view of the fact that the first principal component accounts for the greatest variance and the components are ordered in size as they are extracted. For the dimensions that consist of one variable, that particular value is used in the final calculation of the LVI. For the subsequent construction of the LVI, principal components analysis is once again used on either the value of a specific domain or the first principal component saved for each domain to extract the final LVI value. After principal components analysis is conducted on the ten single valued domains, the first principal component was once again saved and used as the final LVI value.

For each of the ten indicators listed above, a relative score (ranking) for each subnational magisterial district is calculated. The average over the period 1996 to 2005 is calculated (the dataset utilized is discussed in the following section). The overall rankings are divided into nine (roughly) equal groups and converted into a 9-point index (the highest ranking group of 40 magisterial districts is given a score of one, the subsequent ranking, a score of two, etc.). Each magisterial district is then given a final (aggregate) score as the average of all its ten scores. As in CIFP (2006), a magisterial district with a low score is considered to perform well relative to other districts, and a magisterial district with a high score performs poorly relative to the others.

An income-conditioned vulnerability index

It was noted above that vulnerability tends to be correlated with per capita income. This is true of the LVI. The Spearman rank correlation coefficient between this variable and income per capita for our sample of 354 magisterial districts is -0.569. It is no surprise

8 ABSA bank branches were used seeing as it is South Africa's largest financial services provider.

that the relationship is negative. Traditional development strategies aimed *inter alia* at increasing per capita incomes are thus appropriate as they also reduce local vulnerability. Yet, the correlation between the LVI and the per capita magisterial district income is not perfect. Some districts—intentionally or otherwise—are better than others at achieving lower vulnerability with higher incomes. This has important implications for policy. It suggests that there are factors other than achieved incomes that drive vulnerability levels. This, of course, is hardly a revelation. The relevance for policy is that actions taken to reduce local vulnerability should not rely primarily on increasing incomes in districts where vulnerability levels deviate substantially from those predicted by their incomes per capita. A measure of this deviation would appear to be appropriate, therefore. We label this measure as the *vulnerability intervention index*. Let us be very clear about what we mean by the term 'intervention'. We refer to interventions that directly tackle vulnerability, rather than a passive strategy that relies on reductions in vulnerability that are due either directly or indirectly to higher income levels. The higher the value of this index, the greater the case for such interventions.

The measure follows directly from the preceding observations. It is obtained by first estimating the following regression using the ordinary least squares method:

$$LVI_i = \alpha + \beta Y_i + \mu_i \qquad i = 1,...,354 \tag{1}$$

where LVI_i is the local vulnerability index value for magisterial district i, α is an intercept term, β is a slope coefficient, Y_i is some transformation of the per capita income of magisterial district i and μ_i is an error term. The transformation of income is based on the recognition that the relationship between local vulnerability and per capita income will be non-linear. The transformation, based on the well-known Atkinson formula for the utility of income, is as follows:

$$Y_i = \frac{1}{1-\varepsilon} y_i^{1-\varepsilon} \tag{2}$$

where y_i is the magisterial per capita income prior the transformation and ε is a parameter measuring the extent of diminishing returns in the conversion of income into lower vulnerability. If $\varepsilon = 0$ there are no diminishing returns and Y_i reduces to y_i. As ε approaches unity Y_i becomes the natural logarithm of y_i. Our vulnerability intervention index for any given district i is simply the absolute value of the estimated value μ_i obtained from estimating Equation (1). It is therefore written as:

$$VII_i = \left|\hat{\mu}_i\right| \tag{3}$$

where VII_i is the vulnerability intervention index for magisterial district i.

Before presenting the results, we discuss the data and variables used.

4.3 Data and variables

The data used for the indices were obtained from Global Insight's Regional Economic Focus (REF) (see www.globalinsight.co.za) which in turn is compiled from various official sources of data, such as Statistics SA Census and survey data, as well as data

from the CSIR's satellite imagery (used for environmental data). Table 2 summarizes the variables and sources of data.

