TRACING THE ECONOMY-WIDE IMPACT OF AGRICULTURAL DROUGHT IN THE NORTHERN CAPE:

A Social Accounting Matrix (SAM)-based Multiplier Analysis

by

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DECLARATION

I, **Kane Troy Jules**, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

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ABSTRACT

This paper uses a 2004 provincial social accounting matrix (SAM) to conduct a multiplier analysis that simulates the impact on the Northern Cape economy of an exogenous shock to the agricultural sector (such as a drought). By analysing the ripple effects of agricultural drought, this exercise highlights the multiplier effects (direct, indirect and induced effects) that manifest through the backward and forward linkages between agriculture and other related economic sectors. Through analysis of the multiplier effects on various sectors and the provincial economy as a whole, the study finds that the negative 10 percent exogenous shock to agricultural commodities exerts significant indirect effects throughout the Northern Cape economy. Sectors involved in the production of intermediate goods and consumer goods were found to experience the largest decline in response to the agricultural shock. In line with expectations, unskilled labourers and their dependent communities were found to experience the bulk of the distributional impact. However, impacts to the income of skilled labourers as well as services sectors were found to be particularly sensitive to the inclusion of enterprises as an endogenous account. Furthermore, the results suggest that expanding farmers' and households' access to credit can be a helpful short-term tool to limit the induced effects of the shock.

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I) Introduction

> **"Our communities are under severe stress. All of the local economies in Northern Cape are based on agriculture. When agriculture suffers, everybody suffers."**
>
> – Willem Symington, Vice-president – Agri Northern Cape

Source: Quoted directly from Qukula (2019)

The impacts of extreme weather events are far reaching, exerting effects on both the natural and built environments, as well as their points of intersection. Climate constraints are often primary drivers of performance in industries that rely on environmental inputs for their production processes. While the impacts of climate on production and output are visible in many sectors, one of the most obvious is the agricultural sector, which in the Northern Cape includes activities as diverse as irrigation farming, extensive livestock rearing, intensive feed-lot operations, and fisheries. These depend on conditions ranging from temperature, rainfall, to atmospheric pressure and oceanic upwelling.

There is a growing belief that climate change affects not only mean temperatures, but also increases the coefficient of variation in climatic phenomena, including rainfall patterns (Thornton et al., 2014). However, significant uncertainty exists over how the effects of anthropogenic climate change will manifest – in terms of its nature and timing – and therefore over its implications for human civilisation at large. Although civilisations have demonstrated their propensity to adapt – and perhaps thrive – in a diverse range of climatic regions, forecasting and alleviating the negative short-term economic impacts of anthropogenic climate change remains a subject that is crucial for policymakers to understand in order to devise effective responses. As a result, there is an ever-stronger mandate for the data-driven management of inherent risks within economic sectors.

The bulk of existing research has focused on estimating climate change's direct impacts on agricultural output (Jones & Thornton, 2003; Funk et al., 2008; Lobell et al., 2008); for example, as estimates of likely changes in crop yields. While useful, such studies offer only a limited understanding of its likely impacts.

The aim of this project is to better understand the relationship between climatological variables – such as temperature, rainfall, and oceanic upwelling – and the spectrum of socioeconomic activities in the Northern Cape. This sort of approach could contribute to a better regional adaptation strategy for the Northern Cape in the face of escalating climatological variability. Specifically, this paper simulates the impact of drought – the most frequent and visible environmental shock in the province – as an exogenous shock to the agricultural sector.

The impacts of environmental shocks extend through multiple sectors, and therefore require a multi-sectoral approach in their assessment and response. As a result, this project will employ a social accounting matrix (SAM)-based multiplier approach to conduct an impact assessment of the economy-wide ripple effects the modelled shock. In light of the growing level of awareness and urgency around water scarcity in South Africa – and water scarce regions such as the Northern Cape – this assessment highlights key socio-economic linkages between society and the climate, as well as their policy relevance.

At its core, the estimation of a shock's economic impact is simple. One compares two situations: the baseline scenario is the state of the economy without (before) the shock; and the counterfactual is the state of the economy after it. Multiplier effects of key economic indicators – specifically output, gross regional product[1] (GRP) and income – serve as the primary measures of the economy-wide impact. Four scenarios are used to test the sensitivity of the shock's results to the inclusion of endogenous institutional accounts – households, enterprises and government – where multiplier effects increase as we incorporate their income-expenditure loops.

II) Background

The Northern Cape

The Northern Cape is the largest of South Africa's nine provinces. While its 372 882 sq. km of land accounts for approximately 30.5 percent of the country's total land area, it is the most sparsely populated, holding a little more than two percent of the country's total population. Vast arid and semi-arid plains characterize most of the landscape, covered by grass in the

[1] GRP (Gross Regional Product) is simply the gross domestic product (GDP) for the specific region of the study, the Northern Cape province in South Africa.

Kalahari and low shrub land in most of the rest of the province (Jordaan, Sakulski & Jordaan, 2013).

Figure 1. Geographic regions within the Northern Cape

Source: Image adapted from Jordaan et al. (2013)

Economy of the Northern Cape

Despite being home to South Africa's renowned diamond fields, the Northern Cape's contribution to GDP is the least amongst the country's provinces. This can be ascribed to a variety of factors, amongst which are its extreme geographic and climatological features. However, it is not merely the extremity of the province's climate that drives a relative lack of economic development – many regions across the world have thrived in conditions of extreme temperature and rainfall; and in the Northern Cape, years of drought are often followed by years of good rainfall. Rather, it is the *uncertainty* that compromises the ability of certain industries to invest with a promise of a consistent rate of return. Following the broader trend of rural-urban migration, the province has experienced substantial outwards migration in recent decades (Trade & Industry Policy Strategies [TIPS], 2016).

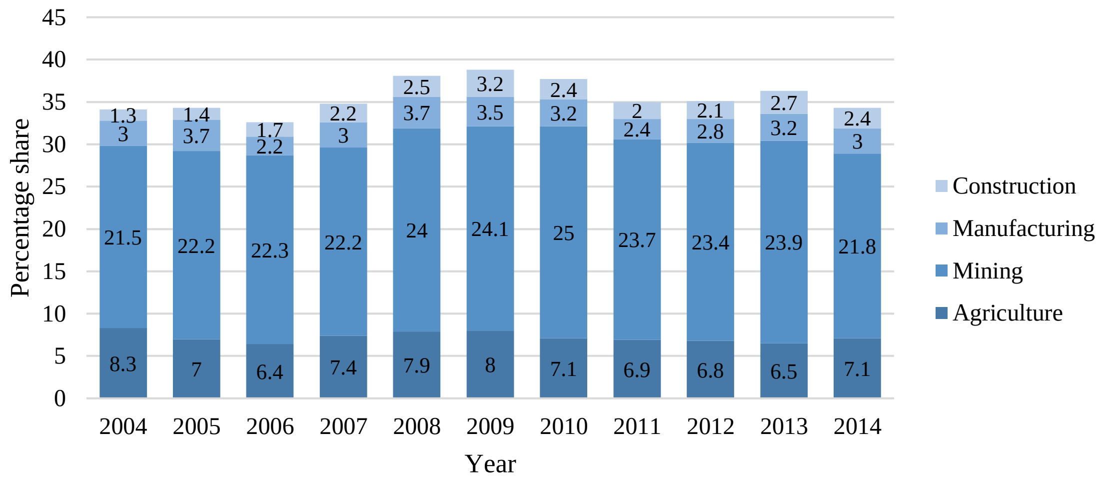
As illustrated in Figure 2, the largest economic sector in the province is mining, followed by agriculture[2], mining and construction. In 2015, of the 102 500 people employed in the province's real economy, 39 500 were in mining, 36 000 were in agriculture, 29 000 were in construction, and 11 000 were in manufacturing (TIPS, 2016).

The real economy of the Northern Cape is dominated by industries related to iron ore and ferro alloys, with significant investments in rail transport linking mines to the coast (TIPS, 2016). Manufacturing and services tend to be linked to mining, and to a lesser extent, linked to agriculture. The shocks which tend to be felt in the mining sector tend to be initially price-based (demand is inextricably tied to changes in global commodity prices and exchange rate fluctuations), while shocks to agriculture and fishing, by contrast, tend to affect output directly.

When looking at those sectors outside of the four major sectoral contributors depicted in Figure 2, there remains approximately 65 percent of the province's economy made up by sectors including electricity, gas and water; trade, catering and accommodation; finance, real estate and business services; personal services; and general government services (Northern Cape Provincial Government, 2021). Some of these sectors, such as financial services, are functionally climate-independent. Others, such as those activities related to tourism, are heavily reliant on climatic conditions.

[2] Agriculture involves various activities that encompass several key sub-sectors, including livestock, fishing and aquaculture (Food and Agriculture Organization [FAO], n.d.).

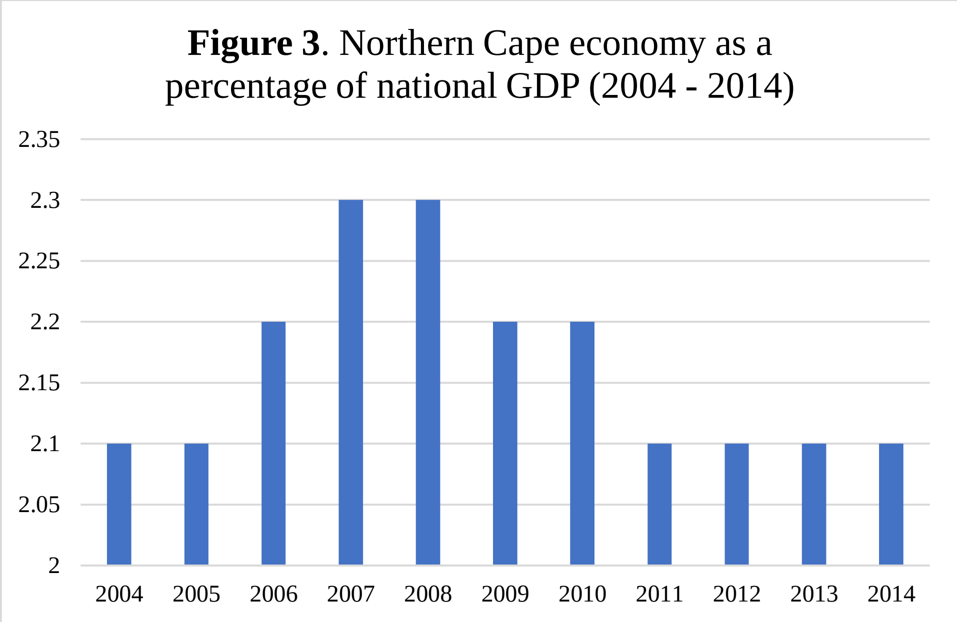
Figure 2. Percentage shares of the real economy sectors in the Northern Cape (2004 - 2014)



Source: adapted from TIPS (2016)

Corridors of fertile land support the province's agricultural industry, particularly in the Orange River Valley where the Orange River serves as an invaluable source of irrigation to local cultivators. Around the towns of Upington, Kakamas, and Keimoes, the cultivation of grapes and fruits is a major source of economic activity, and the Orange River Valley is home to the bulk of South Africa's sultana vineyards (Burger, 2008). The production of several other crops is supported by the Vaalharts Irrigation Scheme near the town of Warrenton, including wheat, fruits, peanuts, maize and cotton (Burger, 2008).

With approximately 1.2 million residents, the province contributed just over 2 percent to South Africa's GDP in 2014/2015 (TIPS, 2016). Just as the percentage shares of the major contributing sectors of the province's real economy remained relatively stable between 2004 and 2014, Figure 3 illustrates that the percentage contribution of the provincial economy to national GDP has remained relatively stable over the same period, peaking somewhat during the commodity price boom around 2008/2009, but returning to approximately 2.1 percent in 2014.



Source: adapted from TIPS (2016)

Problem Statement

Extreme weather events typically affect the Northern Cape in the form of strong winds, rainstorms and drought – or the persistence of poor rainfall over a number of years in a cycle (Harmse, Du Toit, Swanepoel & Gerber, 2021). Some of these occurrences are seasonal and some are more persistent. As is the case with most extreme climatological phenomena, their determinants are imperfectly understood.

A variety of socio-economic problems exist in the Northern Cape. Like most of South Africa, the Northern Cape is subject to a trinity of developmental challenges – poverty, inequality and unemployment. The literature and empirical data confirm the correlation between these economic challenges and a range of corrosive social issues, including high levels of crime, violence, alcoholism, and rural poverty, which further amplify distress in local communities (Burger, 2008). Naturally, many of these challenges stem from the structure of the provincial (and national) economy. Walker et al. (2018) highlights the need for politically and economically marginalised regions, such as the semi-desert Karoo region which covers a significant portion of the Northern Cape, to have natural scientists and social scientists work collaboratively with government to address its needs in a holistic way. This is particularly important when considering how to better manage the region for present and future generations, and to counter the perception of it as a vast landscape whose resources are primarily used to benefit external constituencies (Walker et al., 2018). Naturally, such collaboration requires taking stock of the impact of extreme weather events, their socio-economic effects, as well as driving policy towards supporting adaptation and mitigation measures that will aid local constituents in absorbing climate shocks.

In the context of economic activity in the rural and smaller urban centres of the province, however, many of the socio-economic problems stem from extreme and recurring droughts. These are not a new problem. The province's extremely low rainfall levels have long hindered economic development. Average annual rainfall over the province is 202 mm, with few areas receiving in excess of 400 mm of annual rainfall (Dent, Lynch & Schulze, 1989). As a result, production conditions are challenging in many sectors, particularly in those that heavily rely on water as a key production input.

Annual variability and the relative scarcity of rainfall affect many of the province's economic sectors and water security, in general. Due to the cascading nature of a drought's impact over time, and with respect to inter-industry linkages, lasting impacts are likely to be felt across multiple sectors, including public water supply, energy production and agriculture (Dilley et al,, 2005; United Nations Office for Disaster Risk Reduction [UNDRR], 2009).

However, their impact on the agricultural sector is particularly pronounced (Kuwayama et al., 2019). Diminished surface water and ground water, coupled with below average precipitation, can cause lower crop yields and reduced livestock carrying capacity in the agricultural sector (Kuwayama et al., 2019). Naturally, these impacts are more profound in regions where agriculture holds a relatively large share of GDP; or where the sector is a major employer of workers – this is most often the case in more rural, agrarian economies, resulting in these populations experiencing significant socio-economic hardship as a result (Carrão, Naumann & Barbosa, 2016). These effects demonstrate that there are a variety of variables which determine the impact of a drought: not only frequency, severity and duration, but also the degree of exposure, susceptibility and coping capacity of a socio-ecological system. Meza et al. (2020) consider all of these factors when conducting a drought risk assessment for a given agricultural system.

