Sub-national vulnerability measures: A spatial perspective

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Abstract

Most empirical investigations into economic vulnerability focus on the national level. Although some recent contributions investigate vulnerability from a sub-national perspective they contribute to the literature in an aspatial manner, as they do not explicitly account for the relative locations of areas and for the potential of spillovers between contiguous areas. This paper extends the current literature on a number of important fronts. First, we augment a principal components model to take explicit account of spatial autocorrelation and apply it to South African magisterial district level data. Second, by comparing spatial and aspatial models estimates, our empirical results illustrate the presence and importance of spatial spillovers in *local vulnerability index* estimates. Third, we augment the methodology on the *vulnerability intervention index* and present results which highlight areas that are performing better and worse than would be expected. After accounting for spatial spillovers, the results illustrate a clear urban-rural vulnerability divide.

Keywords: Economic vulnerability; Environmental vulnerability; Governance vulnerability; Demographic vulnerability; Health vulnerability

JEL Classification: R11; C21; I31

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1. Introduction

The concept and measurement of economic vulnerability is not a new area of academic interest but there has been a shift in thinking about economic vulnerability in recent years, which is associated with the general belief that the alleviation of poverty is a prerequisite for the achievement of development goals. With 2015 set as a deadline for the achievement of the Millennium Development Goals it is logical that policy makers are looking for a better understanding of the meaning and measurement of vulnerability concepts if any progress on this front is going to be made.

Naudé *et al*. (2009b) argue that in order to reduce poverty sustainably one must reduce the vulnerability of households and improve individual pliability. Many poverty measures are based on an *ex post* weighing; typically they only consider the current poverty and neither consider what has contributed to this poverty over time nor assess the possibility of slipping into poverty in the future. It is this vulnerability to poverty that needs to be addressed by policy makers.[1] Bird *et al*. (2007) believe that characteristics of place have a significant influence on spatially-defined poverty traps once household characteristics have been controlled for. Such a perspective prompted the need for a better understanding of how different areas contribute to the creation and sustainability of spatial poverty traps that in turn contribute to the overall vulnerability of a country.

Although Naudé *et al*. (2009a) have added to the growing literature on how regional vulnerability can be measured, we find that one important aspect has not been addressed, namely; the influence of spatial spillovers on said vulnerability. Therefore, this paper contributes to the literature by extending their vulnerability intervention index by

[1] This 'misinterpretation' of poverty is one of the reasons for the so-called poverty traps observed for specific areas within countries.

incorporating the spatial spillover effect which ultimately might steer policy makers in a better direction when developing policies for the alleviation and eradication of poverty.

This paper is structured as follows: the next section reviews the growing literature on sub-national vulnerability. Section 3 argues that a sub-national perspective on vulnerability should take an explicit account of relative location. With this argument in mind, Section 4 proceeds to detail the model and the data, which will allow for the estimation of spatial and aspatial, local vulnerability and vulnerability intervention indices. The estimated results are presented and discussed in Section 5, while Section 6 provides conclusions.

2. Literature review

Vulnerability origins and the spatial scale of analysis

Primary concerns associated with negative events (or shocks) are their impacts on productivity growth, development potential and the extent to which they alter vulnerability (Guillaumont, 2004).[2] However before vulnerability can be accurately measured attention needs to be focused on where potential shocks may arise. Three basic channels of origin can be identified: (i) environmental or natural shocks, such as natural disasters; (ii) other external shocks (trade and exchange related), such as slumps in external demand, and (iii) other (non-environmental) internal shocks, such as political instability (Guillaumont, 2004). The origins of vulnerability therefore transcend the geographical, economic and political. Once the

[2] For a more in-depth discussion on the empirical and conceptual viewpoints of economic vulnerability, see Briguglio (1995, 2003) and Atkins *et al*. (2000). Guillaumont (2009) suspects that there has been an upsurge in interest concerning macro vulnerability because of the unsustainability of growth episodes and contemporaneous increase in poverty rates in Africa, the Asian crisis' unveiling of emerging markets' vulnerability and the debate surrounding the construction of an appropriate vulnerability measure that can be applied for specific country groups.

origins of vulnerability have been identified the next stage in an analysis is to decide on the appropriate spatial scale.

Literature pertaining to the study of vulnerability has focused on three levels of analysis: household, regional and national. A large majority of this literature is devoted to measuring the relative vulnerability of a country. However Baliamoune-Lutz and McGillivray (2008) identify that the World Bank's country policy and institutional assessment (CPIA), under which a country is classified as being more or less vulnerable, has some severe flaws which can result in the incorrect classification of countries located close to classification boundaries. Unfortunately this has significant policy implications as CPIA ratings are used in deciding how International Development Association (IDA) assistance is allocated.

Turvey (2007) advocates the need for place vulnerability indices and constructed a composite vulnerability index (CVI) for 100 developing countries out of four sub-indices: coastal index, peripherality index, urbanisation index and a vulnerability to natural disasters index. She further argued that without a geographical component in the measurement of vulnerability, the construction of vulnerability profiles may be useless for framing development policy and evaluating developing countries.[3]

Although the main spatial scale of analysis has been at the country-level there are a growing number of articles that examine vulnerability at the household level. For instance, Bird and Prowse (2008) investigated the vulnerability of households in Zimbabwe and found that if official donors did not intervene then the poor and very poor were likely to be driven into long-term chronic poverty and such chronic poverty would be extremely difficult if not impossible to reverse. Gaiha and Imai (2008) also argued that idiosyncratic shocks (e.g.

[3] For further studies on country specific vulnerability see for example, Birkmann (2007); Easter (1998); Marchante and Ortega (2006), Mansuri and Healy (2001) and McGillivray (2008).

unemployment or illness) were primarily the cause of Indian rural households' vulnerability although poverty and aggregate risks (weather and crops) were also very crucial contributory factors; the last of which is clearly a geographical issue.[4]

Not a lot of attention has been given to the vulnerability of regions within a country. Hulme *et al*. (2001) link poverty to the vulnerability of specific regions and Kanbur and Venables (2005) show that not only is spatial inequality between regions on the increase but that it will ultimately cause an overall increase in the inequality of specific countries. Ivaschenko and Mete (2008) present strong evidence of geographic poverty mobility traps and argue that higher levels of poverty in a region appear to reduce radically the chance of a household emerging out of poverty, and that living in a region with an overall slow economic growth weakens the odds of exiting poverty and increases the risk of slipping into poverty.

It is not simply the spatial scale of analysis that should be of interest to those investigating the spatial dimension of vulnerability. Also of crucial importance is the relative location of the area. For instance, Chauvet and Collier (2005) stress the importance of spatial spillover effects from fragile neighbouring countries and calculate that the negative effects of having such neighbours are significant and average 1.6 per cent of GDP every year. Tondl and Vuksic (2003) emphasise the importance of contiguity and spatial dependence at the regional scale by showing that a region's growth is significantly more likely to be higher if it is a neighbour of another high growth region. They estimate that about a fifth of a region's growth is determined by that of surrounding regions. Similarly, Florax and van der Vlist (2003) suggest that it is necessary to include 'neighbourhood' effects in explaining the spatial distribution of indicators related to wages, crime, health or schooling; all of these ultimately influence the vulnerability of a place.

[4] Other household level vulnerability studies include Chaudhuri *et al*. (2002) and Kühl (2003).

Vulnerability in South Africa

South Africa's economic growth rate averaged about 3 per cent during the decade after the first democratic elections which was seen as a triumph in contrast to the below average growth of 1 per cent for the preceding decade. In 2005, the growth rate reached 5 per cent and all expectations indicated this strong performance should continue. South Africa experienced exceptionally high inflows of foreign capital and foreign direct investment after 2003 which assisted in speeding up the process of employment creation; for instance, during the year ending 2005, approximately 540 000 jobs were created. Nevertheless although there has been a considerable drive for further job creation and poverty reduction in South Africa unemployment remains severe.