Table 2
Variables and data sources

Variable	Source of data
Total population, 1996-2005	Regional Economic Focus data from Global Insight
GDP growth (%), 1996-2005	Regional Economic Focus data from Global Insight
Population density, 1996-2005	Regional Economic Focus data from Global Insight
Urbanization rate(%), 1996-2005	Regional Economic Focus data from Global Insight
Proportion of primary production, 1996-2005	Regional Economic Focus data from Global Insight
Exports as (%) of GDP, 1996-2005	Regional Economic Focus data from Global Insight
Imports as (%) of GDP, 1996-2005	Regional Economic Focus data from Global Insight
Diversity in exports, 1996-2005	Matthee and Naudé (2007)
Distance from closest hub/market, 1996-2005	Naudé and Matthee (2007)
HDI, 1996-2005	Regional Economic Focus data from Global Insight
No. of people in poverty as (%) of total, 1996-2005	Regional Economic Focus data from Global Insight
Unemployment rate (%),1996-2005	Regional Economic Focus data from Global Insight
Volatility in income, 1996-2005	Regional Economic Focus data from Global Insight
Population growth rate (%), 1996-2005	Regional Economic Focus data from Global Insight
Total people HIV+, 1996-2005	Quantec Easydata, RSA Regional Market Indicators (2007)
Capital budget expenditure/ local municipalities (R '000)	Statistics South Africa
Average rainfall (annual mm), 1996-2005	Regional Economic Focus data from Global Insight
Degraded land (%) of total area, 1996-2005	Regional Economic Focus data from Global Insight
Total land cover km^2 (forests, waterbodies & wetlands)	Regional Economic Focus data from Global Insight
No. of population per bank branch	Naudé et al. 2008
GDP share of the financial services sector, 1996-2005	Regional Economic Focus data from Global Insight

5 Results

In this section we outline the results of the compilation of our indices as follows. First, we set out and discuss our local vulnerability index (LVI) as calculated using principal components analysis (PCA) and following international examples on the level of countries (such as the country indicators for foreign policy-CIFP). Second, we measure the correlation of this LVI with per capita income, and construct an income-conditioned LVI which we term the vulnerability intervention index (VII). The LVI and VII are given in Appendixes A and B, respectively. Figure 1 shows the least and most vulnerable magisterial districts in South Africa based on the LVI.

5.1 The local vulnerability index

Table 3 gives the results as derived from the combination of the various 9-point indices, highlighting the 20 magisterial districts in the least-vulnerable and most-vulnerable groups. See Appendix A for the complete ranking and Figure 1 for the location of all magisterial districts ranked from least vulnerable to most vulnerable.

As can be seen from Panel A, all six metropolitan areas are in the least vulnerable category with respect to external/internal shocks to the South African economy. Most of the magisterial districts (non-metropolitan areas) considered to be the least vulnerable are located in the proximity of one of the metropolises, which could be interpreted that the 'closeness' of a metropolitan area to the particular magisterial district helps to insulate it against shocks.

Panel B lists the magisterial districts considered to be the most vulnerable to any external/internal shocks to the economy of the country. The results suggest that isolation is a significant factor driving subnational vulnerability (see also Bird and McKay 2007) since most of these districts are remote and isolated from any nearby hub of economic activity.

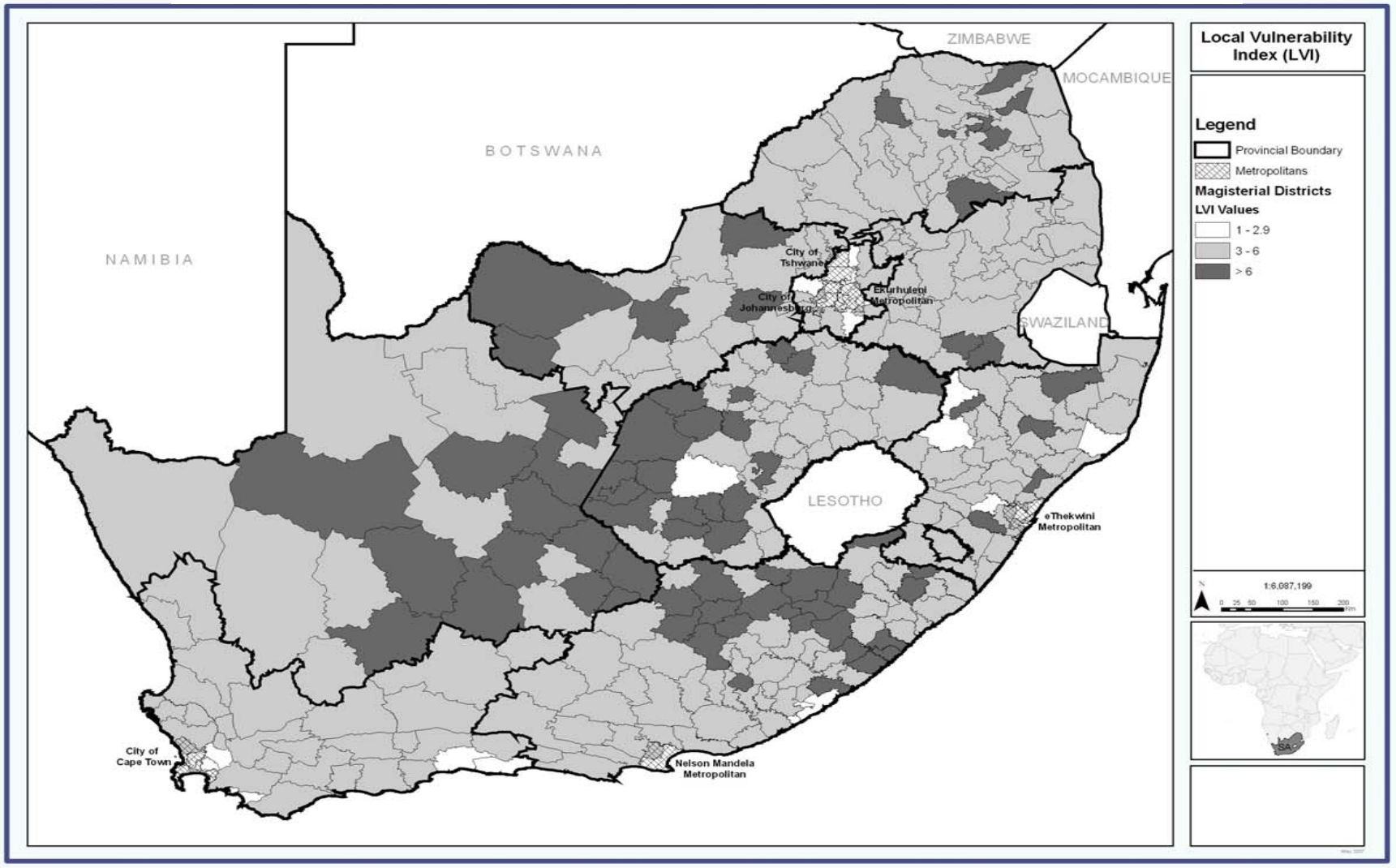
Table 3
Vulnerability of magisterial districts in South Africa according to the LVI