Communal farmers often experience normal dry periods as droughts, with the Department of Agriculture and district municipalities reporting that requests for external support, or drought relief, are received from communal farmers nearly every second year (Jordaan et al., 2013).

Where government has not been able to provide relief, private sector agents have had to lead emergency relief operations.

While support is often required in normal dry period, the need for relief is even greater in periods of drought extended over several years. In July 2019, at the height of a drought that remains of the worst in more than a century and affecting all of the province's districts, the Shoprite group made a delivery of five trucks worth of fodder to supports farmers where the lack of rainfall had been exerting a devastating effect on livestock and the livelihoods of those in the industry ("Drought in Northern Cape", 2019). The quote below offers an account from a local farmer that illustrates the impact of the drought on farmers struggling to nourish their animals and, importantly, the linkage relationships that transmit these effects into the lives of local service providers and communities:

> **"Farmers are so indebted that they cannot secure loans to buy feed to keep their animals alive. More and more farm workers are at risk of losing their jobs. Businesses, like abattoirs, are battling to keep their doors open and are downscaling working days from five-day weeks to four-day weeks. Farming communities are bearing the brunt of the drought, as children are being taken out of school because their parents cannot afford transport costs, while the sick are foregoing health care because they cannot afford to get to the nearest clinic."**
>
> – Kobus Cornelia, a farmer in Springbok, Northern Cape

Quoted directly from "Drought in Northern Cape" (2019).

The direct impact to the agricultural sector is the most visible effect of drought, but the effects extend beyond the exogenous shock to output. Those working in the sector, either as employers or employees, feel a tangible impact in their everyday lives. Ultimately, the impact ripples throughout the network of income-expenditure relationships in the province and corrodes overall societal welfare in the absence of effective adaptation and mitigation measures.

Climatological Patterns in the Northern Cape

Du Toit and O'Connor (2014) highlight the importance of rainfall as a fundamental driver of ecosystem dynamics in semi-arid regions – understanding its patterns and determinants is particularly salient when considering the underlying dynamics of vegetation cover. When taking a more long-term view of rainfall and drought patterns in the province, historical records suggest the presence of cycles of between 20 and 50 years during the past 124 years (Webster, 2020). As a result, it is difficult to ascertain whether periods of prolonged drought, as have been witnessed in the last decade, are the manifestation of a long-term oscillation in temperature and rainfall patterns, or the consequence of anthropogenic climate change.

Regardless, the drivers of extreme weather events are clearly varied. Recent research has provided some insight into the effects of phenomena referred to as Benguela Niños. Like their namesake Pacific El Niños, Benguela Niños are thought to be the result of abnormal atmospheric conditions – in this case in the western tropical Atlantic (Boyer, Cole & Bartholome, 2000). Like the Pacific El Niño, they affect both onshore rainfall – and therefore agriculture – and offshore sea temperatures and upwelling conditions – and therefore fisheries.

A typical dynamic of the Benguela Current system is the annual southward intrusion of warmer water off the Angolan coast into the northern Benguela. Driven by the prevailing south-easterly trade winds[3], coastal upwelling inshore of the Benguela Current forms the Benguela Upwelling System (BUS). The upwelling of cold water from around 200-300 meters is rich in nutrients, energises the reproductive rates of phytoplankton and sustains the productivity of the Benguela ecosystem. Waldron and Probyn (1992) estimate that annual biomass production in the BUS is 30 to 65 times more productive per unit area than the global average. Regions with high plankton biomass have been found to hold high fish stocks. The success or failure of fisheries – especially small pelagic species – is highly dependent on the availability of plankton as a food source.

During a Benguela Niño, however, the normally limited intrusion of warm Angolan water into the northern Benguela is strengthened; the Angola-Benguela front shifts further south, causing the advection of warm, highly saline water as far south as 25°S, extending up to 150 km offshore at depths of 50 meters (Shannon et al., 1968; Boyer et al., 2000). While the causes and effects of the Benguela Niño are not well understood, observations of certain epiphenomena have led to comparisons with the Pacific El Niño. Heavy rains, changes in fisheries stocks and temperatures proximal to the Pacific El Niño have been recorded (Mann & Lazier, 2006).

[3] Wind strength is a significant determinant of the intensity of an upwelling event in the BUS, with variations in wind strength causing pulses of upwelling propagating southwards along the coast (Nelson, 1992).

Economic Impact of Environmental Changes

Regardless of the mechanism, extreme weather events typically have consequences for the communities in which they occur. In some instances, such as those regions which experience above average precipitation and bountiful harvests during the manifestation of a La Niña event – the oscillatory response to El Niño – atypical climatic conditions can have positive impacts on local economic sectors where the event increases the availability of a key production input such as rainwater for crops and grazing. However, as will be discussed in the proceeding literature review, extreme weather events often manifest through some form of disruption to existing socio-economic activity.

In the economic literature, a distinction is made between various forms of negative impacts. In particular, the term 'damages' has come to refer to the direct physical destruction of factors of production, while 'losses' denote any proceeds lost by affected firms or sectors as a result of the damages (Okuyama, 2003). 'Indirect losses' – a metric that is fundamental to interpreting the results of an impact assessment using the SAM-based multiplier approach, where insights garnered through intra-industry linkages are of fundamental value to the research – are the losses incurred by other economic agents through their relationships with the impacted sector or firm (Jahn, 2015). Indirect losses could manifest through disruptions to demand or supply-side relationships, with an example of the latter being the reduced supply of animal feed available for a livestock farmer when a drought reduces grass cover and brings a poor harvest of fodder crops. Animal feed processing is a linked industry that purchases raw agricultural products and processes them into stock feed. Maintaining normal economic activity in this industry is dependent on the supply of agricultural inputs, as well as the demand for stock feed from the agricultural industry.

Drought can have a significant impact on a variety of sectors. In terms of the direct impact, the losses incurred by a sector will be a function of the water needed for its operations – i.e. the size of its technical production coefficient with respect to water supply – and its short and long-term elasticities of substitution for water in production. For agriculture, the direct effects are particularly stark, as the sector uses approximately 60 percent of water resources for irrigation at the national level; and the secondary and tertiary agricultural sectors, too, require significant amounts of water for operation (Maluleke, 2020). Where irrigation is practiced, the problem of drought-induced water shortages can be mitigated to some extent, as much of the Northern Cape's irrigation water actually rises in the country's better watered eastern regions, benefitting towns and rural farmlands located within the Orange River Valley, and before that, the farmers of the Vaalharts Irrigation Scheme. However, dryland and livestock farms that do not enjoy the benefits of irrigation and are at severe risk.

The longer a drought has run, the more severe the consequences of another year's poor rainfall. Should the drought persist over consecutive seasons, supply shortages are a likely consequence. However, the implications of such shortages will depend on several factors, including the proportion of a country's non-irrigated agricultural output produced in the drought-affected area.

Nevertheless, the result of supply shortages, both in terms of economic theory and empirically verifiable case studies, is twofold. The inability of domestic producers to satisfy the demand for commodities – where few substitutes exist, such for key food products – is likely to lead to an increase in imports; and ultimately, higher prices for produce (Maluleke, 2020). Higher prices will tend to erode the purchasing power of consumers, meaning that consumers can afford to purchase fewer goods for the same amount of income.

The impact of drought on producers can be even more devastating and could conceivably lead to the closure of a dependent business or enterprise. Without reliable irrigation, crop farmers suffer diminished or non-existent harvest yields. Livestock experience poorer nutrition, causing loss of condition, reduced fecundity, more frequent natural deaths, and a need to destock. This is particularly important in the Northern Cape, where farmers in the Namaqualand region have struggled to adapt to periods of drought due to spatial constraints, resulting in the death of many animals (Samuels, Allsop & Knight, 2007).

The economic cost of these, in the short-term at least, is reduced farm profit margins. However, the reduced level of output and profit is likely to catalyse a variety of negative externalities as the production process is re-calibrated to optimise profit (or minimise economic loss) at this lower level of output, including reducing the number of labourers employed in the business. In addition, farmers may struggle to meet loan repayments, and credit may become more difficult to obtain.

When looking at how the indirect and induced effects of agricultural drought manifest throughout the rest of the economy, one needs to consider the structure of the agricultural value chain and thus the linkages between economic agents. Effects are transmitted to downstream input suppliers, whose sales are negatively affected; while the limited supply of produce creates shortages and increased production costs for upstream agri-processors (Maluleke, 2020).

III) Review of Literature

The anticipated findings of this paper are that, according to the fixed-price multiplier analysis resulting from the SAM modelling approach, an exogenous negative environmental shock will have significant adverse economy-wide impacts in the Northern Cape. To contextualise this hypothesis, and the rationale for its development, a variety of sources have been consulted from within the literature on the socio-economic impact assessment of environmental shocks. It is through this type of evaluation that societies can be assisted in understanding the strengths and weaknesses of the economic system with respect to incubating the effects of negative shocks, as well as maximising the absorption of positive shocks.

Extreme Weather Shocks

The broader impacts of extreme weather events have been studied extensively within the literature. Attempts to quantify the total cost of exogenous environmental shocks – factoring direct, indirect, and induced effects – have arisen from the continual imperative to optimise the relationship between society and the natural world, such that its inhabitants are able to augment their welfare with respect to the propensity for variability in the surrounding environment.

Extreme weather events can be distinguished by 'occurrence' extremity – which is based on values of meteorological variables which are used to identify the weather event – and 'impact' extremity – which is based on the magnitude measurement of the event's impact (Jahn, 2015). This paper will, for the most part, rely on 'impact' extremity in its conceptualisation of extreme weather events. Analysing the effects of extreme weather events along the impact dimension requires the use of the concept of 'absolute' extremity, which necessitates that a certain characteristic number – e.g. – exceeds or falls below a predefined absolute threshold in order for it to be considered 'extreme' (Jahn, 2015). An example of a characteristic number could be annual levels of precipitation, where exceeding the predefined absolute threshold by a certain degree over a period of time would lead to the declaration of a flood, while precipitation falling below the predefined absolute threshold would lead to the declaration of a drought. Absolutes, nevertheless, can be deceptive. Rainfall that would be considered a drought in one region may be seen as a good rainfall season in another. The point is that agriculture, the broader economy and society develop with an expectation of rainfall at some level. When this expectation is not met, they tend to experience short-term disruptions – i.e. it is relative, rather than absolute, levels that matter (for example, one standard deviation below the mean level of rainfall in a particular region).

Using a methodology that exploits the annual variation in temperature and precipitation to estimate causal effects on short and long-run economic activity in a range of sub-sectors, Acevedo et al. (2020) found that climate shocks, such as global temperature increases, tend to exert uneven macroeconomic effects. The consequences of their effects are disproportionately concentrated in countries with hot climates, where most low-income countries are positioned – and crucially, in which the proportion of the population dependent on agriculture tends to be high. Based on a conservative set of assumptions, a long-run simulation suggests that under a scenario of unmitigated climate change, the projected temperature increase over time would result in a loss of approximately nine percent of output for a representative low-income country by 2100 (Acevedo et al., 2020).

These projections, however, are not universally accepted. Some, such as Lomborg (2021), hold that the narrative around climate-alarmist reporting is contradicted by empirical data, and that studies focusing exclusively on estimates of the destructive impacts of temperature increases do not account for the benefits incurred through the loss of extremely cold temperatures. For example, Burkart et al. (2021) found that temperature rises in the US and Canada over the past two decades have resulted in approximately 7 200 additional heat deaths annually. However, the study also showed that the same increase in temperature means that the countries avoid 21 000 cold-related deaths each year. This demonstrates the importance of understanding the full nature of the trade-offs involved when estimating the impacts of climate change – something that was not fully explored by Acevedo et al. (2020). In this sense, the estimates of economic losses from temperature increases should also account for the trade-offs – some of which may be beneficial – incurred through the absence of previous temperature lows.

Various reasons have been identified for the different severity of temperature change impacts between countries across regions. As most advanced economies are located in countries with relatively cooler climates[4], marginal temperature increases do not materially affect contemporaneous growth (Acevedo et al., 2020). On the other hand, they suggest that most emerging market economies and low-income countries tend to be located in regions with significantly hotter climates, meaning that an equivalent increase in temperature at the margin,

[4] Most advanced economies are located in regions with annual average temperatures proximal to the 13°C – 15°C threshold (Acevedo et al., 2020).

ceteris paribus, will have a stronger effect on output and more significantly lower their per capita GDP. Moreover, the disproportionately high reliance on agriculture – and therefore climatological predictability – as a contributor to GDP compounds the climate change impact on low-income countries. By illustration, overlaying the marginal effect of a 1°C increase in temperature on contemporaneous per capita GDP by initial temperature, the median emerging market economy with an initial average annual temperature of 22°C will experience 0.9 percent lower growth in the same year (Acevedo et al., 2020). The same temperature shock imposed on the median low-income country with an average annual temperature of 25°C will see an even larger economic effect, with growth falling by 1.2 percentage points in the same year (Acevedo et al., 2020). Food security also becomes less of an existential threat when a wealthier country can afford to import and has a strong infrastructure base that easily facilitates food distribution. In a poor country, even a mild, localised drought can have severe impacts on the local economy.

Factors that help countries mitigate the negative impact of climate shocks have been found to be inextricably linked to levels of economic development. Acevedo et al. (2020) found that, on average, less economic damage is sustained from the effects of rising temperatures by high-income countries in hot regions than by low-income countries in hot regions. This is an important differential given the finding that the economic impact of temperature shocks is more extreme in countries concentrated in hot regions (Acevedo et al., 2020). Despite some potentially problematic assumptions, such as overlooking the extent to which countries' GDP may grow through access to new industries, the study helps to shine a light on the relative vulnerability of poorer countries to climate change.

Input-Output Tables and Social Accounting Matrices as a Framework for Impact Assessment

Regional input-output (I-O) tables are scarce in South Africa. This is due, in large part, to the national mandate for economic development that has resulted in the centralisation of power, particularly in terms of data collection and analysis (Janse van Vuuren, 2015). Due to the large amount of data and effort required to construct them, I-O tables are typically developed over long periods of time, with a gap of several years between each publication. This challenge is particularly pronounced in developing countries and less-developed countries, where resources limit the availability of experts and advanced tools for data collection and manipulation (Siddig, 2011).

When examining the total impact of an extreme weather event, one can distinguish between three categories of effects that together constitute the full picture. As discussed by Jafri and Buland (2016), the immediate effects experienced in the short-term are known as direct effects and are the result of a specific activity. These direct effects proceed to act as catalysts for subsequent effects over iterative rounds of income and expenditure. The effects experienced over proceeding iterations are indirect and induced effects. Indirect effects refer to changes in production, employment, and income as a consequence of the initial direct effect on sectors that share a linkage, directly or indirectly, with the sector that housed the initial impact (Taljaard, 2007). Any resulting changes to household income and expenditure behaviour are referred to as induced effects. Leakages, as defined by Jafri and Buland (2016) refer to expenditures which exit the area considered in the model via income or expenditure without returning.