The Accelerated and Shared Growth Initiative for South Africa (AsgiSA) was formally launched in 2006 to help the South African Government halve poverty and unemployment by 2014. It was the conclusion of the AsgiSA committee that in order for South Africa to achieve its social objectives it had to keep on growing at a rate of 5 per cent per annum until 2014, and while South Africa had a very strong and focused central government one of the major binding constraints for the achievement of this goal is the reduction of deficiencies in state organisations, capacity and leadership. AsgiSA launched 'Project Consolidate' which was designed to address the skills problems of local government and service delivery. The skills intervention includes the deployment of experienced professionals and managers to local governments to improve project development implementation and maintenance capabilities.

Two years on, the OECD's economic assessment (2008, p.1) states that South Africa is seen as a "….*stable, modern state,* (and) *in many ways* (is) *a model for the rest of the African continent*" but "*there have also been notable weaknesses in* (its) *economic record to* *date, especially as regards to unemployment, inequality and poverty…HIV/AIDS and crime*". This report views South Africa not as a vulnerable state in the traditional sense but it does recognise the role its strong institutions played in bringing about this result. By using considerable forethought, the government has refrained from resorting to economic populism in an effort to boost short-term growth. In the absence of these institutions South Africa could be rendered vulnerable as it is plagued by high unemployment, widening inequality, poverty, AIDS related deaths and a rapid increase in the crime rate.

Accordingly this paper seeks to identify regions which could be considered to be vulnerable and by identifying them we could assist in directing policy changes to those specific areas (or groups of areas) and thus contribute to the successful outcome of AsgiSA.

3. Towards a spatial perspective

Socio-economic variables have a spatial dimension. Any paper claiming to have a geographic context should be aware of and perhaps even take account of the spatial evolution of variables under consideration. One way of examining spatial patterns is to exploit the spatial nature of a data set. This has two important elements: maps and Moran's I statistics; both elements provide an important visual indication of the importance of spatial patterns and contiguity.

To stress this point further consider Figure 1 which shows a map of rates of poverty expressed as standard deviations away from the sample mean.[5] It illustrates that poverty rates in South Africa have a spatial dimension. There is an East-West split with western (eastern) parts having relatively low (high) rates of poverty. Poverty rates are relatively low throughout

[5] To undertake these tasks we employed the GeoDa open source software. This is free software and was developed at the Spatial Analysis Lab at the University of Illinois. It can be downloaded from: https://www.geoda.uiuc.edu/

the Western and Northern Capes and relatively high in the North West and in the Free State. Generalisations are more difficult for Limpopo, Kwa-Zulu Natal, Mpumalanga and the Eastern Cape because of the relatively large variation in poverty rates. Urban areas appear to have relatively low rates of poverty, specifically Johannesburg, Durban, Cape Town, East London, Port Shepstone and Richard's Bay. It is also noteworthy that areas with high (low) rates of poverty are more likely to be contiguous to areas that also have high (low) rates of poverty, at least at this spatial scale.

{Insert Figure 1 about here}

Moran's I values are produced to test statistically for spatial clustering. Typically a Moran's I value is obtained via the Moran scatter plot, which in this case plots poverty rates on the horizontal axis and its spatial lag on the vertical axis, as shown in Figure 2.[6] The upper right quadrant of the Moran's I scatter plot shows those areas with above average poverty values which share boundaries with neighbouring areas that also have above average poverty values (high-high). The bottom left quadrant highlights areas with below average poverty, which have neighbouring areas that also have below average poverty values (low-low). The bottom right quadrant displays areas with above average poverty surrounded by areas that have below average poverty (high-low) and the upper left quadrant shows the opposite (low-high). The slope of the line through these points expresses the global Moran's I value (Anselin, 1996). The Moran's I value of 0.641, which is statistically significant at the 1% level, leads us to reject the null hypothesis that there is no spatial clustering. Hence, the visual interpretations of Figure 1 are supported with the quantitative results of Figure 2 and leads us

6 That is any area that shares a common boundary with area *i*. Throughout this paper, a queen contiguity spatial weights matrix is employed and statistical significance of Moran's I statistics is based on the randomisation approach with 999 permutations.

to believe that spatial autocorrelation in socio-economic variables may be important in the construction of vulnerability indices.

{Insert Figure 2 about here}

Vulnerability and spatial autocorrelation

The determinants of vulnerability are clearly an important research issue. However, application of standard methodologies to investigate vulnerability issues will be inefficient if account has not been taken of the spatial autocorrelation of contributing factors. Spatial autocorrelation is problematic if there are processes operating across space, as exemplified when adjacent observations are not independent of each other. One of the clearest expositions of the reasons why spatial autocorrelation can occur has been provided by Voss *et al*. (2006) who emphasise the importance of, amongst other things, *feedback*, *grouping forces* and *grouping responses*. These can be positive or negative and can result in some areas being vulnerability black-spots.

There is the potential for *feedback* forces to influence individuals and households' preferences and activities, willingness to accept greater vulnerability and activities to reduce vulnerability. *Ceteris paribus*, the smaller the spatial scale of analysis then the higher the likelihood and frequency of contact between individuals and the greater the potential feedback between individuals and between policy makers. Greater similarity in socio-economic measures and conditions will mean less justification for individuals to perceive that they are relatively more vulnerable. For reasons related to the adoption/diffusion theory (Rodgers, 1962) and the agent interaction theory (Irwin and Bockstael, 2004), we should generally expect there to be the potential for spatial spillovers in underlying vulnerability dimensions with a positive correlation in dimensions between contiguous areas. This might mean that in terms of variables like unemployment or population growth you could reasonably expect some degree of imitation. Individuals might incorrectly associate unemployment benefits or social grants received for children with more leisure time or freedom from not working and therefore follow suit. This could ultimately increase the vulnerability of the area or group of areas.

Geographically close districts with similar socio-economic characteristics and vulnerability dimensions are more conducive to *grouping forces*, such as the formulation of parallel policy initiatives. The clustering of underlying vulnerability dimensions might be due to a number of reasons including policy that has been applied to groups of areas or socio-economic issues that lead to spatial clustering (e.g. high house prices force low income people into other areas, seaports attract international trading activities, etc.). For example, in South Africa there is a serious problem with informal settlements. Informal settlements are the illegal and unauthorised occupation of private or government owned land and consist out of dwellings usually made out of corrugated metal. These informal settlements are established by unemployed, impoverished, illiterate, homeless or illegal immigrants all of whom typically respond the same way to policy due to their socio-economic circumstances. They can usually be found on the periphery of large urban areas, which could be negatively affected by the increase in crime and the decrease in house prices. Alternatively *grouping responses* can occur where the application of policy is reacted to in similar ways, often due to the spatial clustering of similarly socio-economically characterised individuals. As the people occupying informal settlements share the same plight they tend to band together and demand ownership of the occupied land as well as the installation of water and refuge systems. If they do not receive what they demand protests will be organised and this could cause damage not only to the reputation of the area but also to property such as schools, libraries, etc. Such demonstrations could greatly increase the vulnerability of a specific area and its neighbours.

Sub-indices used for the construction of vulnerability indices are particularly likely to possess a spatial dimension. For instance, the size of the local economy domain is based on GDP, population size, population density and urbanisation rate, factors which are all likely to have high (low) values in areas that are contiguous to areas also with high (low) values. As a result two important considerations arise: first, if the spatial evolution of socio-economic characteristics is serendipitous then recognition of such spatial patterns when formulating policy could improve the effectiveness of the policy; second, application of policy designed to alleviated vulnerability should not be focused on one area without contemporaneously and explicitly considering similarities across neighbouring areas. This is supported by Chauvet *et al*., (2007) who argue that since failing regions impose a large cost on their neighbours it is not only required but also justified to have cross-region intervention in decision-making processes.