Location	Final LVI	Ranking	Location	Final LVI	Ranking
	Panel A: Least vulnerable districts				
Goodwood	1.4	1	Randburg	2.1	11
Durban	1.6	2	Pretoria	2.1	12
Johannesburg	1.7	3	Pietermaritzburg	2.2	13
Cape Town	1.7	4	Krugersdorp	2.2	14
Bellville	1.8	5	Soweto	2.3	15
Kuilsrivier	1.9	6	Pinetown	2.4	16
Chatsworth	1.9	7	Boksburg	2.4	17
Umlazi	2	8	Stellenbosch	2.5	18
Port Elizabeth	2	9	Springs	2.5	19
Wynberg	2.1	10	Paarl	2.5	20
	Panel B: Most vulnerable districts				
Hanover	7.7	1	Theunissen	6.9	11
Huhudi	7.5	2	Colesberg	6.8	12
Lady Grey	7.4	3	Fauresmith	6.8	13
Richmond	7.3	4	Philipstown	6.8	14
Amersfoort	7.2	5	Britstown	6.7	15
Bolobedu	7.1	6	Dannhauser	6.7	16
Hofmeyer	7.1	7	Elliot	6.7	17
Sekgosese	7.1	8	Koffiefontein	6.7	18
Barkley-West	7	9	Malamulela	6.7	19
Kudumane	6.9	10	Mpofu	6.7	20

Source: Authors' own calculations.

Figure 1 depicts the location of the least to the most vulnerable magisterial districts in South Africa. All the magisterial districts indicated by the darker colour are considered to be the most vulnerable to any external/internal shocks to the South African economy.

Figure 1
Vulnerability of the magisterial districts in South Africa according to the LVI



Source: Compiled for the authors, based on own calculations.

5.2 The vulnerability intervention index

The vulnerability intervention index (VII_i) was estimated for all 354 magisterial districts. In converting income into reduced local vulnerability, careful consideration was given the chosen value of ε, the parameter measuring the extent of diminishing returns. According to the criterion used, the chosen value was the one that returned the highest function fit (based on adjusted R^2s) from estimating Equation (1). Values within the range of 0.1 to 0.9 in intervals of 0.05 were considered, along the logarithm of *yi* (as mentioned above, this corresponds to a value of ε that approaches unity). This process led to a value of 0.80 being chosen for ε.

Table 4 shows the twenty locations with the highest VII values; that is, the highest absolute values of the residual obtained from the regression of the LVI on per capita income and defined in Equation (3) above. In these sites, the level of vulnerability as predicted by per capita income deviates from their actual vulnerability level, suggesting that increases in per capita income will perhaps not be effective in reducing vulnerability. Given the implication that this would require interventions aimed at addressing the underlying sources of non-income vulnerability, this residual in (3) can be interpreted as a VII.

As can be noted, vulnerability is high in certain locations (Kuruman) but low in others (Pietermaritzburg). It would suggest that building resilience by efforts to raise per capita incomes would perhaps not address the root causes of vulnerability as effectively as it would elsewhere. Here, addressing the root causes of vulnerability more directly is implied; interventions may be necessary for each of the non-income dimensions of the index. For example, national and local governments could address the remoteness of many of these locations directly through improvements in infrastructure and reductions in domestic transport costs. To determine the extent to which the most vulnerable magisterial districts in South Africa exhibit such low resilience through income per capita, Table 5 lists these districts, based on the LVI and the corresponding VII.