The linkages shown in a SAM can be backward (from an industry to other sectors that supply its inputs) and forward (to sectors for which it is a supplier of inputs) (Taljaard, 2007). Effects resulting from backward linkages can be viewed as demand derived for the provision of inputs needed to sustain production for a non-primary economic activity (Jones, 1973). On the other hand, forward linkages represent the output utilisation induced by economic activities that do not solely serve final demand as inputs in activities (Jones, 1973).

The nature of the economy-wide transmission of the shock's impact through inter-industry linkages is further highlighted by Roberts (1990), who asserts that observers of agricultural production will find that that the sector operates through direct interfaces with other industries in the value chain, both 'upstream' and 'downstream'. When considering the impact of changes in agricultural production, Roberts's (1990) hypothesis implies that the effects of any shock to agriculture will not be incubated to this sector, but will reverberate throughout the economy through various channels in the value chain, and both backward and forward linkages.

Analysis of the economy-wide impact of a shock requires consideration of the multiplier effect of the change. The multiplier process is well described by Taljaard (2007:21): "a unit increment of autonomous investment causing an initial increase in income, which generates successive rounds of consumer spending and incomes – each round producing numerically smaller increments until the process has worked itself out, i.e. has reached equilibrium". Typically, the findings of this type of conceptual analysis of a stimulus are that, in the first response, savings equal initial investment, and subsequent consumer spending is observed that is significantly greater than the initial unit change in investment (Taljaard, 2007). Such economic multipliers can help explain how the impact of a negative shock, such as an exogenous shock to the final demand or supply for a particular commodity, may end up being larger than the size of the initial direct effect to the particular sector.

As defined by Jafri and Buland (2016) a multiplier is a numeric measurement that is expressed as a ratio of its total effects – i.e. the sum of its direct, indirect, and induced effects – to the direct effects of the impact. For example, given a multiplier of 1.2, one could conclude that for every R1 spent through direct expenditure, there will be an additional R0.2 generated in the economy. Using multiplier analysis, one can estimate the likely total effects of a unit change in an output of a particular industry. These effects are typically on key indicators such as input, output, employment, income or value added (United Nations, 1999). In this sense, multipliers can be used to draw conclusions which highlight the importance of a particular sector or activity to the economy as a whole (Taljaard, 2007). For example, a simulation that reveals a significantly larger multiplier for sector A in comparison to sector B can be used to argue for increased subsidisation or a tax decrease in sector A over sector B. Note, however, that multipliers only demonstrate how an economy operates within certain parametric assumptions and should thus be interpreted in the context of these conditions (Pyatt, 1988). Pyatt (1988) also cautions that any inferences drawn from multipliers ought only to be understood as results from counterfactual experiments run under specific conditions.

The size of the multiplier is dependent on a range of idiosyncratic factors. Van Leeuwen, Nijkamp and Rietveld (2005) highlight the overall size and diversity of the regional economy as an important determinant, arguing that larger economies with a high degree of diversification (meaning that the economy produces many different types of goods and services) will have higher multipliers as consumers will tend to purchase from firms within the economy. Another factor is the geographic scale of the regional economy, suggesting that transportation costs will tend to inhibit leakages (such as imports) due to the associated transport costs. Likewise, regions that act as a central hub within a broader region will also tend to have higher multipliers than isolated economies (Van Leeuwen et al., 2005). With respect to their varying usage of production inputs, the nature of the particular industry or economic sector is also said to exert a significant effect on the size of the multiplier. For example, industries that are more labour-intensive (such as tourism) will tend to have larger induced effects than indirect effects because of their role in supporting household income, and therefore household consumption (Van Leeuwen et al., 2005). These factors serve as important considerations in the discussion and interpretation of results derived through multiplier analyses.

Building on Roberts's (1990) hypothesis regarding the 'upstream' and 'downstream' linkages that characterise the interconnectedness of agricultural production to other economic sectors, a variety of relationships have been proposed to explain the link between farming and the broader economy. Investigating the linkage, Josling (1985) proposes three links between farming and the rest of the economy. First, the savings and consumption of farming households are important determinants of supply and demand in non-agricultural markets in the real economy. Second, the procurement of factors of production in farming – particularly labour – is frequently influenced by the integration of rural and urban markets, In the third linkage, which concerns the relationship between farming and the financial sector, farm asset and debt valuations are reflective of non-farm valuations, as well as the prosperity of the agricultural sector.

Sectoral linkages mean that droughts often instigate a variety of knock-on effects that create significant problems in affected communities whose socio-economic circumstances may already be precarious. Agricultural communities, in particular, tend to rely disproportionately on the earnings of seasonal workers whose services are procured during periods of high demand.

By definition, the variable impacts of extreme climate events on particular sectors – those pertaining to the supply of food and water, for example – depend on changes in the characteristics of climate-related variables, such as temperature and precipitation. However, these impacts are also dependent on sector-specific non-climatic pressures, management characteristics pertaining to organizational and institutional arrangements, as well as adaptive capacity (Kundzewicz, 2003).

Through their ability to coalesce the aforementioned considerations, I-O tables underpinning SAM-based multiplier models have been a useful tool for impact analysis – and, specifically, disaster impact analysis. Examples include the use of an adaptive regional I-O model by Hallegatte (2008) to assess the economic cost of Hurricane Katrina (2005, USA); a regional indirect economic impact evaluation by Wu *et al.* (2012) of the Wenchuan Earthquake (2008, China); and modelling the demand reduction following the 9/11 attacks (2001, USA) by Santos and Haimes (2004). Each of these investigations demonstrated the capacity for researchers to utilise I-O economic models in disaster impact assessment (Galbusera & Giannopoulos, 2018). In disaster loss analysis, I-O economic models confer certain idiosyncratic advantages to researchers, especially the strong possibility that indirect and induced losses may outweigh direct losses, with a SAM-based multiplier analysis well-positioned to illustrate the economywide impact of a disaster. This is particularly true when considering the short-run impact of a disaster as it disseminates through an economy under the assumption of constant prices and fixed technologies. Depending on the parameters of the model and comparison of its results to the empirically verifiable data on the impact of a shock, this feature may represent either an advantage or a misrepresentation.

Within the same class of impact assessment methodologies, the greater degree of price flexibility conferred by computable general equilibrium (CGE) models should make them better assessors of impacts over multiple rounds. Both SAM-based and CGE models are commonly used and well-documented approaches to disaster impact analysis (Koks & Thissen, 2016), and both are deemed acceptable methods of assessing propagation of an initial exogenous shock as it moves the economy's complex system of linkages (Okuyama & Santos, 2014). Their advantages also point to their respective limitations which can produce different economic outcomes. The flexibility of CGE models arises from its inclusion of substitution effects following relative price changes – this also leaves open the possibility for underestimating impacts due to extreme, potentially unrealistic substitution effects and relative price changes. In contrast, I-O models, such as those underpinning the SAM-based multiplier model, have the potential to overestimate impacts due to their linearity and lack of substitution effects (Rose, 2004).

On a regional (provincial) level of analysis, Ziolkowska (2016) employed an I-O and SAM-based model to retrospectively analyse the economy-wide ripple effects of the 2011 drought in Texas's agriculture sector. The paper focuses on the socio-economic drought that is the result of meteorological, agricultural, and hydrological droughts, tracing its impact throughout the state economy. Losses from the 2011 Texas drought represented approximately 43 percent of the average value of agricultural receipts over the preceding four years (Fannin, 2012). Direct effects were felt in livestock, cotton, sorghum, wheat, corn, hay, and timber production. Indirect effects were felt in a range of related sectors, in addition to induced effects from behavioural changes in consumers. While the largest effect was found in those agricultural sub-sectors with a high demand for water as a production input – such as animal production and cotton farming – indirect effects were also felt in agricultural sub-sectors that had a relatively smaller technical production coefficient with respect to water; and in sectors outside of agriculture, such as real estate. The proliferation of losses beyond the agricultural sector – and agricultural sub-sectors with a high demand for water, in particular – is ascribed to the backward and forward linkages from those sub-sectors to others in the agricultural sector, and in the state economy as a whole. Overall, the paper found that the $7.62 billion loss in the agricultural sector caused economic losses of $16.9 billion in the state economy, dramatically increasing unemployment by approximately 166 895 people in a range of sectors.

Unless a local product is globally traded, decreased local production means falls in market supply; they therefore affect market prices for the affected products. This suggests that additional spillover effects are likely to influence volumes and values of exports and imports. However, due to the assumption of fixed prices in the SAM framework, these spillovers are not factored into the model – a significant limitation of this methodological approach.

Despite the caveat above, this type of study demonstrates the usefulness of SAM-based modelling in examining the economy-wide impact of a shock to a specific sector – agricultural drought, in this case. With its methodological approach that focuses on the estimating the multiplier effect of the initial shock, Ziolkowska's (2016) paper serves as a strong empirical case study that demonstrates the application of SAM-based modelling at the state or provincial level, with some methodological limitations, such as the assumption of fixed prices.

Taljaard (2007) adopted a similar approach to quantify the economy-wide impact of certain regional shocks and structural changes in the Northern Cape – a region where irrigation agriculture underpins much socio-economic activity. The focus of the investigation was the impacts of changing efficiency in the use of irrigation water along the banks of the middle and lower Orange River (which traverses the province).

Jordaan et al. (2013) found that communal small-scale farmers in Northern Cape were highly exposed to the economic impact of drought due to high levels of vulnerability and low coping capacity. Even during seasonal dry periods – i.e. those occurring under typical climatic conditions – these farmers experienced effects akin to disaster droughts (Jordaan et al., 2013). An investigation into this relationship led the rejection of the hypothesis that climate change is the main driver of increased drought in the Northern Cape. Interestingly, analyses of the mean trend in precipitation based on available historical meteorological data from 1920 reveals an increase in mean annual precipitation of 0.51mm (Jordaan et al., 2013). Counterintuitively, the implication of this is that the perception of more frequent droughts is not entirely due to lower levels of precipitation. Instead, the authors highlight several non-meteorological reasons for the economic impact of droughts amongst small-scale farmers in the Northern Cape, centred around low levels of adaptation and coping vulnerability, echoing the conclusions of Kundzewicz (2003) who outlines the relationship between the economic impact and sector-specific non-climatic pressures. These include mitigating factors such as adaptive capacity and management characteristics pertaining to organizational and institutional arrangements.

Economic Cost of Environmental Shocks

On the vulnerability of the South African agricultural sector to climate change, Gbetibouo and Ringler (2009) highlight the lack of vulnerability assessments at the regional level, identifying this as a significant deficiency in the country's climate risk assessments. This sentiment echoes that of Jordaan et al. (2013), who had pointed to inadequate funding, and authorities under-estimating the importance of detailed risk assessments, as significant impediments that would be compounded by the lack of a defined and consistently implemented methodology for Disaster Risk Assessments (DRA) in South Africa. The National Disaster Management Framework (NDMF) clearly outlines the need for disaster risk assessments as a key performance area for a successful disaster risk reduction strategy (Jordaan et al., 2013).

IV) Research Methodology

The objective of this paper is to examine the socio-economic impact of an exogenous shock (e.g. a drought) that first reduces the Northern Cape's agricultural output by 10 percent. The impacts of extreme weather events are often far reaching, exerting effects on both the natural and built environments, as well as their points of intersection. These impacts often extend throughout multiple sectors, thus requiring a multi-sectoral approach in their assessment and in development of responses to future shocks.

To conduct this impact assessment with a view to capturing the economy-wide impact of the shock, the employed methodological tool will be a multiplier analysis based on the existing provincial SAM.

Social Accounting Matrices

SAM-based multiplier analysis is an important analytical tool. A SAM is a static depiction of an economy at a specific point in time, typically one year in duration. It represents the macro and meso-economic accounts of an economy whose system is characterised by transactions and transfers between its participating economic agents (Pyatt & Round, 1985; Reinert & Roland-Holst, 1997). These flows are captured within the SAM as incomes and expenditures between agents; SAMs have three main features (Round, 2003:1):

1) The accounts take the form of a square matrix – where each account's incomes and expenditures (*incomings* and *outgoings*) are shown explicitly through a corresponding row and column whose respective totals are equal.
2) They offer a comprehensive portrayal of all economic activities in the system (i.e. consumption, production, accumulation, and distribution), although the level of detail may not necessarily be equivalent across these activities.
3) They offer the researcher a large degree of flexibility; their standard, basic framework can be utilised with different degrees of disaggregation and emphasis on different aspects of the economic system.

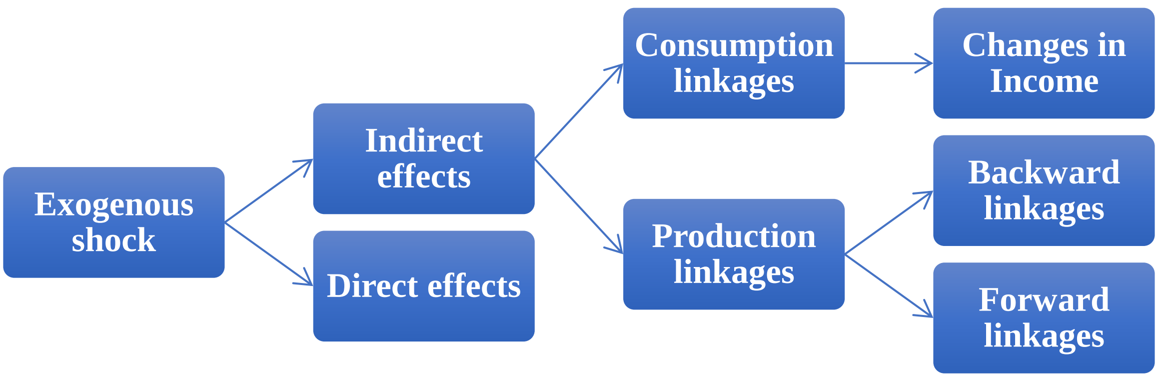
The development of these matrices as a tool for impact assessment can be underlined by three principal motivations (Round, 2003:2):

1) The construction of a SAM assists in merging data from a variety of sources towards a description of an economy's structural characteristics, where it can also be used to identify key gaps in the data that contributes to the improvement of the range and quality of the available data.
2) The SAM holds the advantage of being a relatively simplistic method of displaying information of structural interdependence in an economy, offering a clear illustration of complex linkages between income distribution and economic structure.
3) The SAM represents a useful analytical framework for modelling the impacts of exogenous shocks and policy interventions. They form a direct input into a range of models, such as a fixed-price multiplier models and are integral to the benchmark dataset used in the calibration of computable general equilibrium (CGE) models (Pyatt, 1988).