Policy directed towards reducing vulnerability needs to have a spatial dimension, and can be articulated into two simple groups. First, areas may suffer higher levels of vulnerability because they are distinctly different from other areas, including those areas, which are contiguous. In this case the policy would need to be area-specific and designed to improve the vulnerability of the area in question and in isolation. Second, areas may suffer higher levels of vulnerability because they are strongly influenced by spatial spillovers. In this case the appropriate policy would need to be targeted towards not simply the specific area but also the group of contiguous areas. Friedmann (1963) argues that a country could be divided into the following development areas: (i) metropolitan development, (ii) transitional-upward, (iii) frontier regions and (iv) transitional-downward areas. Although each area has its own local development opportunities they do form a spatial system, and a country’s rate of growth would be constrained if it ignores the problems of the less developed and more vulnerable transitional-downward areas. Thus any policy decisions should explicitly consider surrounding areas. Ward and Brown (2009) argue that regional policy should be directed towards relatively poor developing regions but they warn that a 'one-size-fits-all' policy is not the way to go and that policy should be changed according to the area-specific problems.

In summary, a lack of appreciation of the spatial autocorrelation that is present in sub-domains may result in the under-specification of a model and inefficient vulnerability estimates, irrespective of whether such non-independence of observations is random, as it is also possible that vulnerability rates in district *i* are influenced by spatial contagion effects from district *i*'s neighbouring districts. Modelling under-specification and inefficient vulnerability estimates can result in sub-optimal and inappropriate policy formation.

4. Data and methodology

Currently, South Africa has 283 local governments, which include 234 local municipalities, six metropolitan governments and 43 district municipalities. This municipal demarcation dates back to December 2000 when the country was segregated into 354 magisterial districts at the local government level. We decided to focus on the 354 magisterial districts and not the 283 local municipalities for two reasons; (i) it will provide us with an advanced spatial view and (ii) our data set, with its basis in the 1996 and 2001 Census precincts, follows the magisterial district precincts.

Our main data set were obtained from IHS Global Insight's Regional Economic Explorer (REX) (see www.globalinsight.co.za), which in turn is compiled from various official sources of data, such as Council for Scientific and Industrial Research's (CSIR) satellite imagery (the data pertaining to the environment, i.e. percent degraded land, proportion of forest-covered land and water-bodies, wetlands and rainfall) and Statistics SA Census and survey data. Table 1 summarises the variables and sources of data.

{Insert Table 1 about here}

Estimation technique

Turvey (2007) argues that it is extremely important to differentiate between baseline and current vulnerability. Baseline vulnerability considers "*the physical characteristics and intrinsic properties of a place, the internal and/or external forces, and the inherent and recurrent factors that may affect, alter or change the condition or situation of a place*" and current vulnerability reflects "*change in any or all of the component variables of the baseline vulnerability as a pre-existing parameter*" (Turvey, 2007, p.261). The reason why it is so important to differentiate between the two is because it measures the time and spatial vulnerability dimensions in order to understand better the causal structure and sources of what renders a place vulnerable. She argues that a comparative system of vulnerability assessment regionally is needed in order to programme the needs of developing areas according to time and space configuration.

Furthermore, vulnerability measures are necessarily multidimensional. We adopt the multidimensional perspective of Rossouw *et al*. (2008) by employing a principal components analysis statistical approach (PCA),[7] which after a process of elimination was found to be the

[7] Other approaches followed include: Glaeser *et al.* (2000) which standardised (subtracting the mean and dividing by the standard deviation) responses to various survey questions and then simply adding them together in order to derive an index of trust. Mauro (1995) uses the average of indices – such as political and labour stability, corruption, terrorism etc. – and then uses this average as a regressor in models of growth and investment across countries and to determine institutional efficiency and corruption. He deems his strategy as correct because many of these indices measure the same fundamental trend. Lubotsky and Wittenberg

best suited to the analysis of multidimensional phenomena because it transforms highly correlated factors into a set of uncorrelated principal components. Execution of the PCA technique is thought to reveal the internal structure of the data with each component being ranked in accordance with its importance to the multidimensional phenomena and with the first component known to capture much of the data's variability. It is this first component that we analyse in depth. Furthermore the PCA technique is selected because i) it does not require the assumption of correlation between variables that is due to a set of underlying latent factors that are being measured by the variables (as would need to be the case when applying factor analysis) and ii) the application of PCA should permit in-depth comparison of results with Rossouw *et al*. (2008) and Naudé *et al*. (2009) and permit methodological development.

Local Vulnerability Indices

Construction of the principal component is initially undertaken using the same theoretical foundations and empirical estimation procedure as presented by Naudé *et al*. (2009). They propose the construction of ten[8] domains, which are constructed from sub-domains highlighted in brackets:

1. *Size of local economy* (GDP, population size, population density and urbanisation rate),
2. *Structure of the local economy* (share of primary production in total production),

(2006) proposed that a regression with multiple proxies might provide better results than that of principal components.

[8] The choice of using ten domains and it's associated variables comes from representing indices compiled by the Country Policy and Institutional Assessment (CPIA), CFIP (2006), USAID (2006), Anderson (2007), Liou and Ding (2004), Briguglio (1997) and Turvey (2007). The amount of variables or clusters used differs in each and range from 70 to 3.

3. *International trade capacity* (ratio of exports and imports to local GDP and export diversification),
4. *Peripherality* (distance from the market),
5. *Development* (HDI, percentage of the local population in poverty and the unemployment rate),
6. *Income volatility* (standard deviation of GDP growth),
7. *Demography and health* (the incidence of HIV/AIDS and the population growth rate),
8. *Governance* (per capita capital budget expenditure),
9. *Environment* (percent degraded land, proportion of forest-covered land and water-bodies, wetlands and rainfall),
10. *Financial system* (the number of people per bank branch and the ratio of the percentage share of the country's financial sector in a particular magisterial district).

Each separate domain, as described above, is aspatial by construction, as each area's estimate does not explicitly consider what is happening in neighbouring magisterial districts. Subsequent to the construction of each domain, a final local vulnerability index (LVI) is created through the application of PCA using all ten domains as inputs. This results in a single principal component from which district ranks and area comparisons can be made.

To facilitate a spatial perspective, the empirical analysis is replicated through the inclusion of the above sub-domains along with (queen-contiguity) spatially-weighted sub-domains. This results in a doubling of the number of sub-domains forming each spatial LVI, but through further application of the PCA technique using all ten spatially-enhanced domains as inputs, a final spatial local vulnerability index (SLVI) is created. Comparison can then be made between the LVI and the SLVI.

It should be noted that we retain the final principal component value for each managerial district in order to sustain a clear quantitative indicator of disparity between district *i* and *j*. This is contrary to Naudé *et al*. (2009) who instead categorise districts into nine groups and subsequently convert them into a 9-point index, where members of group 1 have a value of 1, group 2 have a value of 2, etc. Categorisation into groups can be problematic and misleading if gaps between groups are arbitrary; for instance an area with a very low value that is part of group 4 might actually be closer to a high value member in group 5 than a high value member in group 4. This is similar to the criticism made by Baliamoune-Lutz and McGillivray (2008) of the World Bank's CPIA measure discussed above.

Vulnerability Intervention Index

Naudé *et al*. (2009) also propose the construction of a vulnerability intervention index (VII), which is designed to reflect the conviction that vulnerability is correlated with per capita income, such that:

$$LVI_i = \alpha + \beta Y_i + \mu_i \qquad i = 1, \ldots, 354 \qquad (1)$$

where α is an intercept, β is a slope coefficient, Y is per capita income of magisterial district i and μ is the well-behaved error term. Assuming that there are no scale returns disparity issues across magisterial districts, the estimation of equation (1) leads to a vector of residuals, one for each magisterial district, where each individual residual represents the deviation between the actual and the predicted level of vulnerability based on per capita income. This residual is a reflection of whether the magisterial district is performing better or worse than would be expected under the fitted model.