Table 5 shows that only five of the twenty most vulnerable magisterial districts in South Africa were also amongst the districts with the highest VII. This suggests that, first, attempts to reduce vulnerability through increased per capita income in these districts would be important. Second, there are five districts—Hanover, Huhudi, Lady Grey, Richmond and Theunissen—where increases in per capita income may not be sufficient.

Table 4
Magisterial districts in South Africa with the highest VII

Location	VII	Rank	Location	VII	Rank
Umlazi	3.442065	1	Mitchellsplain	2.464736	11
Soweto	3.118176	2	Phalaborwa	2.456742	12
Chatsworth	3.021128	3	Richmond	2.454046	13
Mdantsane	2.916892	4	Pietermaritzburg	2.403063	14
Kuilsrivier	2.681625	5	Goodwood	2.364468	15
Kriel	2.653671	6	Heidelberg	2.319403	16
Hanover	2.621291	7	Lady Grey	2.265819	17
Kuruman	2.511939	8	Kliprivier	2.189867	18
Inanda	2.508449	9	Soshanguve	2.167464	19
Theunissen	2.496317	10	Huhudi	2.087433	20

Source: Authors' own calculations.

Table 5
The most vulnerable magisterial districts and their corresponding VII ranking

Place	Final LVI	Ranking	Ranking in VII
Hanover	7.7	1	7
Huhudi	7.5	2	20
Lady Grey	7.4	3	17
Richmond	7.3	4	13
Amersfoort	7.2	5	25
Bolobedu	7.1	6	68
Hofmeyer	7.1	7	42
Sekgosese	7.1	8	80
Barkley-West	7.0	9	33
Kudumane	6.9	10	82
Theunissen	6.9	11	10
Colesberg	6.8	12	41
Fauresmith	6.8	13	24
Philipstown	6.8	14	27
Britstown	6.7	15	49
Dannhauser	6.7	16	115
Elliot	6.7	17	65
Koffiefontein	6.7	18	21
Malamulela	6.7	19	133
Mpofu	6.7	20	164

Source: Authors' own calculations.

Table 6
Selected characteristics of the most vulnerable magisterial districts

Place	Population density	% of primary production in GDP	Km from hub/markets	Population size in 2005	Degraded land, %
Hanover	1	42	322	4,891	15.0
Huhudi	4	50	426	113,004	17.5
Lady Grey	6	55	367	8,178	3.2
Richmond	54	62	400	6,852	8.5
Theunissen	28	86	264	41,211	14.1

Source: Global Insight Regional Explorer (2007).

The high vulnerability of these districts should not be addressed only by efforts attempting to increase per capita income, but more directly through the underlying causes of vulnerability. Some of these can be explored from the non-income domains that underlie the construction of the LVI.

For illustrative purposes, Table 6 shows the population density, primary production share and remoteness of the five most vulnerable places with high VII. The table indicates that in these five magisterial districts, the local economies are characterized by a dominance of primary production, low population densities, and remoteness from major internal markets and export hubs. The table also shows that degraded land ranges from a low of 3.2 per cent to as high as 17.5 per cent. Moreover, population in these vulnerable areas tends to be low in numbers, apart from Huhudi and Theunissen. Furthermore, Huhudi was found be to a relatively high population growth (on average 0.9 per cent) compared to population growth rates in other areas that are almost stable

(at around 0.2 per cent growth per annum). This underlines the importance of non-income interventions in Huhudi: these could be aimed at economic diversification, population densification in terms of settlement development, provision of infrastructure (including transportation links) and land rehabilitation and protection.

6 Concluding remarks

There are subnational regional factors that will affect household income, wellbeing capabilities and the way assets are accumulated. These factors can lead to both transient poverty and the occurrence of geographic poverty traps. Moreover, concerns with respect to broadly-defined poverty must focus on vulnerability. The 'vulnerability of place', distinct from national economic vulnerability or household vulnerability, is a potentially important concept that needs to be taken into consideration in dealing with human wellness within a country. Given the relative few existing studies on subnational vulnerability, the present paper aimed to make three contributions.

First, we discussed the concept and need for measuring subnational vulnerability. We provided an example of a local vulnerability index by using data from South Africa based on ten vulnerability domains across the country's 354 magisterial districts and illustrated how a LVI can be derived. The LVI made it possible to identify locations with high, moderate and low vulnerability. In the case of South Africa, places with high vulnerability are located mostly in the north-western interior, which is characterized by remoteness and environmental fragility. The major metropolitan areas are generally areas of low or moderate vulnerability.