In summary, the SAM framework holds value in two primary ways: first, by serving as a standard database for most modellers of economy-wide phenomena (both in terms of multi-sectoral linear models or more complex CGE models); and secondly, by offering a complete intuitive snapshot of the economy at a particular point in time (Mainar Causapé, Ferrari & McDonald, 2018).

Relative to other tools of impact assessment, the main advantage of SAM-based multiplier models is their simplicity and transparency. They provide a simple framework for investigating the potential impacts of exogenous shocks – such as policy interventions or, in this case, the economic impact of an extreme weather event – on incomes and expenditures of different sectoral accounts and household groups (Round, 2003:13). Moreover, the SAM-based modelling approach 'attempts to classify various institutions to their socioeconomic backgrounds instead of their economic or functional activities' (Chowdhury & Kirkpatrick, 1993). As a result, the methodology allows for a holistic appraisal of specific changes to the economy by modelling the linkage between income and expenditure (Golan et al., 2000).

Figure 4. Transmission of the exogenous shock through the provincial economic system



Source: adapted from Breisinger et al. (2009:13)

Limitations

While the SAM-based multiplier analysis is a useful tool, the validity of the resulting multipliers is constrained by a few important limitations. Firstly, the framework is set flexibly around a standardised structure, meaning that there is no single, universal SAM. Another significant limitation of SAM-based multipliers is in its treatment of household expenditure, taxation and saving rates as fixed with respect to any change in income (Taljaard, 2007). This assumption runs counter to theoretical and empirical economic literature which confirms the sensitivity of household expenditure patterns to changes in the availability of income and wealth levels (Jappelli & Pistaferri, 2010). With household consumption constituting the bulk of GDP in most countries, the knowledge of how consumers respond to income changes is important for evaluating impacts (Jappelli & Pistaferri, 2010), rendering the SAM's constant expenditure coefficients a significant short-coming. Moreover, it is essential to note that multipliers are only useful for examining real effects of quantity shocks – they are not appropriate for assessing the effects of price-based shocks (Round, 2003:14).

Application

Following the SAM-based modelling approach, the direct impact of a drought, modelled as an exogenous shock to the agricultural sector, is estimated by comparing a measure of economic output for the sector in the year of the shock with a measure of economic output for the sector in a previous non-drought year. In essence, one is using basic data taken to represent an average year and comparing two synthetic situations: one without the shock; and another, contrived, with it. While this approach allows for the estimation of a direct impact in a relatively straightforward manner to the extent that is able to observe the behavioural responses of economic agents, it holds some important limitations. Firstly, the direct impact observed may be inaccurate if time trends are not considered; and secondly, the intensity of the shock may not, in reality, be felt equally across all geographic regions of the economy, meaning that an average size of the direct impact cannot be inferred for the whole of the Northern Cape (Schreiner, Mungatana & Baleta, 2018).

Operationalising the SAM-based multiplier model requires two major decisions according to the objectives of the study:

1) The process of extending the I-O model to the SAM framework requires the partitioning of accounts into either endogenous or exogenous accounts. Accounts where changes in expenditure levels directly follow changes in income are classified as endogenous. Alternatively, those accounts for which expenditure is independent of income are classified as exogenous. Exogenous accounts are set in accordance with the objectives

of the research, although the standard practise typically entails choosing a selection of government, capital, and rest of world accounts.

In this study, the shock scenarios will all consider the impact of a negative 10 percent shock to final demand of agricultural output. However, the scenarios are differentiated according to the accounts which are endogenised. In each of the four scenarios, capital and the rest of world accounts will be treated as exogenous. Those which will be used to test the sensitivity of the results to endogeneity are households, enterprises and government.

2) Setting the assumption that the supply capacity of certain sectors is either able to respond according to changes in demand, or whether supply capacity is constrained with respect to the available resources. The most basic form of the SAM involves the development of an unconstrained multiplier model, which assumes that supply capacity is infinite. Put simply, the basic unconstrained SAM model would assume that a change in demand would be matched by a corresponding change in supply – this is based on the assumption of excess capacity for production in a particular sector. In this case, resources can be commanded as needed in response to a change in demand, and that prices will remain constant during the resource reallocation (Breisinger et al., 2009).

   In reality, however, the production processes in many economic sectors are not able to keep pace with increasing demand – at least in the short term. Various factors contribute to supply constraints, including inadequate infrastructure, difficulties in obtaining credit, a lack of labour supply (whether due to a shortage of labourers or skills that are not easily transferrable), and a lack of technology. When developing a SAM-based model to estimate the impact of a shock, these restrictions should be accounted for by introducing supply constraints into the modelling assumptions for the affected sectors.

   If these are not accounted for, ignoring supply constraints can lead to unconstrained multiplier models overstating the impacts of the linkage effects (Breisinger, Thomas & Thurlow, 2010). Importantly, in the context of the shock considered in this paper, an investigation by Haggblade, Hammer, and Hazell (1991) found that unconstrained multiplier models tend to overestimate multipliers of agricultural growth by a factor between two and ten.

> However, in the context of this paper, which investigates the impacts of a negative shock, designed to model the effects of a drought or a bad rainy reason, supply constraints are not relevant. If the paper were considering the impact of a positive exogenous shock – a 10 percent increase in the export demand for agricultural output, for example – it would be important to consider the extent to which linked sectors can cope with an increase in demand, and therefore ascertain appropriate multiplier sizes.

An additional caveat is that the SAM-based multiplier model is demand-driven (Breisinger et al., 2009). This means that the catalyst of the shock scenarios is a change in exogenous final demand. However, this paper seeks to analyse the impact of supply-driven shock in the agricultural sector (e.g. crop failures; livestock losses). In modelling this shock, the results would then, according to the demand-driven model, be caused by a decline in the demand for agricultural output. In this simulation, it will be assumed that the effects of a drought in the agricultural sector – which reduces agricultural output – are the same as the decline in demand for output itself. This follows the same approach as Betho et al. (2021) in modelling the macroeconomic impact of COVID-19 in Mozambique using a SAM-based multiplier analysis. Lockdown measures impacted the economy in two ways: the first, a demand-driven shock, was through the prevention of expenditure by restricting the activity of households; and the second, a supply-driven shock, arose through mandating the closure of economic activities in non-essential industries. To capture the impact of the second supply-driven shock, Betho et al. (2021) adapted the methodological approach of Arndt et al. (2020), which evaluated the economy-wide impact of COVID-19 in a similar manner, using a SAM-based multiplier analysis to model the effects of both supply and demand-driven shocks.

Given these assumptions, the unconstrained multiplier formula is derived using the algebraic process given in Appendix B (Breisinger et al., 2009:18-19). Ultimately, conclusions will be drawn from the model results derived from the multiplier analysis of several scenarios with different sets of assumptions to test the sensitivity of the model to the inclusion of endogenous institutional accounts.

Contextualising the shock

This paper draws on estimates of historical drought impacts to devise and contextualise the size of the shock. With respect to the Southern African drought of 2019, Agri SA[5] found that South Africa's real agricultural output had declined by 9.2 percent in the first half of 2019 when compared to the same period in 2018 (Mkentane, 2019). This followed the release of Agri SA's (2019) Agricultural Drought Report 2019/2020, which detailed the transmission of a meteorological drought[6] that lands first, although not exclusively, in the agricultural sector, and ultimately disseminates into a financial drought. Of course, drought impacts vary significantly from one instance to another. Moreover, the estimated impacts of drought can also vary between groups of researchers. Nevertheless, to contextualise the simulation in a manner that is relevant to the type of drought impacts that are seen in the region, this paper draws upon the 9.2 percent decline in national agricultural output provided by Agri SA (2019:3) for the first half of 2019 compared with the same period in 2018, abstracting it to a provincial level – in absence of estimates of the effect on real agricultural output at the provincial level – and utilises an approximated 10 percent value for the size of the exogenous shock to agricultural activities in the simulations.

However, due to the nature of the SAM-based multiplier analysis as the chosen methodological approach, the central quantitative measure of interest is not the initial shock size, which is exogenously given. Nor is it the currency denominated values of the total economy-wide effects of the initial shock, or its effects on related sectors. Rather, this paper is primarily concerned with the multiplier effects of the shock, which are solely a function of the technical production coefficients of the accounts within the SAM. For an exogenous shock of any size to a given account, multipliers will only vary in scenarios where the endogeneity of institutional accounts is adjusted to account for whether these agents – households, enterprises, and government in this case – adjust their expenditure patterns in response to revenue fluctuations. We would expect to see larger multipliers as we endogenise each of these accounts, with institutions reducing expenditures in line with their fixed technical production coefficients to satisfy a new budget constraint with lower income levels. Hence, the scenarios outlined in the following simulation will be presented in an ascending order with respect to the anticipated multiplier effect sizes: first, a simple Leontief model set-up where all final demand accounts

[5] "Agri SA, a federation of agricultural organisations, was established in 1904 as the South African Agricultural Union and consists of nine provincial and 26 commodity organisations as well as 49 corporate members" (Agri SA, 2019:3).

[6] "Meteorological drought is defined based on the degree of dryness in comparison to 'normal' or average amounts of rainfall for an area or place and the duration of the dry period" (Agri SA, 2019:5).

are exogenous, meaning that there will be no induced effects from the demand by institutional accounts; second, we adjust the first scenario with households becoming endogenous; third, we adjust the second scenario with enterprises becoming endogenous; and fourth, we adjust the third with government becoming endogenous. In each of these scenarios, we expect to see larger multiplier effects than the previous. While each of these scenarios offer some value, they are not all equal in terms of their propensity to reflect the real-world transmission of the exogenous shock through the provincial economy. Consequently, the results of each scenario, and their respective strengths and weaknesses, will be considered in the subsequent discussions.

V) Data Description

To quantify the economy-wide effects of a drought in the Northern Cape, one requires the use of a macroeconomic database – in this case, a provincial SAM based on I-O tables for the Northern Cape province

As tools of policy and impact analysis, SAMs have been used in South Africa since the 1970s (Eckert, Liebenberg & Troskie, 1997). Several SAMs exist in the South African context, most of these databases have been developed to aid in macroeconomic modelling at the national level. As described by Van Seventer et al. (2019), the most recent 2015 national SAM offers a detailed representation of the economy encompassing 62 activities and 104 commodities; with labour categories disaggregated by level of educational attainment; and households by per capita expenditure deciles. This database would be ideal for conducting an analysis of a climate-shock at the national level; however, the 2015 national SAM does not account for disaggregation at the provincial level, i.e. one cannot conduct an analysis of impact of a climate-based shock as it pertains to the Northern Cape economy. One then needs to turn to a SAM that includes disaggregated data for the income and expenditure flows between economic accounts at the provincial level, such as that utilised by Eckert et al. (1997) which emphasised the agricultural sector in the Western Cape province. These, however, tend to be fewer in number and less up-to-date.

As a result, this paper utilises data based on an unpublished adjusted national and regional SAM[7] that incorporates disaggregated information for the transactional relationships between various economic activities, households, and production factors in the Northern Cape. The SAM is based on I-O tables that used 2004 as its base year (Conningarth Economists, 2005).

As highlighted in previous discussions, it is difficult to obtain up-to-date I-O tables to build a SAM-based model of an economy. This is particularly true for smaller regional economies; and is even more difficult in emerging-market economies where statistical resources may be relatively scarce. The 2004 SAM originally used 2004 prices, in units of Rands (millions). To illustrate a picture of the province's economy that is more accurate to the contemporary landscape, the values in each cell were then inflated to 2021 prices[8], but the structural relationships have not been amended. As a result, the values stated in the results of the study are given in 2021 prices (Rands, millions). Clearly, the inflated SAM still reflects the provincial economy as it existed in 2004; fortunately, the fundamental structure of the Northern Cape's economy has remained relatively stable over the intervening period – analysis of the graph shown in Figure 2 (Percentage shares of the real economy sectors in the Northern Cape (2004–- 2014) reveals relatively little change in the structure of the real economy between 2004 and 2014.

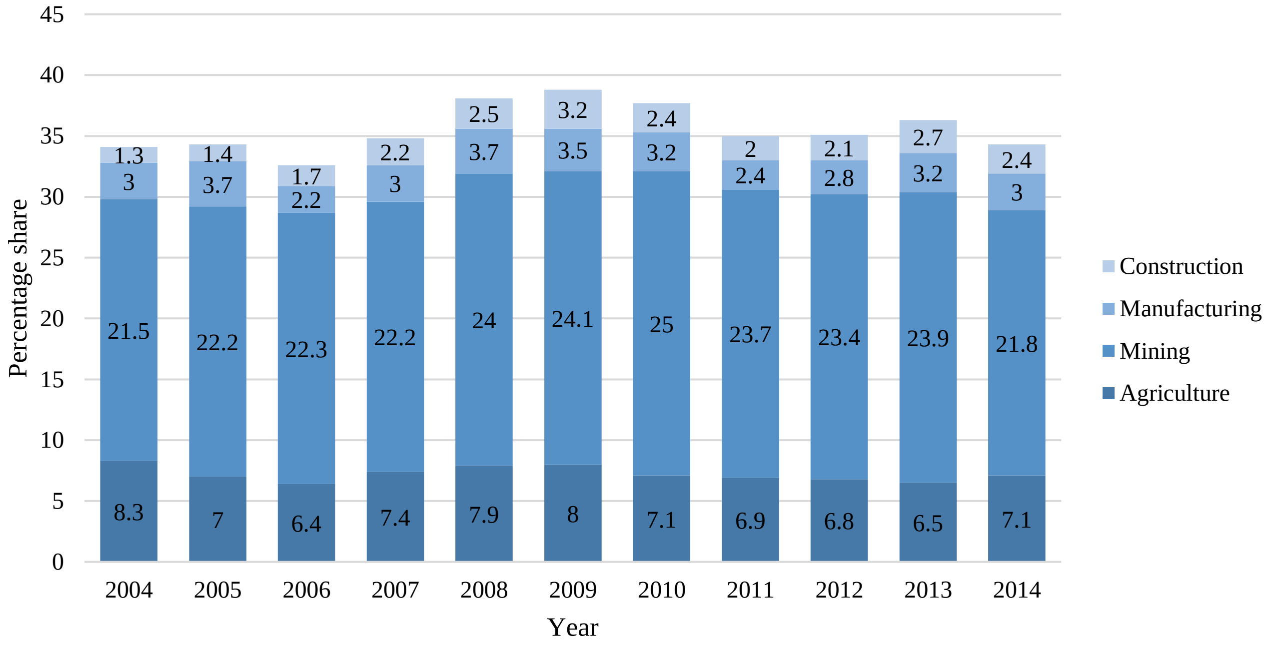
[7] The SAM was obtained from Dr Cecilia Punt of the Faculty of AgriSciences, Stellenbosch University. The reduced SAM is provided in Appendix C. The full reference for the original dataset is given as:
Conningarth Economists. 2005. *Provincial Social Accounting Matrix for the Northern Cape Province for 2004* [Dataset]. Unpublished Social Accounting Matrix. Pretoria.