It is worth pointing out that this is a clear extension of the methodology employed by Naudé *et al*. (2009), as they take the absolute value of the residual values as an indication of the level of vulnerability of an area. However their methodology would collate and muddle areas into a vulnerability intervention index irrespective of whether they were performing much better (a *good* form of vulnerability) or much worse (a *bad* form of vulnerability) than would be expected under the fitted model. Good (and bad) forms of vulnerability may be the result of appropriate (and inappropriate) policy; for instance, some areas may have been influenced by beneficial policy or naturally occurring economic phenomena (such as urbanisation and localisation economies) that make areas perform better than would be expected, while the absence of appropriate policy (or the application of inappropriate policy) may result in the deterioration of other areas.

5. Results

Local vulnerability indices

Application of the PCA approach permits the estimation of LVI and SLVI. Figures 3 and 4 present Local Indication of Spatial Association (LISA) maps based on the results of LVI and SLVI estimations. LISA maps are special choropleth maps that highlight those locations with a significant local Moran statistic classified by type of spatial correlation (Anselin, 1995). They highlight areas with high (low) vulnerability that are surrounded by areas with relatively high (low) vulnerability; LISA maps can also highlight areas with high (low) vulnerability that are surrounded by areas with relatively low (high) vulnerability. Through visual inspection it becomes clear that an appreciation of the influence of contiguity effects will affect LVI estimates.

Several observations obtainable from comparing Figures 3 and 4 are worth highlighting. First, magisterial districts within and surrounding Cape Town, Durban and Johannesburg are least locally vulnerable. This emphasises a (large-) urban / rural disparity vulnerability effect. The same pattern is not identifiable for other urban areas, with the only exception being Umtata. Taken together, the results suggest that Umtata is an area that is doing relatively well in comparison to its hinterland (see Figure 3) but it is at risk because its hinterland is performing relatively poorly and spatial spillovers might deteriorate the extent of vulnerability within this conurbation (see Figure 4). Umtata's characteristic could be the result of policies that have been directed at this large conurbation without concern for its surrounding hinterland; policies designed to improve vulnerability measures for Umtata should explicitly consider its hinterland.

{Insert Figure 3 about here}

{Insert Figure 4 about here}

Second, Figure 4 suggests that the greater hinterland of the three main urban areas of Cape Town, Durban and Johannesburg are much less vulnerable than Figure 3 indicates. This is illustrated by the significant spillovers between contiguous districts, which appear to diminish vulnerability. Such a contagion issue will be related to either spatial feedback, grouping or response forces. Of particular interest are the magisterial districts of Heidelberg and Bronkhorstspruit which are low-highs according to Figure 3 and high-highs according to Figure 4; these differences are due to the spatial spillovers between contiguous districts and without these spatial spillovers it is likely that these two districts would be much more vulnerable. An alternative perspective is that individuals are being marginalised in and around Johannesburg and are being forced out of relative affluent areas and clustered into these two relatively poorly performing districts. Thus, policy geared towards diminishing the vulnerability of people in Heidelberg and Bronkhorstspruit should be both district specific (as highlighted in Figure 3) and take account of spatial spillovers (as highlighted in Figure 4).

Third, there are also important differences between Figures 3 and 4, which reflect differences in estimates obtained that result from the inclusion of spatially-weighted sub-domains. The results presented in Figure 3 suggest that there are magisterial districts that suffer high levels of vulnerability, but the results presented in Figure 4 illustrate that this is not a characteristic that stops at the districts border. Instead the most vulnerable areas are clustered and contiguous in several areas. Of most concern are i) magisterial districts occupying the area to the south of Swaziland and which continues, mainly inland, down to Ladysmith [highlighted in Figure 4 by area A], ii) much of the eastern part of the Eastern Cape to the south of Lesotho [B], and iii) a large, central part of the Northern Cape [C]. The extent of vulnerability is not fully emphasised enough in Figure 3; the reason why this spatial perspective is so important is because any attempts by policy makers to alleviate vulnerability in these areas need to take a larger spatial perspective and explicitly consider large swathes of districts in their policy formations rather than simply considering the circumstances within specific districts in isolation.

When account of spatial spillovers in vulnerability sub-domains are explicitly considered in the estimation process the rankings of districts can differ substantially from estimates where account of spatial spillovers is excluded. Table 2 presents the SLVI estimates of the top and bottom 20 magisterial districts and each of these districts' ranks if the rank was constructed using the (non-spatial) LVI. Although there are some districts where the rank is unaffected, such as Nelspruit (rank=1) and Soweto (rank=354), the estimates of the ranks of many other districts do alter substantially; for instance, Rustenburg's rank improves from 228th to 18th after taking into account spatial spillovers, while Simonstown's rank falls from 62nd to 350th after this application.[9]

{Insert Table 2 about here}

Vulnerability intervention indices

As discussed above the vulnerability intervention index is based on the estimation of equation (1) with spatial and aspatial data with the residual estimates indicating whether an area is performing better or worse than would be expected given their level of GDP per capita. Estimation of this model using LVI as dependent variable results in what is termed VII residual values; however we extend the literature by replacing LVI with our SLVI measure and therefore generate a spatial vulnerability intervention index (SVII). Such parameter estimates are presented for the top and bottom 20 districts in Table 3 and Figures 5 and 6 provide visual support.

Table 3 highlights the importance of accounting for spatial spillovers in VII estimates. Although the top three districts (Johannesburg, Soweto and Durban) only switch places when the VII and SVII estimates are compared, many of the ranks of the other districts detailed do change rank quite substantially.

{Insert Table 3 about here}

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[9] One much highlighted issue concerning rankings is that they are highly sensitive to gaps in the underlying parameter. For instance, although the LVI estimate varies by a substantial margin of over 4 between the bottom 20 districts, the LVI value between the 20th and the 335th is only 2.5.

Several observations can be made when interpreting Table 3 along with Figures 5 and 6. First the association of urbanisation and vulnerability alleviation, perhaps associated with agglomeration economies etc., around Johannesburg, Cape Town, Durban, Richard's Bay and Hluhluwe is much clearer from the visual examination of Figure 6, where the residuals are the result of an equation that explicitly considered spatial spillovers.

Second although Figures 5 and 6 both highlight large areas of central South Africa in white, therefore suggesting that the areas are not performing substantially different than expected given their GDP per capita level, and the Northern and Western Capes have much worse vulnerability rates than we would expect given their GDP per capital level, the area of greatest disparity between the VII and SVII estimates are in the state of Limpopo. The SVII perspective suggests that Limpopo is an area that deserves much more policy focus as spatial spillovers are resulting in much deeper vulnerability than we would otherwise expect. Policy directed towards individual magisterial districts in isolation within Limpopo will probably be relatively inefficient as the state requires a more holistic policy approach which explicitly accounts for spatial spillovers

{Insert Figure 5 about here}

{Insert Figure 6 about here}

It is clear that the values of the VII shown in Table 3 do not have a large spread: the value for the 15th highest spatially-ranked district (Bloemfontein) is equal to 1.88 whereas the value for the bottom spatially-ranked district (Pelgrimsrus) is equal to -1.34. This is in contrast to the top 14 spatially-ranked districts which vary between 6.47 for Johannesburg (1st) and 2.05 for Cape Town (14th). Further examination of this data is carried out using the multivariate Moran scatterplot, as show in Figure 7, which presents the SVII estimates on the horizontal axis and the SLVI on the vertical axis. Initial execution of this technique reveals a strong, statistically significant Moran's I value of 0.616, but the exclusion of these top 14 ranked areas reveals a much shallower Moran's I value of 0.104. Although this latter value is still statistically significant, it becomes clear that a substantial part of the spatial correlation between SVII and SLVI is due to a large conurbation effect.