Second, we conditioned the LVI on income per capita (which is often used as a measure of resilience) and interpreted the saved residuals as a vulnerability intervention index (VII). This indicated the regions where higher income per capita in itself may be unlikely to reduce vulnerability. Thus, a part of this paper's contribution was in qualifying the extent to which income per capita is useful as a measure of resilience.

Third, in our LVI, we included environmental and geographical indicators, explicitly taking these into account in a single composite index. We find from the South African illustration that there are indeed a number of districts where levels of vulnerability are high, and where increases in income per capita will not necessarily lead to a reduction in vulnerability. Many of these places are affected by low population numbers and low population growth rates. However, the study identified one district, Huhudi, which has a population of 100,000 and a relatively population growth: here, intervention to address the non-income aspects of vulnerability would be important. We argue that in areas similar to Huhudi, interventions should be aimed at the underlying non-income factors that drive the LVI, such as environmental and geographical indicators. In South Africa, it was in particular the remoteness, dominance of primary (agricultural) production in the economy, and low population densities that characterized the magisterial districts with both high vulnerability and a high vulnerability intervention index.

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Appendix A: Local vulnerability index

Magisterial district	Ranking in 2005	Magisterial district	Ranking in 2005
Hanover	1	Odendaalsrus	61
Huhudi	2	Sekhukhuneland	62
Lady Grey	3	Hoopstad	64
Richmond	4	Hopetown	65
Amersfoort	5	Mankwe	66
Bolobedu	6	Mapumulo	67
Hofmeyer	7	Smithfield	68
Sekgosese	8	Sterkstroom	69
Barkley-West	9	Vrede	70
Kudumane	10	Vredefort	71
Theunissen	11	Wakkerstroom	72
Colesberg	12	Adelaide	73
Fauresmith	13	Impendle	74
Philipstown	14	Ingwavuma	75
Britstown	15	Kentani	76
Dannhauser	16	Kranskop	77
Elliot	17	Mt Fletcher	78
Koffiefontein	18	Mt Frere	79
Malamulela	19	Polela	80
Mpofu	20	Simdlangentsha	81
Reddersburg	21	Stutterheim	82
Steynsburg	22	Utrecht	83
Victoria-West	23	Willowmore	84
Bochum	24	Bethulie	85
Elliotdale	25	Dzanani	86
Excelsior	26	Kuruman	87
Hay	27	Mahlabathini	88
Idutywa	28	Mbibana	89
Indwe	29	Nkandla	90
Jacobsdal	30	Pearston	91
Komga	31	Prieska	92
Tarka	32	Qumbu	93
Barkley East	33	Steytlerville	94
Cala	34	Tsolo	95
Edenburg	35	Tsomo	96
Koppies	36	Ventersburg	97
Petrusburg	37	Virginia	98
Babanango	38	Vryheid	99
Boshof	39	Williston	100
Bultfontein	40	Winburg	101
Hlanganani	41	Bizana	102
Noupoort	42	Clocolan	103
Trompsburg	43	Flagstaff	104
Wodehouse	44	Joubertina	105
Albert	45	Keiskammahoek	106
Carnarvon	46	Moutse	107
Delareyville	47	Murraysburg	108
Fraserburg	49	Peddie	109
Kenhardt	50	Pelgrimsrus	110
Maclear	51	Rouxville	111
Mt Ayliff	52	Senekal	112
Mutali	53	Viljoenskroon	113
Willowvale	54	Wepener	114
Dewetsdorp	55	Wesselsbron	115
Herbert	56	Zastron	116
Maluti	57	Aberdeen	117
Molteno	58	Aliwal North	118
Mqanduli	59	Bedford	119
Ngotshe	60	Bergville	120
		Eerstehoek	121