[8] Values were calculated using the formula:

$$Value_{2021} = Value_{2004}\left(\frac{CPI_{2021,January}}{CPI_{2004,January}}\right), \text{ where } \left(\frac{CPI_{2021,January}}{CPI_{2004,January}}\right) = \frac{128}{55.3}$$

*Consumer Price Index (CPI) data was obtained at Organization for Economic Co-operation and Development (OECD, 2010).

Figure 2. Percentage shares of the real economy sectors in the Northern Cape (2004 - 2014)



Source: TIPS (2016)

The complete, disaggregated Northern Cape SAM is made up of 202 column and row accounts, respectively, and a corresponding residual to account for any discrepancy, though none are present in the SAM. The matrix comprises 46 activities (7 informal sector activities in addition to 39 formal activities), 39 commodities, factor payments to labour (disaggregated by racial demographic), factor payments to capital, enterprises (disaggregated according to type of enterprise), households (disaggregated by income decile within each demographic category), government (disaggregated into various departments and local government), capital account, the 'rest of the world' (flows between the Northern Cape and the broader South African economy), and the 'rest of the world' (flows between the Northern Cape and international markets).

Within the SAM framework, six main categories of accounts are considered:

1) **Activity accounts** reflect economic transactions made to produce one or more commodities, recording data on value addition by factor services and intermediate inputs within the economy.

2) **Commodity accounts** reflect economic transactions through supply linkages from activities, as well as imports; and are demanded for final and intermediate use within the domestic economy, as well as exports.
3) **Factor accounts** reflect the flow of income to, and expenditure made by factors of production. This category accounts for the services provided agents in the production process.
4) **Institutional accounts** record information on the way in which institutional arrangements interact to influence final demand for goods and services, both between productive accounts and institutions, and between institutions themselves (Taljaard, 2007:16). These institutions are entities that own factors of production, consume their resulting commodities, invest, pay or receive taxes and transfers. The main types of institutional accounts represented in the I-O framework are households, enterprises, government and rest of world.
5) **Capital accounts** contain income derived through savings from institutional accounts such as households, firms, and government, in addition to transfers from the rest of world. This income is then spent as the primary component of investment in the economy.
6) **Rest of World accounts** consist of economic transactions between accounts within the Northern Cape and those outside of the province, such as the balance of trade.

In theory, a SAM framework is always required to 'balance' – meaning that each column total is equal to the corresponding row total for each account. In practise, however, it is often the case that empirically estimated SAMs fail to balance at the first attempt of collation. While the original SAM has been aggregated according to various categories of account to allow for a more targeted analysis[9], some additional steps[10] have been taken to create a balanced SAM to facilitate the execution of the multiplier analysis. These include:

1) Households were originally displayed according to income decile within four race groups. These were:
   - 'Blacks – P1', 'Blacks – P2',…, 'Blacks – P12'
   - 'Coloureds – P1', 'Coloureds – P2', …, 'Coloureds – P12'
   - 'Asians/Indians – P1', 'Asians/Indians – P2', …, 'Asians/Indians – P12'

[9] A summary of the author's SAM aggregation is provided in Appendix A.

- ‘Whites – P1’, ‘Whites – P2’, …, ‘Whites – P12’

  An effort was made to aggregate these accounts to enable an assessment of the distributional effects of the shock: first, by income decile (Total P1, Total P2, …, Total P12); and second, by the given race groups (Blacks, Coloureds, Asians/Indians, and Whites). Although each of the accounts in the original SAM do balance individually (meaning that their respective row and column totals are equal), the categories by which an aggregation was iteratively attempted did not produce a balanced outcome (i.e. the row and column totals of each race group were not equal, and then the row and column totals of each income decile were not equal). Consequently, households had to be aggregated into one account. The partial loss of explanatory power that results from this aggregation is acknowledged as being less than ideal; however, the distributional impact of the shock is instead assessed through an analysis of the relative impacts on categories of labour (i.e. skilled labourers, semi-skilled labourers, and unskilled labourers).

2) In order to balance the government account, R0.2 million (2004 values) was subtracted from government’s income receipts from the rest of world (SA).
3) The residual on the capital account was pre-balanced by rendering the account’s income receipt from rest of world (international) negative R44.90 million.
4) The residual on the rest of world (SA) account was pre-balanced by rendering the account’s income receipt from the rest of world (international) negative R11 412.63 million.

VI) Preliminary Analysis

With reference to the regional SAM, the purpose of the exercise is to gain insight into the economy-wide impact of an environmental shock, such as a drought, with a particular focus on its indirect and induced effects in the regional economy. The multipliers which will be presented in the next section are predicated on the relationships between agriculture and other economic accounts, through backward and forward linkages.

Central to the preliminary data analysis of the economy-wide impact of agricultural drought, we conduct an initial review of SAM account coefficients which offer a quantitative metric for the degree of interrelatedness – or closeness – of sectors within the economy. The technical coefficients provided in Table 1 represent the proportion of expenditure allocated by the column account – agricultural *activities* and agricultural *commodities*, respectively – to the corresponding row accounts. Subsequent explanations are therefore based on a standard understanding of the nature of marginal effects, or the impact that an instantaneous change in one variable will have on another, *ceteris paribus* All values are rounded to two decimal places unless otherwise specified.

The first coefficient of note is the expenditure relationship between agricultural commodities and agricultural activities, with the coefficient of 0.98 indicating that approximately 98 percent of the total expenditures of agricultural commodities are allocated to agricultural activities. A further one percent is allocated to government in the form of taxes, and one percent of expenditures are allocated to the exogenous rest of world (South Africa) account, thereby exiting the model as a leakage.

The coefficients of the agricultural activities account that records the transactions made in order to produce the corresponding commodities illustrates the proportional allocation of expenditures by the sector on various production inputs. In terms of its relationships with other sectors, agricultural activities purchase production inputs in the form of commodities from private services (16 percent), consumer goods (10 percent), agriculture (6 percent), capital goods (5 percent), metal products (1 percent), and electricity (1 percent). Agricultural activities also purchase a further 14 percent of their inputs as intermediate goods. Many of these inputs, which one would expect to take the form of certain types of pesticide, fertiliser, and machine components amongst others, are not likely to be produced at any significant scale in the provincial economy and would thus be imported from other South African provinces (RoW – SA) or sourced in international markets (RoW). To trace this linkage, one needs to look beyond the technical production coefficients of agricultural activities presented in Table 1, where no significant linkage between the account and the external economy is apparent. Instead, these imports are captured in the technical production coefficients of the intermediate goods commodities account, where 56 percent of the input bundle is imported from RoW – SA, and a further 15 percent is sourced from RoW. This linkage is further consolidated in the SAM as 14 percent of expenditure in the agricultural activities account is allocated to purchasing intermediate goods. Along with private services and consumer goods, we would expect to see significant indirect effects of an exogenous climate-based shock to agriculture disseminate to producers of intermediate goods.

Factor payments are made to capital (35 percent) and labour (12 percent) – distributed amongst unskilled labourers (5 percent), semi-skilled labourers (5 percent), and skilled labourers (2 percent). Intuitively, one would expect that land rent would also feature as a technical production coefficient if people were leasing their farms, but this is not displayed in the SAM. One possible explanation is that land and capital may have been aggregated as a single item of capital expenditure in the original SAM.

Table 1. Agricultural Account Technical Production Coefficients

		Agricultural activities	Agricultural commodities
Activities	Agriculture	0.00	0.98
	Mining	0.00	0.00
	Consumer Goods	0.00	0.00
	Intermediate Goods	0.00	0.00
	Metal Products	0.00	0.00
	Capital Goods	0.00	0.00
	Electricity	0.00	0.00
	Water	0.00	0.00
	Construction	0.00	0.00
	Private Services	0.00	0.00
	Government Services	0.00	0.00
Commodities	Agriculture	0.06	0.00
	Mining	0.00	0.00
	Consumer Goods	0.10	0.00
	Intermediate Goods	0.14	0.00
	Metal Products	0.01	0.00
	Capital Goods	0.05	0.00
	Electricity	0.01	0.00
	Water	0.00	0.00
	Construction	0.00	0.00
	Private Services	0.16	0.00
	Government Services	0.00	0.00
Factor Payments	Skilled Labourers	0.02	0.00
	Semi-skilled Labourers	0.05	0.00
	Unskilled Labourers	0.05	0.00
	Capital	0.35	0.00
Institutions	Enterprises	0.00	0.00
	Households	0.00	0.00
	Government	0.00	0.01
	Capital Account	0.00	0.00
	RoW–- SA	0.00	0.01
	RoW	0.00	0.00
	Total	**1.00**	**1.00**

Source: author's own calculations

Behind the percentage of total factor payments allocated to unskilled labourers employed in buildings (15.55 percent), the expenditure allocation of agricultural activities to unskilled labourers (as a percentage of total factor payments) is the largest of all the aggregated activity accounts, as depicted in Table 3. This relatively large share for unskilled labour can be explained by the nature of the processes involved in the activity, with construction and building-related maintenance typically requiring a skillset that requires fewer years of formal education. Unskilled labour in the Northern Cape may, nonetheless, involve considerable skills in terms of horticultural expertise in irrigation farms, or stock-handling skills in extensive livestock raising.

Table 2. Percentage distribution to factor payments by activity accounts

		Factor Payments			
		Skilled Labourers	**Semi-skilled Labourers**	**Unskilled Labourers**	**Capital**
Activities	**Agriculture**	3.42	10.26	10.69	75.63
	Mining	9.10	23.54	5.39	61.97
	Consumer Goods	15.58	22.70	7.01	54.71
	Intermediate Goods	13.08	18.60	4.60	63.71
	Metal Products	23.66	38.59	5.02	32.73
	Capital Goods	25.19	30.75	4.90	39.16
	Electricity	15.33	22.90	1.90	59.86
	Water	11.95	15.01	5.42	67.62
	Buildings	11.08	29.10	15.55	44.27
	Private Services	25.60	17.69	3.54	53.17
	Government Services	25.18	54.77	7.71	12.35

Source: author’s own calculations

Similarly, the share of factor payments allocated to capital by agricultural activities (75.63 percent) is the largest of all activity accounts by a considerable distance. Since the advent and widespread adoption of irrigation technologies and harvesting machinery, an increasing share of agricultural income has been won by capital over labour. This mirrors the long-term trend seen in most sectors since the industrial revolution, as the advent and adoption of labourenhancing technologies enabled firms to increase productivity without hiring additional employees. As a result, labourers in the agricultural sector see smaller and smaller shares of total output. In the context of the negative 10 percent shock to agricultural commodities, we would expect capital to experience the largest percentage decline amongst all the factor accounts. In reality, we might expect this to manifest through farm owners postponing or cancelling purchases of new machinery; however, debt repayments to financial institutions are prescribed, meaning that debts will remain fixed or refinanced unless insolvencies increase, although this will not be considered in the analysis. Empirically, various scenarios are capable of manifesting, where farmers and agricultural unions could approach both the state and financial institutions to engage regarding soft loans, loan renewal, bridging finance, or the extension of repayment periods. However, overcoming these financing uncertainties will guide one dimension of the paper's recommendations for improving the adaptive capacity of farmers in the face of a drought-induced shock.

Amongst factor payments to labour however, the largest decline in income would be experienced by unskilled labourers. This is expected to manifest as a decline in household income – and therefore the revenues of those sectors to which households proportionately allocate their expenditure.

Table 3. Factor and Institutional Account Technical Production Coefficients

		Factor Payments			Institutions			
		Skilled Labourers	Semi-skilled Labourers	Unskilled Labourers	Capital	Enterprises	Households	Government
Activities	Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Consumer Goods	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Intermediate Goods	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Metal Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Capital Goods	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Electricity	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Private Services	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Government Services	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Commodities	Agriculture	0.00	0.00	0.00	0.00	0.00	0.01	0.00
	Mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Consumer Goods	0.00	0.00	0.00	0.00	0.00	0.12	0.01
	Intermediate Goods	0.00	0.00	0.00	0.00	0.00	0.02	0.02
	Metal Products	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Capital Goods	0.00	0.00	0.00	0.00	0.00	0.02	0.02
	Electricity	0.00	0.00	0.00	0.00	0.00	0.01	0.02
	Water	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	Construction	0.00	0.00	0.00	0.00	0.00	0.00	0.02
	Private Services	0.00	0.00	0.00	0.00	0.00	0.59	0.06
	Government Services	0.00	0.00	0.00	0.00	0.00	0.04	0.00
Factor Payments	Skilled Labourers	0.00	0.00	0.00	0.00	0.00	0.00	0.17
	Semi-skilled Labourers	0.00	0.00	0.00	0.00	0.00	0.00	0.07
	Unskilled Labourers	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	Capital	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Institutions	Enterprises	0.00	0.00	0.00	0.64	0.00	0.00	0.01
	Households	0.96	0.96	0.96	0.00	0.63	0.02	0.10
	Government	0.00	0.00	0.00	0.01	0.28	0.12	0.38
	Capital Account	0.00	0.00	0.00	0.27	0.04	0.05	0.10
	RoW–- SA	0.03	0.03	0.03	0.07	0.04	0.00	0.00
	RoW	0.02	0.02	0.02	0.01	0.01	0.00	0.00
	Total	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**

Source: author's own calculations

The multiplier effect is expected to differ with the extent to which institutional accounts are assumed to be endogenous or exogenous. As revenue changes logically follow any changes in economic activity when accounts are endogenised with the model, endogenizing the income-expenditure loop of households and government is expected to result in higher multipliers. This effect is expected to be even greater when both households and government are endogenised simultaneously. Intuitively, this means that a decrease in household income – as a result of decreased labour income – would have the effect of reducing household consumption, as household income is the key variable in a household consumption function that allows for budgetary flexibility, depending on the extent to which households can access credit and whether they prefer to smooth consumption. Assuming that household accounts are endogenous allows us to capture the induced economy-wide effects arising from a change in labour income (in directly and indirectly affected sectors) that trickles through to household budgets and inspires them to change their expenditure behaviour, albeit in the fixed proportions given as technical coefficients within the SAM. Governments, too, are subject to budgetary constraints and hence depend on income in order to fuel consumption. At the level of provincial government, however, annual budgets are centrally allocated by the national government, and would hence be relatively insulated against an income shock in the Northern Cape.

VII) Results

This section serves as a presentation of the results of the shock scenarios in the form of a SAM-based multiplier analysis. The justification for the use of SAM-based modelling as a methodological approach for impact analysis is predicated on the appropriate interpretation of the results (Cloete & Roussouw, 2014). As such, the specific set of assumptions which underpin the methodology must be kept in mind when interpreting its results.