The large conurbation effect reflects the fact that those areas that are wealthier also have better vulnerability values. Such attributes could be due to the benefits of agglomeration, typically associated with urbanisation and location economies, but may also be due to national policies that are geared towards improving the lives of urban-dwellers rather than their rural counterparts. This is in line with Friedmann (1963), Alonso (1968) and Yang (1999) who found that regional policies are biased in that they are likely to reflect the development of the urban areas as they are seen to have the most potential for development but ultimately cause greater inequality. Similarly, Little (2009) found that government policy needs to change in order to rectify the geographical imbalances in both recorded and hidden unemployment in the urban and rural areas, while Etherington and Jones (2009) argued that policies implemented for city-regions emphasise, and have the potential to increase rather than resolve, uneven development and socio-spatial inequalities.

{Insert Figure 7 about here}

6. Conclusion

There are national and sub-national empirical studies that investigate vulnerability concepts and measurements from an aspatial perspective. This paper attempts to fill this gap in the literature by augmenting an established principal components model to take explicit account of spatial autocorrelation and applying it to South African magisterial district level data. Through the comparison of spatial and aspatial models estimates the paper presents empirical results that illustrate the presence and importance of spatial spillovers in local vulnerability index estimates. After a further augmentation of the methodology on the vulnerability intervention index more results are then presented which highlight areas that are performing better and worse than would be expected. It is argued that account of spatial spillovers is an important issue if full and accurate vulnerability indices are to be identified and estimated. Our results for South Africa illustrate a clear urban-rural vulnerability divide and the need for appropriate policy.

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Figure 1: Poverty map

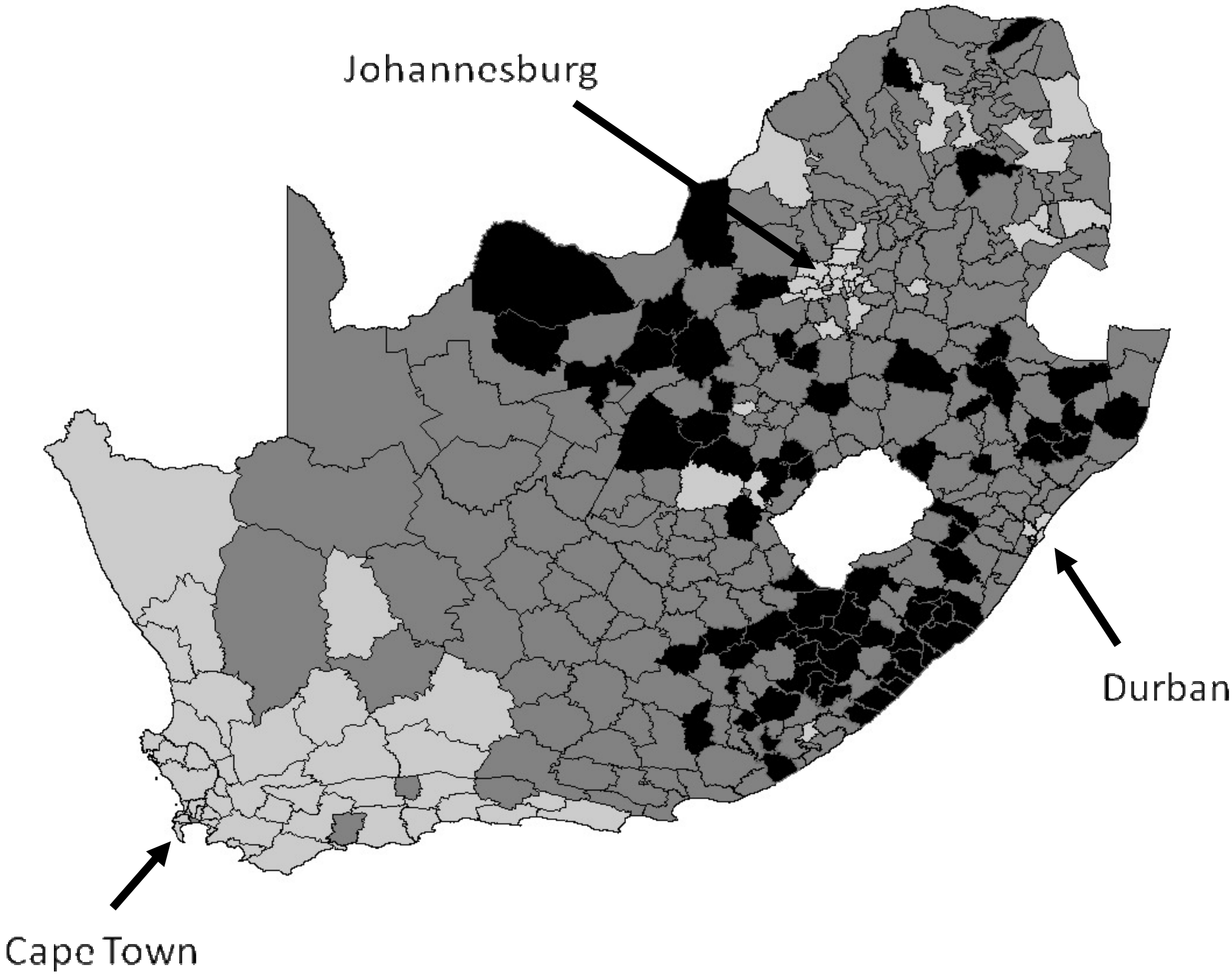

Figure 2: Moran's I of poverty (Moran's I = 0.6410)