Magisterial district	Ranking in 2005	Magisterial district	Ranking in 2005
Fouriesburg	122	Phalaborwa	186
Heilbron	123	Philippolis	187
Jagersfontein	124	Richmond	188
Jansenville	125	Belfast	189
Lusikisiki	126	Carolina	190
Msinga	127	Groblersdal	191
Ndwendwe	128	Marquard	192
Ntabethemba	129	Middelburg	193
Reitz	130	New Hanover	194
Schweizer-Renecke	131	Thaba Nchu	195
Warrenton	132	Uniondale	196
Cofimvaba	133	Balfour	197
Hennenman	134	Ficksburg	198
Middeldrift	135	Giyani	199
Nqamakwe	136	Glencoe	200
Sterkspruit (Herschel)	137	Thabamoopo	201
Sutherland	138	Bothaville	202
Venterstad	139	Butterworth	203
Weenen	140	De Aar	204
Calitzdorp	141	Heidelberg	205
Hartswater	142	Mdutjana	206
Ladybrand	143	Ritavi	207
Libode	144	Ellisras	208
Lindley	145	KwaMhlanga	209
Lulekani	146	Lydenburg	210
Mkobola	147	Mooi River	211
Mthonjaneni	148	Oberholzer	212
Namakgale	149	Umvoti	213
Nkomazi	150	Welkom	214
Vryburg	151	Barberton	215
Brandfort	152	Lichtenburg	216
Cathcart	153	Moretele	217
Hankey	154	Soutpansberg	218
Hlabisa	155	Alexandria	219
Lady Frere	156	Botshabelo	220
Mhala	157	Cradock	221
Mokerong	158	Delmas	222
Port St Johns	159	Frankfort	223
Postmasburg	160	Ixopo	224
Tabankulu	161	Mtunzini	225
Umzimkulu	162	Nebo	226
Underberg	163	Piet Retief	227
Vuwani	164	Piketberg	228
Wolmaransstad	165	Ubombo	229
Alfred	166	Westonaria	230
Dundee	167	Clanwilliam	231
Hewu	168	Harrismith	232
Ladismith	169	Kirkwood	233
Laingsburg	170	Mmabatho	234
Madikwe	171	Phokwani	235
Namaqualand	172	Standerton	236
Naphuno	173	Thabazimbi	237
Ngqueleni	174	Thohoyandou	238
Paulpietersburg	175	Victoria East	239
Prince Albert	176	Camperdown	240
Seshego	177	Cullinan	241
Van Rhynsdorp	178	Estcourt	242
Waterval Boven	179	Fort Beaufort	243
Christiana	180	Ga Rankuwa	244
Kriel	181	Hopefield	245
Messina	182	Letaba	246
Nongoma	183	Mapulaneng	247
Nqutu	184	Brits	248
Nsikazi	185	Moorreesburg	249

Magisterial district	Ranking in 2005	Magisterial district	Ranking in 2005
Queenstown	250	Vereeniging	302
Riversdal	251	Zwelitsha	303
Temba	252	Bredasdorp	304
Volksrust	253	Caledon	305
Vredendal	254	Kimberley	306
Waterberg	255	King Williams Town	307
Bathurst	256	Roodepoort	308
Eshowe	257	Rustenburg	309
Port Shepstone	258	Wellington	310
Umbumbulu	259	Worcester	311
Umzinto	260	Humansdorp	312
Witrivier	261	Lower Tugela	313
Calvinia	262	Mitchellsplain	314
Ermelo	263	Bloemfontein	315
Graaff-Reinet	264	George	316
Klerksdorp	265	Newcastle	317
Umtata	266	Brakpan	318
Bronkhorstspruit	267	Hermanus	319
Oudtshoorn	268	Kliprivier	320
Parys	269	Knysna	321
Pietersburg	270	Mdantsane	322
Warmbad	271	Simonstown	323
Beaufortwest	272	Germiston	324
Bethal	273	Heidelberg	325
Bethlehem	274	Lower Umfolozi	326
Gordonia	275	Somersetwest	327
Mount Currie	276	Strand	328
Somerset East	277	Benoni	329
Highveld Ridge	278	East London	330
Kroonstad	279	Wonderboom	331
Potchefstroom	280	Alberton	332
Tulbagh	281	Inanda	333
Witbank	282	Kempton Park	334
Albany	283	Paarl	335
Montagu	284	Springs	336
Potgietersrus	285	Stellenbosch	337
Swellendam	286	Boksburg	338
Vredenburg	287	Pinetown	339
Ceres	288	Soweto	340
Nelspruit	289	Krugersdorp	341
Nigel	290	Pietermaritzburg	342
Robertson	291	Pretoria	343
Witsieshoek	292	Randburg	344
Malmesbury	293	Wynberg	345
Mosselbay	294	Port Elizabeth	346
Sasolburg	295	Umlazi	347
Randfontein	296	Chatsworth	348
Soshanguve	297	Kuilsrivier	349
Vanderbijlpark	298	Bellville	350
Lions River	299	Cape Town	351
Middelburg	300	Johannesburg	352
Uitenhage	301	Durban	353
		Goodwood	354

Source: Authors' own calculations.