Specifically, the assumption of fixed relative price levels needs to be kept in mind when conducting the multiplier analysis. This proviso is particularly important because droughts have been shown to change relative prices, particularly the prices of livestock. In reality, the trajectory of these changes is difficult to predict, and various intertemporal pricing scenarios are feasible. What is clear, though, is that droughts at the regional or national level tend to result in substantial increases in the price of hay, which is usually locally sourced (Schaub &

Finger, 2020). Feed grain, on the other hand, is often traded transnationally, and is less responsive to regional climate shocks. Thus, for example, while a local drought is likely to drive up prices of stock feed, it tends to raise the price of non-tradables like lucerne hay, more than the price of globally traded feeds such as maize, whose prices are internationally determined and therefore less responsive to local conditions. Overall, this divergence can be ascribed to the important fact that prices in markets with relatively low levels of market integration – for example, due to high transport and transaction costs – are more sensitive to drought-induced shocks (Schaub & Finger, 2020).

When considering how relative prices would change in this simulation – if the fixed price assumption were dropped – one needs to consider the decision-making process of individual economic agents as they adjust strategies in the face of changing resource endowments. Droughts tend to force livestock farmers into making a series of critical decisions that will influence relative prices, and the choices made are subject to various factors, including the extent to which farmers are able to draw upon savings or access credit in order to absorb the shock of increased feed prices caused by reduced harvest yields. To minimise the probability of animals perishing due to malnutrition and illness, farmers may decide to destock in the early stages of a drought – for example, culling via abattoirs; or by sale to other farmers. This may result in an influx of animal products to the market, temporarily decreasing the prices of meat and hides. Over time, however, meat prices would increase, eventually rising above pre-drought levels as the yield from diminished herds, combined with a need to restock, lead to a supply shortage. However, the size of the price increase would depend on several factors, including the extent to which consumers are able to substitute their consumption by sourcing meat from external markets at a comparable price.

Likewise, the SAM assumes a perfectly elastic supply of economic multipliers – a feature to be recognised alongside the results of the multiplier analysis. As this study considers the ripple effect of a negative shock to agricultural production, rather than a positive shock or injection, the commonly cited caveat that SAM analyses ignore supply constraints is not a concern for any of the four shock scenarios.

Instead, the nuanced comparison across the four scenarios focuses on the regional economy's sensitivity to the shock and to the inclusion of endogenous accounts, specifically households, enterprises and government. In essence, the sensitivity analysis is testing the extent to which the economy-wide impact of the shock changes when we assume that a change in the accounts' income induces a change in the accounts' expenditures.

A summary of the four shock scenarios and their respective assumptions is given in Table 4. below.

Table 4. Summary of shock scenarios

Shock (1)	- Shock size: negative 10 percent (-R953.06 million) shock to agricultural commodities - All final demand accounts are exogenous
Shock (2)	- Shock size: negative 10 percent (-R953.06 million) shock to agricultural commodities - Shock (1) + households are endogenous
Shock (3)	- Shock size: negative 10 percent (-R953.06 million) shock to agricultural commodities - Shock (2) + enterprises are endogenous
Shock (4)	- Shock size: negative 10 percent (-R953.06 million) shock to agricultural commodities - Shock (3) + government is endogenous

Table 5. Multiplier effects of shock to individual economic accounts

		Shock (1)	Shock (2)	Shock (3)	Shock (4)
Activities	aAgriculture	1.05	1.06	1.07	1.08
	aMining	0.01	0.01	0.02	0.03
	aConsumerGoods	0.05	0.08	0.10	0.11
	aIntermediateGoods	0.03	0.03	0.04	0.04
	aMetalProducts	0.00	0.00	0.00	0.00
	aCapitalGoods	0.00	0.01	0.01	0.02
	aElectricity	0.00	0.01	0.01	0.02
	aWater	0.00	0.01	0.01	0.01
	aConstruction	0.00	0.00	0.01	0.06
	aPrivateServices	0.20	0.49	0.68	0.73
	aGovernmentServices	0.00	0.02	0.03	0.03
Commodities	cAgriculture	1.08	1.09	1.10	1.10
	cMining	0.01	0.01	0.01	0.02
	cConsumerGoods	0.13	0.21	0.26	0.27
	cIntermediateGoods	0.18	0.21	0.25	0.27
	cMetalProducts	0.01	0.01	0.02	0.03
	cCapitalGoods	0.07	0.11	0.14	0.28
	cElectricity	0.01	0.02	0.03	0.04
	cWater	0.00	0.01	0.01	0.01
	cConstruction	0.01	0.01	0.02	0.17
	cPrivateServices	0.25	0.63	0.87	0.94
	cGovernmentServices	0.00	0.02	0.03	0.04
Factors	Skilled Labourers	0.04	0.08	0.19	0.21
	Semi-skilled Labourers	0.07	0.10	0.16	0.17
	Unskilled Labourers	0.06	0.06	0.07	0.08
	Capital	0.43	0.51	0.57	0.60
Institutions	Enterprises	0.27	0.33	0.37	0.39
	Households	0.34	0.45	0.69	0.75
	Government	0.14	0.24	0.48	0.54
	Capital Account	0.13	0.17	0.25	0.26
	RoW–SA	0.31	0.47	0.59	0.79
	RoW	0.08	0.12	0.16	0.21

Table 6. Multiplier effects by type of multiplier

	Shock (1)	Shock (2)	Shock (3)	Shock (4)
Output	1.35	1.72	1.98	2.12
GRP/Value added	0.60	0.76	0.99	1.06
Income	0.34	0.45	0.69	0.75
Income/GRP	0.56	0.59	0.70	0.71

The results of the model tend to echo the conclusions of several sources within the existing base of literature (such as Ziolkowska (2016), Roberts (1990), Taljaard (2007), Jafri and Buland (2016)), with the initial shock resulting in a large direct effect that is exacerbated by backward linkages and induced effects as the shock spreads throughout the economy, resulting in a total effect that is greater than the size of the initial shock.

The values in Table 5 indicate the multiplier effects for each account in the SAM. They are interpreted as the change in the financial value – as a fraction of the initial shock size – of the economic transactions for each account in each shock scenario. In shock (1), for example, the initial shock of negative R953.06 million in agricultural commodities ultimately results in a total effect of 1.08 times the size of the initial shock (R1 029.31 million) to the economic transactions of the same account. As the total effect size is greater than the size of the initial direct effect (or the shock size), we identify the presence of a multiplier that increases the magnitude of the shock as it moves through the matrix of economic linkages. For the commodity accounts, the effects specifically relate to the economic transactions through supply linkages from activities, as well as imports; and are demanded for final and intermediate use within the domestic economy, as well as exports. Activity accounts, on the other hand, reflect economic transactions made to produce one or more commodities, recording data on value addition by factor services and intermediate inputs within the economy.

Output multiplier

The output multiplier measures the extent to which the initial shock – whose direct effect results in a decline in agricultural commodities – causes a decline in the output of the activity accounts. In essence, it is expressed as the ratio of the sum of change in the output of all economic activities to the financial value of the initial shock to agricultural commodities. When looking at the economy-wide impact across the four scenarios, we see that the provincial gross output effect of the shock houses the largest multiplier effect when compared to GRP/value-added and income, as summarised in Table 6. This confirms that the direct effect of the shock is likely to be most visibly felt through the reduction in economic activities, measured by output.

In shock (1), where all final demand accounts are exogenous, the output multiplier of 1.35 indicates that the total output effect from the initial shock of negative R953.06 million is negative R1 286.63 million. In shock (2), where the household income-expenditure loop is endogenised, the output multiplier increased to 1.72. In shock (3), where the income-expenditure loops of both households and enterprises are endogenised, the output multiplier increased to 1.98, meaning that the total output effect from the initial shock of negative R953.06 million is negative R1 887.06 million. In shock (4), where households, enterprises and government are endogenous, the output multiplier increased again to 2.12, indicating that the total output effect from the initial shock of negative R953.06 million is negative R2 020.48 million.

GRP/Value-added multiplier

The GRP multiplier is expressed as the ratio of the sum of the change in factor payments – where the factor accounts (i.e. those agents who add value in the production process – are skilled labourers, semi-skilled labourers, unskilled labourers, capital, and enterprises – to the financial value of the initial shock to agricultural commodities. When looking at the economy-wide impact across the four scenarios, we see that that the GRP/Value-added effect of the final demand shock is the second largest contributor to the total multiplier of each shock, as summarised in Table 6.

In shock (1), where all final demand accounts are exogenous, the GRP multiplier of 0.60 indicates that the GRP effect from the initial shock of negative R953.06 million is negative R571.84 million. In shock (2), where the household income-expenditure loop is endogenised, the GRP multiplier increased to 0.76. In shock (3), where the household income-expenditure loops of both households and enterprises are endogenised, the GRP multiplier increased to 0.99, meaning that the GRP effect from the initial shock of negative R953.06 million is negative R943.53 million. In shock (4), where government income-expenditure is endogenised in addition to households and enterprises, the GRP multiplier is 1.06, indicating that the total GRP effect from the initial shock of negative R953.06 million is negative R1 010.24 million.

Income multiplier

The income multiplier is expressed as the ratio of the sum of the change in income to all households within the province to the financial value of the initial shock to agricultural output. When looking at the economy-wide impact across the four scenarios, we see that that the income effect of the initial shock is the smallest of the contributors to the overall multiplier of each shock, as summarised in Table 6.

In shock (1), where all final demand accounts remain exogenous, the income multiplier of 0.34 indicates that the income effect from the initial shock of negative R953.06 million is negative

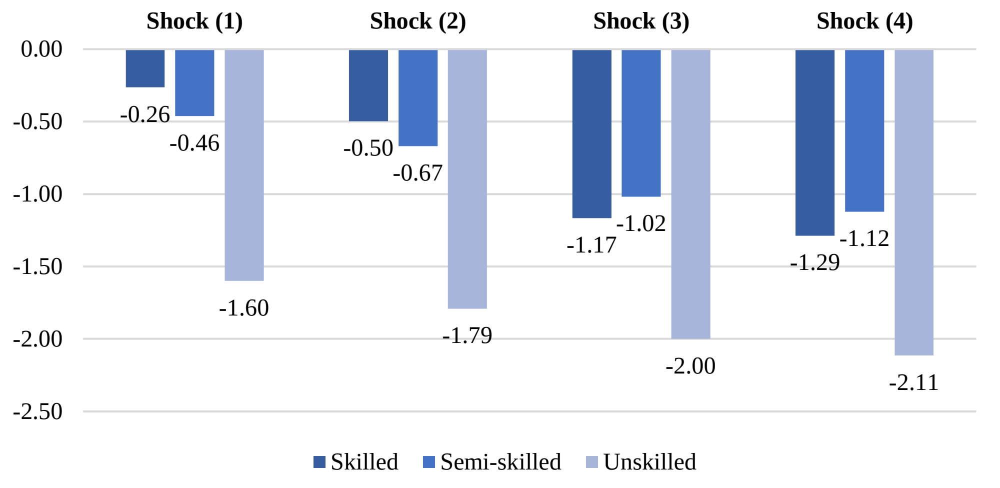
R324.04 million. In shock (2), where the household income-expenditure loop is endogenised, the income multiplier increased to 0.45. In shock (3), where the income-expenditure loops of both households and enterprises are endogenised, the income multiplier increased to 0.69, meaning that the income effect from the initial shock of negative R953.06 million is negative R657.61 million. In shock (4), where government income-expenditure is endogenised in addition to households and enterprises, the income multiplier is 0.75, indicating that the income effect from the initial shock of negative R953.06 million is negative R714.80 million.

As the negative shock to income reverberates throughout the domestic economy as households, enterprises and government reduce consumption in line with their fixed expenditure profiles, the indirect effects of the shocks increase and are represented by a greater multiplier overall.

Distributional Impacts

For its relevance to policy determination, one of the most important considerations to factor into an examination of the effect of a shock is the impact it is likely have on the welfare of local communities. To this end, income serves as an effective, though not perfect, proxy for welfare. Labourers serve as primary breadwinners for their families and dependent communities, with a significant portion of their income transferred to household budgets. Each of the labour accounts (unskilled, semi-skilled and skilled labourers) holds a technical coefficient of 0.96 with respect to households – indicating that labourers transfer approximately 96 percent of their income to households – we would expect to see a shock to labour income reverberate to household income, given that the labour accounts are endogenised within the model.

Figure 5. Percentage change in labour income



Source: author’s own calculations

When looking at the results illustrated in Figure 5, we see that labour income is negatively affected across each of the four simulated shock scenarios. As hypothesised in the preliminary analysis of the agricultural sector’s technical production coefficients with respect to labour, unskilled labourers bear the brunt of the negative shock amongst each of the categories of labour, in relative terms. In shock (1), the impact of a negative 10 percent shock to agricultural commodities results in a 1.60 percent decline in the income of unskilled labourers. In shock (2), where the household income-expenditure loop is endogenised, unskilled labour income declined by 1.79 percent. In shock (3), where the income-expenditure loops of both households and enterprises are endogenised, the impact on unskilled labour increases to 2 percent. Finally, in shock (4), where government income-expenditure is endogenised in addition to households and enterprises, the impact on unskilled labour income is negative 2.11 percent.

The impact on skilled and semi-skilled labourers, while less than that experienced by unskilled labourers, is negative across each of the four shock scenarios. In shock (1), the impact of a negative 10 percent shock to agricultural commodities results in a 0.46 percent decline in semi-skilled labour income, and a 0.26 percent decline in skilled labour income. As the household income-expenditure loop is endogenised in shock (2), we see that the impact on all labour categories increases, with semi-skilled labour income declining by 0.67 percent, and skilled labour income declining by 0.50 percent.