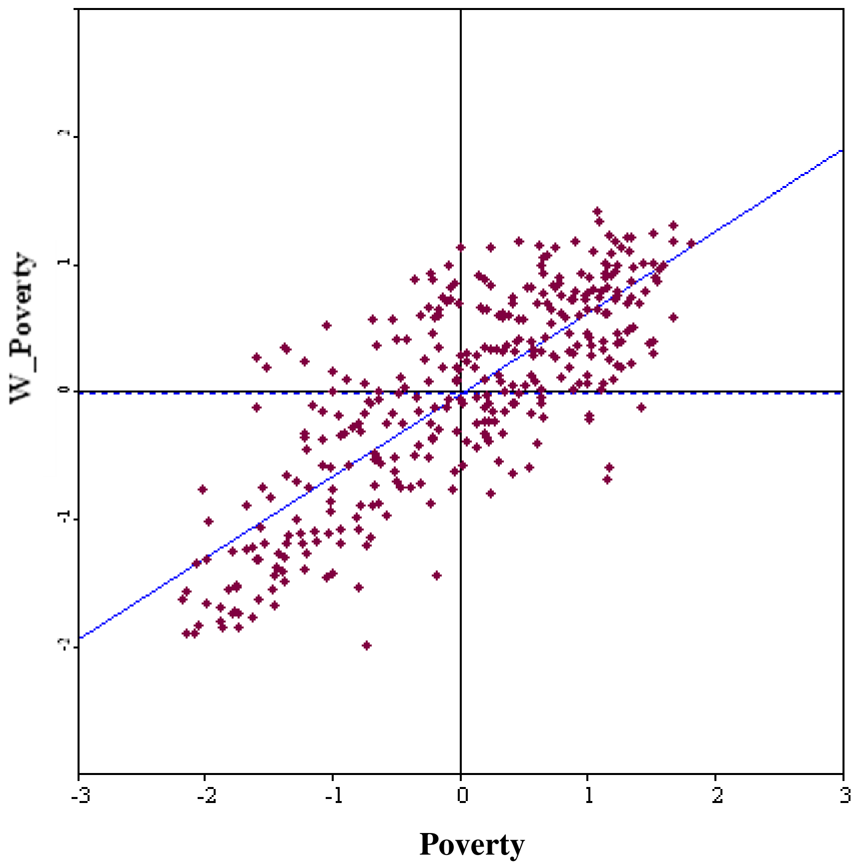

Figure 3: LISA map to show LVI estimates without spatial weights

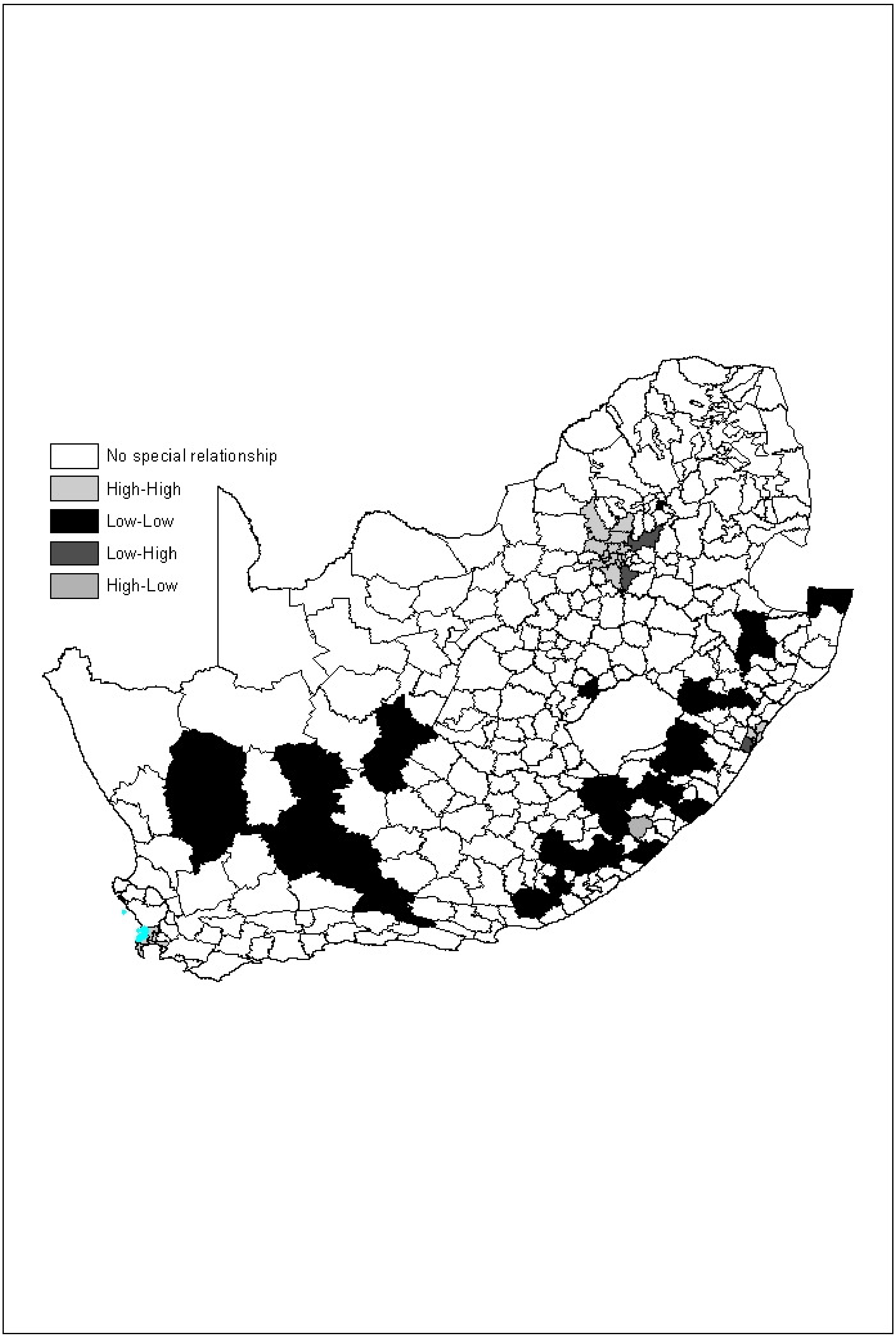

Figure 4: LISA map to show LVI estimates with spatial weights

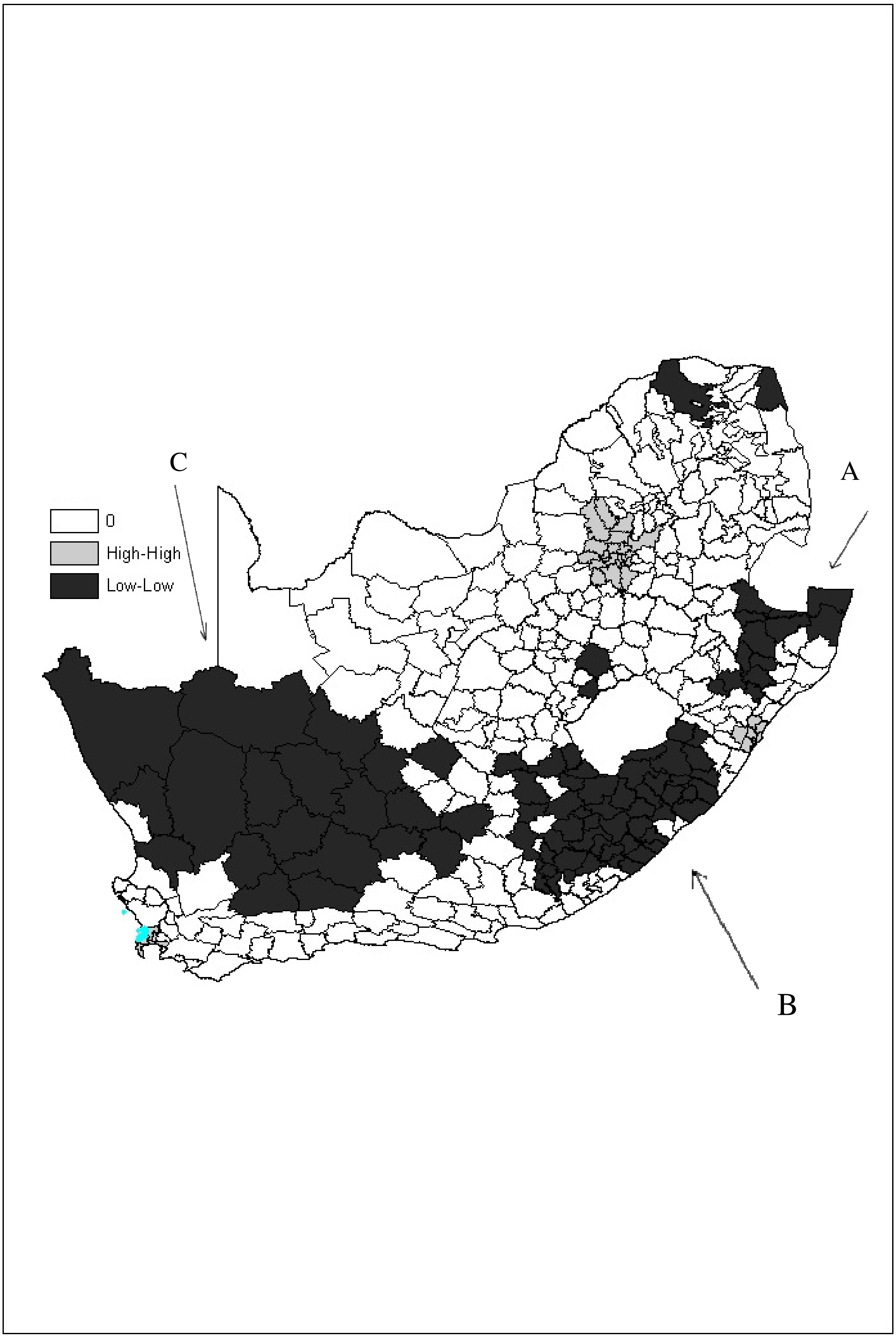

Figure 5: LISA map to show VII estimates without spatial weights

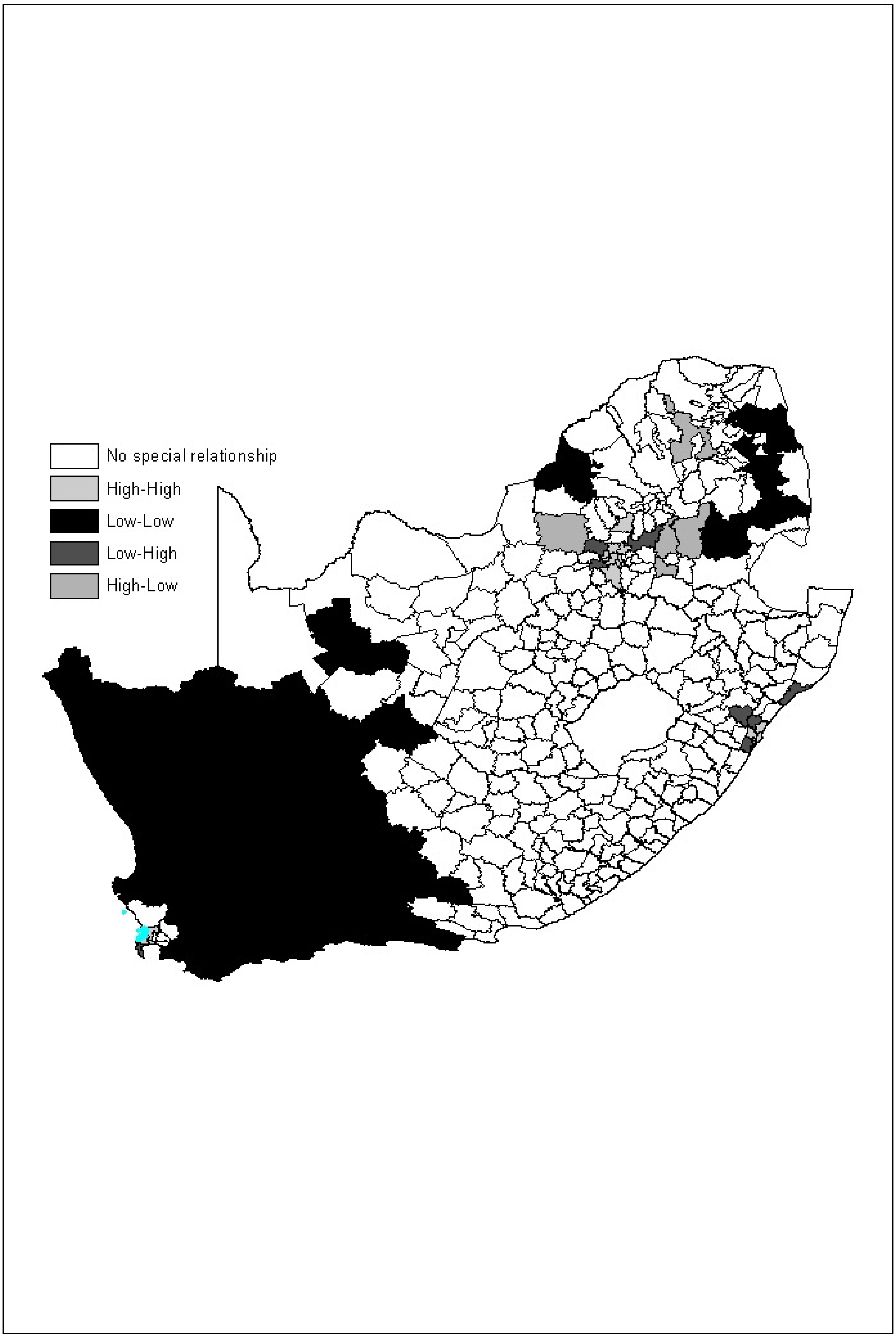

Figure 6: LISA map to show VII estimates with spatial weights

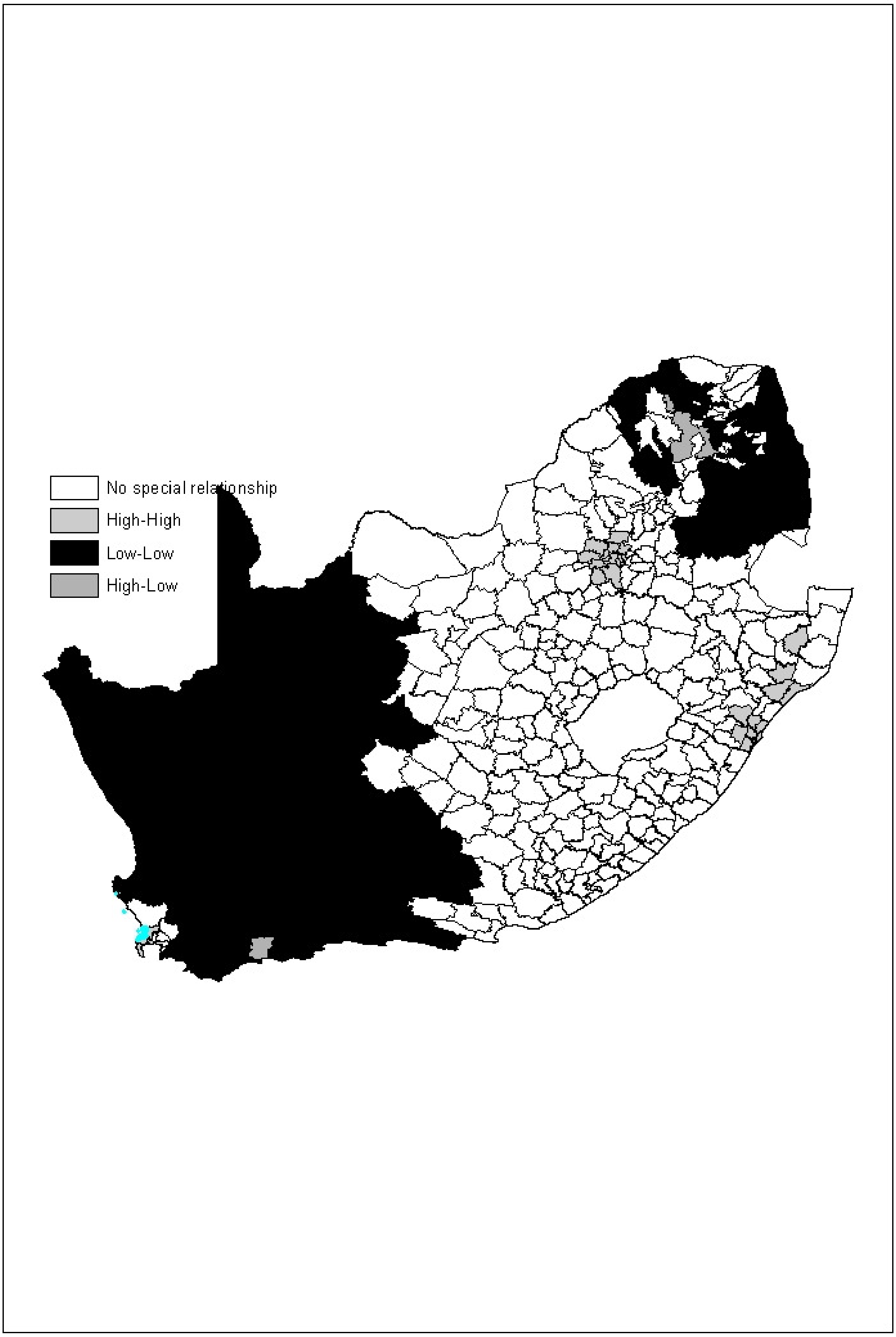

Figure 7: Multivariate Moran scatterplot

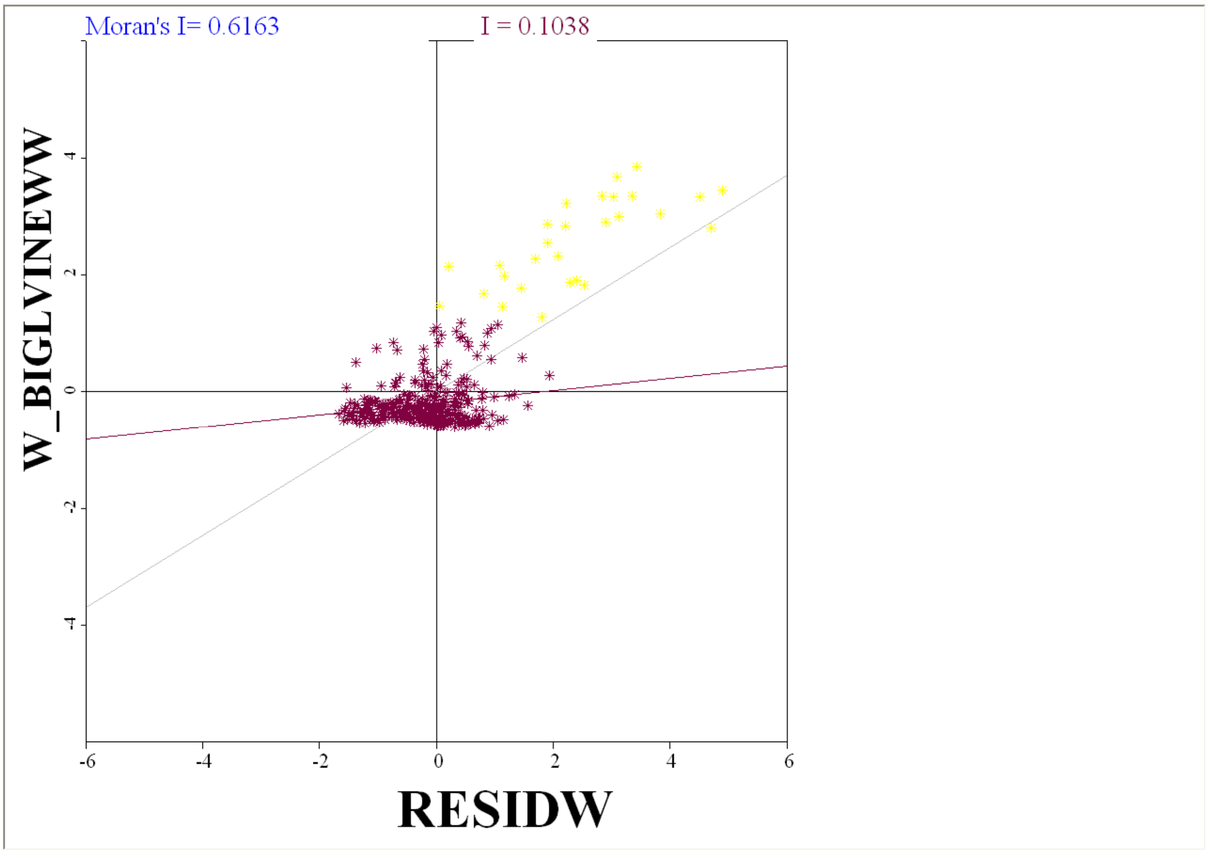

Table 1: Variables used and data sources

Variable	Source of data
GDP	Regional Economic Explorer data from Global Insight
Total population	Regional Economic Explorer data from Global Insight
Population density	Regional Economic Explorer data from Global Insight
Urbanisation rate (%)	Regional Economic Explorer data from Global Insight
Proportion of primary production	Regional Economic Explorer data from Global Insight
Exports as (%) of GDP	Regional Economic Explorer data from Global Insight
Imports as (%) of GDP	Regional Economic Explorer data from Global Insight
Diversity in exports	Matthee and Naudé (2007)
Distance from closest hub/market	Matthee and Naudé (2007)
HDI	Regional Economic Explorer data from Global Insight
Number of people in poverty as (%) of total population	Regional Economic Explorer data from Global Insight
Unemployment rate (%)	Regional Economic Explorer data from Global Insight