Appendix B: Vulnerability intervention index

Location	VII	Location	VII
Umlazi	3.442065	Strand	1.554593
Soweto	3.118176	Thabazimbi	1.545217
Chatsworth	3.021128	Tarka	1.527044
Mdantsane	2.916892	Pinetown	1.516399
Kuilsrivier	2.681625	Albert	1.509743
Kriel	2.653671	East London	1.503234
Hanover	2.621291	Springs	1.453017
Kuruman	2.511939	Sutherland	1.425198
Inanda	2.508449	Kempton Park	1.397475
Theunissen	2.496317	Elliot	1.392928
Mitchellsplain	2.464736	Vanderbijlpark	1.391968
Phalaborwa	2.456742	Reddersburg	1.390026
Richmond	2.454046	Bolobedu	1.386444
Pietermaritzburg	2.403063	Bellville	1.372619
Goodwood	2.364468	Trompsburg	1.363803
Heidelberg	2.319403	Viljoenskroon	1.357692
Lady Grey	2.265819	Hopetown	1.324785
Kliprivier	2.189867	Bultfontein	1.324092
Soshanguve	2.167464	Humansdorp	1.320531
Huhudi	2.087433	Kenhardt	1.31268
Koffiefontein	2.084493	Knysna	1.296207
Port Elizabeth	2.050311	Molteno	1.280654
Alberton	2.047512	Hoopstad	1.269412
Fauresmith	1.984543	Ventersdorp	1.261407
Amersfoort	1.955253	Sekgosese	1.248695
Newcastle	1.945182	Pelgrimsrus	1.248094
Philipstown	1.943194	Kudumane	1.240302
Benoni	1.937425	Komga	1.226004
Krugersdorp	1.934731	George	1.225028
Fraserburg	1.897773	Uitenhage	1.222698
Victoria-West	1.871983	Mount Currie	1.219905
Jacobsdal	1.848794	Somersetwest	1.208171
Barkley-West	1.842464	Odendaalsrus	1.19513
Zwelitsha	1.841824	Ubombo	1.192384
Witsieshoek	1.782734	Durban	1.192124
Brakpan	1.746598	Virginia	1.186591
Umbumbulu	1.740202	Estcourt	1.182537
Wynberg	1.713977	Wodehouse	1.182014
Wonderboom	1.709074	Koppies	1.177905
Hay	1.683255	Excelsior	1.160702
Colesberg	1.67507	Steytlerville	1.143776
Hofmeyer	1.661209	Winburg	1.132183
Postmasburg	1.653584	Noupoort	1.12099
Williston	1.633474	Ixopo	1.117522
Edenburg	1.631999	Nebo	1.110921
Petrusburg	1.629379	Prieska	1.106267
Lower Tugela	1.624649	Wellington	1.102854
Paarl	1.618736	Stellenbosch	1.101047
Britstown	1.611102	Indwe	1.094545
Lions River	1.609293	Kimberley	1.088067
Boksburg	1.607182	Randfontein	1.086846
Carnarvon	1.596088	Herbert	1.077124
Ellisras	1.595835	Bloemfontein	1.076833
Steynsburg	1.56349	Aliwal North	1.071995
Joubertina	1.557369	Mapulaneng	1.068176

Location	VII	Location	VII
Eshowe	1.061372	Umvoti	0.756141
Phokwani	1.058882	Cullinan	0.755721
Temba	1.056828	Vrede	0.754961
Parys	1.054878	Pearston	0.754147
Dannhauser	1.050672	Victoria East	0.752451
Moretele	1.045632	Robertson	0.750298
Calitzdorp	1.039771	Gordonia	0.749448
Caledon	1.03481	Adelaide	0.746183
Vereeniging	1.010643	Port Shepstone	0.7432
Simonstown	1.009688	Ladismith	0.7288
Somerset East	1.00952	Beaufortwest	0.727237
Mankwe	1.00772	Ceres	0.724983
Willowmore	1.007178	Bathurst	0.722841
Boshof	1.005081	Hlanganani	0.721568
Barkley East	1.004069	Mutali	0.718548
Lower Umfolozi	1.00259	Cala	0.71689
Dewetsdorp	1.000496	Mdutjana	0.716101
Soutpansberg	0.997413	Schweizer-Renecke	0.713627
Hermanus	0.995901	Lydenburg	0.708672
Worcester	0.986249	Weenen	0.706396
Bethulie	0.981501	Mosselbay	0.705601
Vryburg	0.980142	Heilbron	0.702513
Malamulela	0.979006	Ladybrand	0.695703
Nigel	0.970785	Fort Beaufort	0.695251
Johannesburg	0.968189	Groblersdal	0.686967
Senekal	0.964468	Clocolan	0.679755
Maclear	0.948736	Msinga	0.679009
Van Rhynsdorp	0.947277	Alfred	0.671808
Aberdeen	0.945393	Umtata	0.671569
Hartswater	0.94328	Murraysburg	0.67053
Smithfield	0.942238	Nqutu	0.667746
Vryheid	0.939179	Mtunzini	0.663103
Bochum	0.936225	Ga Rankuwa	0.661883
Sterkstroom	0.934853	Nelspruit	0.661082
Ngqueleni	0.928223	Randburg	0.658331
Roodepoort	0.907763	Kirkwood	0.649615
Bethal	0.903465	Graaff-Reinet	0.628361
Albany	0.891542	Wesselsbron	0.624649
Namaqualand	0.886907	Highveld Ridge	0.614471
Kroonstad	0.886476	King Williams Town	0.596077
Botshabelo	0.879976	Bethlehem	0.587578
Bredasdorp	0.876379	Hennenman	0.58121
Umzinto	0.870936	Stutterheim	0.579871
Pietersburg	0.843652	Thohoyandou	0.577942
Tulbagh	0.841199	Camperdown	0.575494
Oberholzer	0.834629	Potchefstroom	0.571856
Jansenville	0.821565	Vredefort	0.5714
Nongoma	0.818403	Mthonjaneni	0.57126
Tabankulu	0.817056	Laingsburg	0.566611
Reitz	0.816378	Middelburg	0.566134
Utrecht	0.814232	Venterstad	0.563238
Delareyville	0.785448	KwaMhlanga	0.560698
Montagu	0.780474	Ntabethemba	0.554603
Mpofu	0.779558	Witrivier	0.548656
Pretoria	0.772513	Warmbad	0.543338
Idutywa	0.763045	Rouxville	0.541807
Zastron	0.759308	Paulpietersburg	0.541006