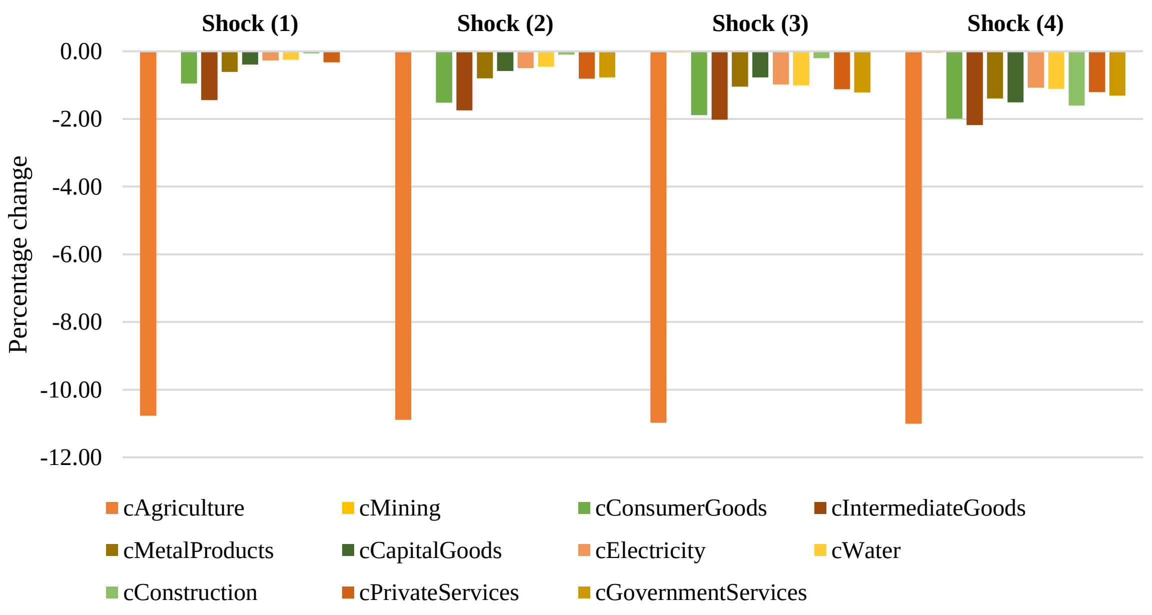
In shock (3), however, we observe a marked changed in the relative impacts experienced by each labour category, where unskilled labour still experiences the largest change, but the percentage change in skilled labour income – which experienced a comparatively small impact in shocks (1) and (2) – now exceeds the percentage change in semi-skilled labour income. The addition of enterprises as an endogenous account, in addition to households, has a marked effect on the size of the multipliers – and the income multiplier in particular, as demonstrated in Table 6, where we see that the ratio of the income multiplier to the GRP/Value added multiplier increases from 0.56 and 0.59 in shocks (1) and (2), respectively, to 0.70 in shock (3). In shock (3), when we endogenise the income-expenditure loops of both households and enterprises, semi-skilled labour income declines by 1.02 percent, while skilled labour income declines by 1.17 percent. With enterprises earning most of their income from the capital factor account – i.e. returns to investment – the shock's impact on capital has a significant negative impact on returns to investment. When enterprises are endogenous, this income shock results in a proportional decline in the account's expenditures, of which approximately 63 percent is paid to households. As households are also endogenous, the reduction in household revenue results in a reduction in the account's expenditures, of which approximately 59 percent is spent on private services commodities. In terms of their fixed expenditure profiles, services activities are the largest proportional contributors to skilled labour income of all productive sectors, with government services activities and private services activities allocating approximately 11 percent and 15 percent to skilled labour income, respectively. In fact, private services activities is the only activity account where skilled labour income is the largest recipient of labour expenditure. Thus, the decline in private services' revenues as a result of reduced household income – caused by the diminished returns on investment reducing income in the enterprises account – can help explain why the endogeneity of enterprises in shock (3) results in a greater proportional impact to skilled labourers.

Shock (4) continues this trend, with government now included as an endogenous account in addition to households and enterprises. As expected, the impact on all labour categories is greater than all preceding scenarios, with reduced government revenues now translating into reduced government expenditures resulting in high multipliers overall. Unskilled labour income, like the previous three scenarios, experiences the largest percentage change. In contrast to shocks (1) and (2), but in keeping with the results of shock (3), skilled labour income experiences a greater percentage change – a 1.29 percent decline – compared to semi-skilled labour income, which experiences a 1.12 percent decline.

Sectoral Impacts

While the impact originates in the agricultural sector, the purpose of the paper is to understand how the initial decline in agricultural commodities affects agents throughout the economy. When looking at the aggregated sectors outside of agriculture, it is evident that the shock has an impact on all commodity sectors in each of the four shock scenarios. As expected, the most profound impacts were felt in consumer goods and, in particular, intermediate goods. As illustrated in Figure 6, the negative 10 percent shock to agricultural commodities resulted in a 1.44 percent decline in the financial value of income earned through the sale of intermediate goods commodities in shock (1). Shock (2) results in a 1.75 percent decline in the income of sectors producing intermediate goods. In shock (3), however, the impact is a marginally stronger 2.02 percent decline. In shock (4), we witness an even greater 2.18 percent decline.

Figure 6. Total Impact by Commodity Sector



Source: Author's own calculations

Significant negative impacts are also seen in consumer goods across the four shock scenarios. The negative 10 percent shock to agriculture resulted in a 0.95 percent decline in the financial value of commodity income by consumer goods in shock (1). Shock (2) results in a substantially greater 1.52 percent decline in consumer goods. In shock (3), the impact again increases to a 1.89 percent decline. In shock (4), we witness a 1.99 percent decline.

Furthermore, significant impacts proliferate across a range of other economic sectors in response to the agricultural shock. A decline in income is experienced by commodity sectors including metal products, capital goods, private services, electricity, and water, while a relatively modest decline is seen in government services. Mining, while not entirely immune to the impact of the shock, appears to be relatively well insulated, with effects ranging from a 0.02 percent decline in shock (1) to a 0.04 percent decline in shock (4).

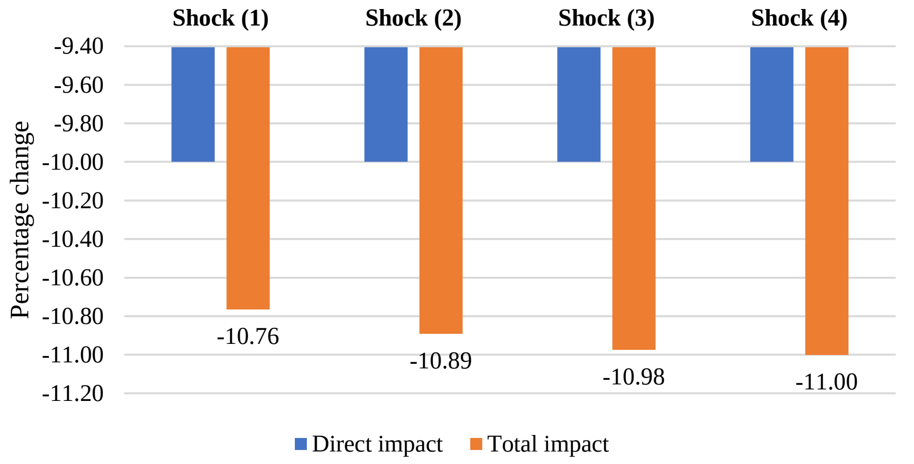
The manifestation of larger percentage impacts in these sectors where institutional accounts are endogenised is consistent with the trend seen in the analysis of the multiplier effects and the distributional impact.

Direct, Indirect and Induced Effects

The only sector directly affected by the initial shock is agriculture. Impacts which ripple throughout the economy, outside of the direct effect on agriculture, are experienced as indirect or induced effects. Across each of the four shock scenarios, the direct impact is negative 10 percent. However, because of the endogeneity of the various accounts in the SAM, the total multiplier effect to agricultural output is greater than one – i.e. the total impact of a negative 10 percent shock to agricultural commodities will be greater than 10 percent.

As illustrated in Figure 7, the total impact to agricultural commodities is negative 10.76 percent in shock (1), meaning that the indirect impact is 0.76 percent (the difference between the total impact and the direct impact). While the direct impact remains constant, the indirect effect – and therefore the total effect – increases as we begin to endogenise institutional accounts. This is seen in shock (2), where households are endogenous, generating a total impact of negative 10.89 percent. In shock (3), the total impact increased to negative 10.98 percent, with an indirect impact of negative 0.98 percent. This is also the case in the results of shock (4), with a total impact of negative 11 percent indicating an indirect impact of negative 1 percent.

Figure 7. Impact on Agricultural Commodities



Source: author's own calculations

Overall, the results indicate the manifestation of impacts across a multitude of sectors throughout the provincial economy as a result of agricultural drought. In line with theoretical expectations, the multiplier effects become more and more pronounced as additional institutional accounts are endogenised. These results, their implications and their potential remedies, will be unpacked in the following discussion.

VIII) Discussion

This aim of this project has been to better understand the relationship between climatological variables – such as temperature, rainfall, and oceanic upwelling – and the spectrum of socio-economic activities in the Northern Cape. A SAM-based multiplier analysis models the impact of an exogenous negative shock (such as a drought) to the agricultural sector, highlighting the process of the shock's dissemination throughout the provincial economy.

By using a SAM-based multiplier approach, this analysis has identified a range of channels through which an exogenous shock to the agricultural sector affects the broader provincial economy. Unlike the classic Leontief I-O model, which only focuses on inter-industry production linkages, a SAM-based model incorporates consumption linkages by assuming the endogeneity of institutional accounts – households, enterprises and government, respectively – under four shock scenarios which test the sensitivity of the results to the inclusion of their income-expenditure loops (Breisinger et al., 2009). While this analysis does not ignore inter-industry linkages – they remain a crucial component of the multiplier analysis – using the

SAM-based model allows us to incorporate consumption linkages as an additional dimension of analysis.

If we compare these results to those of previous studies, we see similar outcomes in terms of the manifestation of economy-wide effects. The proliferation of losses beyond the agricultural sector, was found in Ziolkowska's (2016) assessment of the economy-wide effects of the 2011 Texas drought, can be ascribed to the backward and forward linkages from those sub-sectors to others in the agricultural sector, and in the state economy as a whole. In this paper, we see that the economy-wide impact is increased by the induced income-expenditure effects brought about through consumption linkages in the province. When compared to the simple Leontief model used in shock (1), allowing the direct and indirect impacts of the initial shock to induce additional effects – by enabling institutional accounts to respond to a reduction in revenue with a proportionate change in expenditure – shocks (2), (3) and (4) each result in greater economy-wide impacts than the previous shock.

The results reported output multipliers for the shock scenarios – the sum of all direct and indirect effects across several rounds, reporting the change in output of all production activities (Breisinger et al., 2009). It was found that a drought-induced 10 percent decline (negative R953.06 million) in agricultural commodities, would result in a decline in provincial output of between R1 286.63 million (in the simple Leontief model, where neither households, enterprises nor government is assumed to be endogenous) and R2 020.49 million (where households, enterprises government are all assumed to be endogenous). These results indicate that linked sectors are likely to experience a decline in output, measured through backward linkages as sectors producing agricultural inputs – pesticides and animal feed, for example – reduce their output in response to the lower demand from the agricultural sector. As agricultural industries purchase non-agricultural products with income generated within the sector, those sectors producing non-agricultural products will naturally experience diminished revenues. Forward linkages also play a part in contributing to the total effect, and particularly the output effect, as sectors relying on agricultural output as production inputs – such as industries focused on agri-processing and distribution of agricultural products, such as transport – may be forced to scale down their production, and therefore experience reduced output, given the assumption of fixed relative prices and constant technical production coefficients. In this study, the most profound indirect effects were felt in consumer goods, a sector that relies on agricultural commodities as inputs, and, in particular, intermediate goods, which supplies key inputs to the agricultural sector.

The results reported GRP/Value-added multipliers for the shock scenarios, measuring the total change in factor incomes (or value-added) in response to the direct or indirect effects of the shock (Breisinger et al., 2009). It was found that a 10 percent decline in agricultural commodities would result in a decline of between R571.84 million (where households, enterprises and government are exogenous) and R1 010.24 million (where households, enterprises and government are endogenous) in total factor income throughout the provincial economy.

The results reported income multipliers for the shock scenarios, measuring the total change in household income in response to the shock. It was found that a 10 percent decline in agricultural commodities would result in a decline of between R324.04 million (where households, enterprises and government are assumed to be exogenous) and R714.80 million (where households, enterprises and government are assumed to be endogenous) in total household income. Amongst factor payments to labour however, the largest relative decline in income is experienced by unskilled labourers. Ultimately, this is expected to manifest as a decline in household income – and therefore reduce the revenues of those sectors to which households proportionately allocate their expenditure. This is an important finding of the study, highlighting the vulnerability of low-income labourers – and therefore more economically precarious communities – to climate-based shocks in the agricultural sector.

The results suggest that the impact of the shock is sensitive to the endogeneity of institutional accounts. Once households and government are assumed to be endogenous, the size of the multiplier increases, although by a relatively small margin. When these accounts are endogenous, their expenditures change in response to changes in income. As households and governments experience decreased income through either direct or indirect effects, we observe new induced effects as new budgetary constraints present themselves through reduced expenditures which, in turn, reduces the income of those accounts from which institutions purchase commodities and hence provide factor income. In reality, however, governments are subject to complex internal income-generating and expenditure-allocating processes. These are unlikely to be highly responsive to changing revenues in the short run at the provincial level since the provincial government obtains most of its funding from the national fiscus. When 'enterprises' is treated as an endogenous account, however, the relative size of impacts to the income of the three labour categories changes significantly, with skilled labourers suffering a greater percentage income loss than semi-skilled labourers. This is another important finding with respect to the fact that a certain proportion of income earned by enterprises will be distributed, as a return on investment, to their owners. Many of these owners will be households within the province, meaning that a negative shock to the income of enterprises is, in contrast to government, likely to result in some adjustment in expenditures. As households are also endogenous in shock (3), the reduced returns on investment will result in reduced household income that cause a change in the account's expenditures. As a significant portion of revenues accruing to the services sector is derived from households, and services are major employers of skilled labourers, the indirect effect on enterprises induces additional income and expenditure effects throughout several accounts that ultimately results in reduced skilled labour income. This demonstrates the capacity for a climate-shock, after first landing in the agricultural sector, to continue imposing negative impacts on sectors – such as private services – and their workers, whose core functions are substantially less climate-dependent than agriculture.

Various reasons can be used to explain the relatively small size of the multipliers. As outlined by van Leeuwen et al. (2005), the size of the multiplier depends on several variables concerning the nature of the specific economy. In the Northern Cape, we are considering a provincial economy that produces a relatively small number and volume of goods and services. This can imply a small multiplier as firms and households need to look outside the region to purchase goods and services (including many agricultural inputs). Imports to the region act as a leakage within the SAM framework, and hence exert a negative effect on the multiplier (van Leeuwen et al., 2005). The province's low population density and large rural demographic mean that effects will tend to isolate sub-regions within the province, also resulting in a smaller multiplier. In effect, the small multiplier reflects the idiosyncratic structural dynamics of the Northern Cape economy, with significant leakages and a tendency to incubate the impact of shocks within isolated rural regions.

The results show that the impacts of a shock to agriculture depend critically on the extent to which households, enterprises and government must balance their budgets in the short run. If these institutional accounts have flexible access to credit – or a larger centralised funding base, as is the case for government – then the short-run systemic shock is almost insignificant, and reduced income is unlikely to result in a significant decline in spending. If they are unable to access credit, however, then the effects of the shock can be profound. When the impact sustains over multiple seasonal cycles – as in the case of a prolonged drought – then the provision of short-term credit to farms and households may not be a viable solution, and the implications for regional income are likely to be more grave. Since the provincial government receives most of its funding from the national fiscus, its expenditure is more independent of regional income, meaning that government accounts are effectively exogenous. However, as previously discussed, a large segment of both households and, to a certain extent enterprises, is likely to be endogenous within the model, meaning that shocks (2) and (3) offer the most plausible set of results for the simulation of economy-wide effects.