Volatility in income	Regional Economic Explorer data from Global Insight
Total people HIV+	Quantec Easydata, RSA Regional Market Indicators (2007)
Population growth rate (%)	Regional Economic Explorer data from Global Insight
Per capita capital budget expenditure (R'000)	Statistics South Africa
Degraded land (%) of total area	Regional Economic Explorer data from Global Insight
Total land cover km# (forest, waterbodies and wetlands)	Regional Economic Explorer data from Global Insight
Average rainfall (annual mm)	Regional Economic Explorer data from Global Insight
No. of population per bank branch	Naudé (2008)
Relationship between (%) of SA's financial services and (%) of SA's population	Regional Economic Explorer data from Global Insight

Table 2: LVI top and bottom 20 areas

Area	LVI	Rank with spatial weights	Rank without spatial weights
Nelspruit	-1.736	1	1
Lower Umfolozi	-1.651	2	20
Thabazimbi	-1.613	3	2
Middelburg	-1.559	4	17
Phalaborwa	-1.425	5	3
Pietersburg	-1.391	6	6
Mmabatho	-1.378	7	26
Umtata	-1.337	8	63
Kimberley	-1.284	9	95
Worcester	-1.276	10	21
Postmasburg	-1.226	11	23
Highveld Ridge	-1.224	12	48
Witbank	-1.214	13	78
Rustenburg	-1.200	14	218
Soutpansberg	-1.194	15	7
Namaqualand	-1.183	16	16
Thohoyandou	-1.174	17	106
Bloemfontein	-1.158	18	228
Gordonia	-1.148	19	40
Letaba	-1.104	20	5
Bellville	1.523	335	261
Cape	1.613	336	339
Westonaria	2.162	337	176
Umbumbulu	2.218	338	235
Soshanguve	2.270	339	348
Inanda	2.431	340	347
Alberton	2.570	341	343