Location	VII	Location	VII
Nsikazi	0.518045	Giyani	0.287363
Wepener	0.51753	Namakgale	0.281436
Warrenton	0.516377	Engcobo	0.276761
Malmesbury	0.511964	Cradock	0.276349
Ermelo	0.508266	Calvinia	0.264329
Christiana	0.50034	Impendle	0.263349
Nqamakwe	0.496878	Klerksdorp	0.260247
Libode	0.49633	Moutse	0.260125
Sasolburg	0.494792	Mahlabathini	0.257064
Naphuno	0.486504	Mkobola	0.250676
Thabamoopo	0.485967	Rustenburg	0.25021
Port St Johns	0.48545	Piet Retief	0.24592
Bronkhorstspruit	0.479642	Alexandria	0.239156
Willowvale	0.475506	Simdlangentsha	0.235661
Sekhukhuneland	0.467879	Moorreesburg	0.226318
Waterberg	0.443974	Glencoe	0.226097
Hopefield	0.437889	Prince Albert	0.22558
Waterval Boven	0.43788	Queenstown	0.224264
Messina	0.437747	Dzanani	0.217062
Jagersfontein	0.434593	Umzimkulu	0.215374
Fouriesburg	0.431106	Underberg	0.210987
Harrismith	0.428175	Cathcart	0.205401
Ndwendwe	0.422999	Mhala	0.20435
Nkandla	0.413581	Germiston	0.200071
Lady Frere	0.412327	Mbibana	0.199436
Richmond	0.407892	Vuwani	0.187139
Philippolis	0.398935	Peddie	0.18496
Potgietersrus	0.392082	Wolmaransstad	0.182267
Elliotdale	0.390996	Westonaria	0.181335
Piketberg	0.390073	Vredendal	0.17735
Ritavi	0.387904	Bothaville	0.165638
Welkom	0.387592	Brandfort	0.162948
Frankfort	0.384201	Keiskammahoek	0.162796
Barberton	0.371937	Mmabatho	0.157669
Clanwilliam	0.3694	Belfast	0.156706
Bedford	0.365408	Mt Ayliff	0.150098
Hlabisa	0.364711	Kranskop	0.144903
Mokerong	0.363499	Marquard	0.14119
Oudtshoorn	0.352445	Maluti	0.137692
Uniondale	0.351253	Dundee	0.133355
Heidelberg	0.345866	Flagstaff	0.125409
Sterkspruit (Herschel)	0.344092	Bergville	0.120019
Seshego	0.343272	Bizana	0.119399
Standerton	0.34172	Thaba Nchu	0.118383
Swellendam	0.338375	Vredenburg	0.117456
Hankey	0.329152	Mt Fletcher	0.111896
Lulekani	0.322708	Cofimvaba	0.110659
Lusikisiki	0.321681	Riversdal	0.104196
Ventersburg	0.320571	Mt Frere	0.096186
Nkomazi	0.319042	Mapumulo	0.08625
Hewu	0.305485	New Hanover	0.086229
De Aar	0.30354	Witbank	0.085841
Carolina	0.303502	Polela	0.083942
Tsolo	0.29942	Kentani	0.071554
Volksrust	0.293516	Butterworth	0.06988
Mooi River	0.291171	Mqanduli	0.059167
Ngotshe	0.287885	Ingwavuma	0.056982

Location	VII	Location	VII
Madikwe	0.05659	Qumbu	0.035396
Lindley	0.05449	Babanango	0.02193
Balfour	0.050739	Middeldrift	0.01883
Cape Town	0.045969	Delmas	0.017315
Wakkerstroom	0.045553	Tsomo	0.015789
Middelburg	0.042853	Brits	0.005085
Letaba	0.039347	Ficksburg	0.002949
Lichtenburg	0.038034	Eerstehoek	0.000858

Source: Authors' own calculations.