Roodepoort	2.659	342	292
Kempton Park	2.684	343	337
Germiston	2.790	344	230
Durban	3.070	345	349
Randburg	3.162	346	342
Wynberg	3.224	347	344
Chatsworth	3.775	348	341
Johannesburg	3.883	349	353
Simonstown	3.911	350	62
Goodwood	3.943	351	346
Mitchellsplain	3.979	352	352
Umlazi	4.736	353	351
Soweto	5.935	354	354

Table 3: VII top and bottom 20 areas

Area	VII	Rank with spatial weights	Rank without spatial weights
Johannesburg	6.473208	1	3
Soweto	5.713385	2	1
Durban	5.31242	3	2
Pretoria	4.95736	4	13
Mitchellsplain	4.489239	5	10
Umlazi	4.087025	6	4
Port Elizabeth	3.997531	7	18
Inanda	2.757484	8	12
Pietermaritzburg	2.725692	9	26
Soshanguve	2.34368	10	21
Pinetown	2.342031	11	14
Wynberg	2.328639	12	8
Goodwood	2.200749	13	6
Cape	2.049173	14	16
Bloemfontein	1.883006	15	34
Randburg	1.8787	16	9
Lower Umfolozi	1.75404	17	23
Rustenburg	1.749878	18	50
Vanderbijlpark	1.641831	19	37
Welkom	1.622162	20	27
Moorreesburg	-1.00684	335	333
Vredendal	-1.00964	336	340
Victoria-West	-1.03966	337	308
Malmesbury	-1.04856	338	309
Namaqualand	-1.05074	339	349
Kriel	-1.06366	340	266
Piketberg	-1.07277	341	344
Clanwilliam	-1.07702	342	345
Uniondale	-1.08923	343	334
Belfast	-1.12213	344	338
Carolina	-1.12493	345	322
Bochum	-1.14423	346	342
Van Rhynsdorp	-1.15468	347	353
Bronkhorstspruit	-1.15722	348	157
Waterval Boven	-1.16347	349	352
Bredasdorp	-1.18536	350	351
Caledon	-1.24729	351	350
Ladismith	-1.24927	352	347
Joubertina	-1.3033	353	348
Pelgrimsrus	-1.34627	354	346