If this is the case, then the multiplier effect of shock (4) is likely to offer the least accurate representation of the economy-wide impact. The implication of this is that the impact of a shock to the agriculture can, in the short run, be significantly mitigated by expanding farms' and households' access to credit. If the shock persists over a longer period of time, local communities and policymakers may be forced to improve drought resilience by adopting alternative farm risk management and adaptation strategies that reduce their vulnerability to climate-based shocks. For example, Aslam (2015) suggests that alternative adaptation strategies are more likely to be adopted by farmers with more experience, higher levels of educational attainment, secure tenure rights, better access to electricity and institutional facilities, and greater awareness of climatic variability. Given the prevalence of prolonged drought in the Northern Cape, policymakers could assist by furthering the propagation of these factors amongst local farming communities in order to increase drought resilience.

This paper has outlined a SAM-based multiplier analysis that has produced several results, although these are subject to the constraining methodological assumption of fixed relative prices. This approach has been useful, to a certain extent, in demonstrating how the economy would respond to a shock in a situation where, for example, prices are held constant by a centralised authority. Empirically, however, the decline in agricultural output is likely to have price effects for several reasons, and dealing with this requires a slightly different methodological approach that accounts for behavioural changes. Despite overlooking the price effects, the SAM-based multiplier analysis can be used by stakeholders and policymakers to understand the urgency of devising mitigation measures as decreased production yields are bound to impact market supply for agricultural commodities and those produced in linked sectors, *ceteris paribus*.

Given that scarcity is a theoretical and empirically verifiable determinant of market prices, the short-term effect of a negative supply shock is likely to be accompanied by an increase in price levels, depending on the price elasticity of demand of the commodities traded by various agricultural sub-sectors. As economic agents react to changing relative prices, these effects could also change the account's technical production coefficients, undermining a key assumption of the model.

However, the nature of the price effect is likely to be more complex and may not manifest as one of an outright increase in price levels, although the short-term scarcity-induced price effect is more likely to occur in agricultural crop commodities. Droughts have been shown to change relative prices, particularly the prices of livestock. Intuitively, one would expect prices to fall at the start of a drought when farmers are destocking (in anticipation of continued sub-optimal conditions that would likely increase animal mortality); and rise towards the end of a drought when they hold back sales and try to rebuild herd numbers (in anticipation of a return to 'normal' conditions). The resulting oscillation in price levels across the different phases of drought is likely to determine how the shock's impact affects agricultural income, the income of linked accounts, and hence the welfare of local communities.

These reasons serve as a justification for future research into the economy-wide impact of a climate-based shocks using more complex SAM-based methods. More complex approaches, such as CGE models, also consider quantity effects but do not hold the assumption of fixed prices. Future analyses using these methods can enable policymakers to understand the situation in a more dynamic way, with fewer *ceteris paribus* conditions that do not ignore the impact of price effects and structural behavioural changes.

An additional limitation concerns the extent to which the SAM is able to accurately represent the structure of the provincial economy at present. As outlined in the data description, the original SAM is reflective of the structure and price level of the Northern Cape economy as it stood in 2004. While provisions were to overcome this by inflating each cell's financial values to 2021 prices, and a brief analysis was conducted to confirm that the structure of the Northern Cape's economy has remained relatively stable over the intervening period, this approach is nonetheless an imperfect substitute for working with an up-to-date dataset.

Another short-coming of the study is the use of a SAM dataset that does not disaggregate accounts into sub-sectors would prove useful for examining intra-industry relationships. For this paper, having accounts which are disaggregated into agricultural sub-sectors – such as crops, livestock, fisheries and aquaculture, and forestry – would allow for more specific climate shocks to be assessed. This paper has considered the impact of a blanket negative 10 percent shock to agriculture (which, in the SAM dataset, incorporates all of the previously outlined sub-sectors), but it could be improved by examining the impact on specific sub-sectors, for the effect of a climate shock (a drought, in this case) is likely to differ depending on the extent to which its production process is reliant on water obtained through rainfall. For example, the impact of a drought is likely to be felt more starkly in dryland farming regions than in irrigation crop farming.

Developing a disaggregated regional SAM could prove an invaluable step that allows multiplier analyses to shed light on the economy-wide impact on a range of other climate shocks. Another example of this type of impact assessment in agriculture could be conducted in fisheries. In the Northern Cape, specifically, the effects of the Benguela Niño are of interest to local communities and policymakers alike. The abnormal atmospheric conditions in the western tropical Atlantic which influences the Benguela Upwelling System (BUS) can exert effects on both onshore rainfall – and therefore agriculture – and offshore sea temperatures and upwelling conditions – and therefore fisheries (Boyer et al., 2000). If one could obtain estimates of sea temperature changes during a Benguela Niño and correlate these to changes in catches, then a SAM-based multiplier analysis could be used to assess the economy-wide impact of the phenomenon, as pertains shock to fisheries.

IX) Conclusion

Drought has been a perennial cause of distress to local communities in South Africa's Northern Cape province. Water shortages affect livelihoods through a variety of mechanisms, causing disruptions to certain economic sectors that heavily rely on water as a production input. However, recent droughts have demonstrated the potential for prolonged climatological shifts to exert devastating effects on local communities. Agriculture is a sector that has shown an acute vulnerability to water shortages, for its use in crucial production processes including crop irrigation and the maintenance of livestock. Furthermore, linkages between agriculture and other economic sectors are likely to exacerbate the initial impact of a negative shock to agricultural commodities, suggesting the presence of a significant multiplier effect.

To contribute to the literature that seeks to address this issue, this study has used a SAM-based multiplier approach to investigate the economic impacts of climate shocks (such as a drought) in South Africa's Northern Cape province – a low rainfall area prone to regular droughts.

In an effort to trace the economy-wide impact, the methodological choice of a SAM-based multiplier analysis has produced several results, although these are subject to the constraining assumption of fixed relative prices. They suggest that the negative 10 percent exogenous shock to agricultural commodities exerts significant indirect and induced effects throughout the Northern Cape economy. Sectors involved in the production of intermediate goods and consumer goods were found to experience the largest decline in response to the agricultural shock. In line with expectations, unskilled labourers and their dependent communities were found to experience the bulk of the distributional impact – an important consideration for policymakers. However, the simulation also demonstrated that skilled labour incomes were more sensitive when the income-expenditure loop was incorporated. This can be primarily ascribed to the fact that services industries, which allocate the largest share of labour expenditure to skilled labourers, suffer reduced revenues due to lower levels of household income. A significant proportion of this income is obtained from returns to investment in the enterprises account – and hence proportionately reduce their expenditure on production inputs.

Despite overlooking the price effects, the SAM-based multiplier analysis can prove a useful tool for stakeholders and policymakers to understand the urgency of devising appropriate mitigation measures, as decreased production yields are bound to impact market supply for agricultural commodities and those produced in linked sectors, *ceteris paribus*. In terms of offsetting the local impact of the initial shock to the agricultural sector and its stakeholders – both farm-owners and labourers – the results suggest that expanding access to credit can be a helpful tool in the short-run to limit the induced effects. When the shock is long lasting (as occurs with prolonged droughts) then short-term farm and household credit is no solution, and the implications are likely to be more severe, pointing to the need for more direct adaptation measures.

X) References

Acevedo, S., Mrkaic, M., Novta, N., Pugacheva, E. and Topalova, P. 2020. The Effects of Weather Shocks on Economic Activity: What are the Channels of Impact? *Journal of Macroeconomics*. 65(C). DOI: 10.1016/j.jmacro.2020.103207

Agri SA. 2016. A Raindrop in the Drought – Agri SA's status report on the current drought crisis. Economic Outlook Report 6, February 2016. Agricultural Research Council (ARC).

Agri SA. 2019. Agriculture Drought Report 2019/2020. 2019. Agricultural Research Council (ARC).

Arndt, C., Davies, R., Gabriel, S., Harris, L., Makrelov, K., Robinson, S., Simbanegavi, W., Van Seventer, D. and Anderson, L. 2020. Impact of Covid-19 on the South African economy: An initial analysis. SA-TIED Working Paper 111, April 2020.

Aslam, K. 2015. Farmers' adaptation to water scarcity in drought-prone environments: A case study of Rajshahi District, Bangladesh. *Agricultural Water Management.* 148. DOI: 10.1016/j.agwat.2014.10.011

Betho, R., Chelengo, M., Jones, S., Keller, M., Mussagy, I. H., van Seventer, D. and Tarp, F. 2021. The macroeconomic impact of COVID-19 in Mozambique: A social accounting matrix approach. *Journal of International Development*. 1– 38.DOI: https://doi.org/10.1002/jid.3601

Boyer, D., Cole, J. and Bartholome, C. 2000. Southwestern Africa: Northern Benguela Current region. *Marine Pollution Bulletin*. 41:123-140.

Breisinger, C., Thomas, M. and Thurlow, J. 2009. Social accounting matrices and multiplier analysis: An introduction with exercises. Food Security in Practice Technical Guide 5. Washington, D.C.: International Food Policy Research Institute. DOI: 10.2499/9780896297838fsp5

Burger, D. Ed. 2008. Northern Cape. In *South Africa Yearbook 2007/2008*.Pretoria: Department of International Relations and Cooperation. Available: http://www.dirco.gov.za/sweden/northern_cape.pdf

Burkart, K.G., Brauer, M., Aravkin, A.Y., Godwin, W.S., Hay, S.I., He, J., Iannucci, V.C., Larson, S.L. et al. 2021. Estimating the cause-specific relative risks of non-optimal temperature on daily mortality: a two-part modelling approach applied to the Global Burden of Disease Study. *The Lancet*. 398(10301):685-697.

Carrão, H., Naumann, G. and Barbosa, P. 2016. Mapping global patterns of drought risk: An empirical framework based on sub-national estimates of hazard, exposure and vulnerability. *Global Environmental Change*. 39:108–124. DOI: https://doi.org/10.1016/j.gloenvcha.2016.04.012

Chowdhury, A. and Kirkpatrick, C. 1993. Development Policy and Planning: An Introduction to Models and Techniques. London: Routledge. DOI: http://dx.doi.org/10.4324/9780203423905

Cloete, P.C. and Rossouw, R. 2014, The South African wildlife ranching sector: A Social Accounting Matrix Leontief multiplier analysis. *Acta Commercii*. 14(1). DOI: http://dx.doi.org/10.4102/ac.v14i1.225

Conningarth Economists. 2005. *Provincial Social Accounting Matrix for the Northern Cape Province for 2004* [Dataset]. Unpublished Social Accounting Matrix. Pretoria.
*author's reduced SAM is given in Appendix C.

Dent, M.C., Lynch, S.D. and Schulze, R.E. 1989. *Mapping Mean Annual and Other Rainfall Statistics over Southern Africa.* Water Research Commission. (WRC Report no. 109/1/89). Pretoria: Water Research Commission.

Dilley, M., R.S. Chen, U., Deichmann, A.L., Lerner-Lam, M., Arnold, J., Agwe, P., Buys, O., Kjekstad, B.L. and Yetman, G. 2005. Natural Disaster Hotspots: A Global Risk Analysis. No. 5 Disaster Risk Management Series. Washington, D.C.: The World Bank Hazard Management Unit.

"Drought in Northern Cape". 2019. *Solomon Star* [Online]. Available: https://solomonstar.co.za/drought-in-northern-cape/ [2021, November 30]

Du Toit, J.C.O. and O'Connor, T.G. 2014. Changes in rainfall pattern in the eastern Karoo, South Africa, over the past 123 years. *Water SA*. 40:453-460.

Eckert, J.B., Liebenberg, G.F. and Troskie, D.P. 1997. An agricultural SAM for the Western Cape. *Development Southern Africa.* 14(2):275-283. DOI: https://doi.org/10.1080/03768359708439963

Fannin, B. 2012. Updated 2011 Texas agricultural drought losses total $7.62 billion. *AgriLife* [Online]. 21 March. Available: https://agrilifetoday.tamu.edu/2012/03/21/updated-2011-texas-agricultural-drought-losses-total-7-62-billion/ [Accessed: 2021, November 12]

Funk, C., Dettinger, M.D., Michaelsen, J.C., Verdin, J.P., Brown, M.E., Barlow, M. and Hoell, A. 2008. Warming of the Indian Ocean threatens eastern and southern African food security but could be mitigated by agricultural development. *Proceedings of the National Academy of Sciences of the United States of America*. 105(32):11081–11086. DOI: https://doi.org/10.1073/pnas.0708196105

Galbusera, L. and Giannopoulos, G. 2018. On input-output economic models in disaster impact assessment. *International Journal of Disaster Risk Reduction.* 30(B):186-198.

Gbetibouo, G. A. and Ringler, C. 2009. Mapping South African Farming Sector Vulnerability to Climate Change and Variability. IFPRI Discussion Paper 885. Washington, D.C. USA: IFPRI.

Golan, E.H., Vogel, S.J., Frenzen, P.D. and Ralston, K.L. 2000. Tracing the Costs and Benefits of Improvements in Food Safety. Agricultural Economic Report 791. USA: Food and Rural Economics Division, Economic Research Service, US Department of Agriculture.

Food and Agriculture Organization. N.d. Agricultural sub-sectors. Available: https://www.fao.org/rural-employment/agricultural-sub-sectors/en/ [2022, January 12]

Haggblade, S., Hammer, J. and Hazell, P. 1991. Modelling agricultural growth multipliers. *American Journal of Agricultural Economics*. 73(2):361–74.

Hallegatte, S. 2008. An adaptive regional input-output model and its application to the assessment of the economic cost of Katrina. *Risk Analysis: An International Journal.* 28(3):779-799.

Handmer, J., Y. Honda, Z.W., Kundzewicz, N., Arnell, G., Benito, J., Hatfield, I.F., Mohamed, P., Peduzzi, S. et al. 2012. Changes in impacts of climate extremes: human systems and ecosystems. In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation*. C.B. Field, T.F.V. Barros, D. Stocker, D.J. Qin, K.L. Dokken, M.D. Ebi, K.J. Mastrandrea, G. Mach, Eds. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). UK: Cambridge University Press. 231-290.

Harmse, C.J., Du Toit, J.C.O., Swanepoel, A. and Gerber, H.J. 2021. Trend analysis of long-term rainfall data in the Upper Karoo of South Africa. *Transactions of the Royal Society of South Africa.* 76(1):1-12. DOI: 10.1080/0035919X.2020.1834467

Höppe, P. and T. Grimm, 2009. Rising natural catastrophe losses: What is the role of climate change? *In Economics and Management of Climate Change: Risks, Mitigation and Adaptation*. B. Hansjürgens & R. Antes, Eds. Heidelberg, Germany: SpringerVerlag. 13-22.

Jafri, S. H. A. and Buland, D. 2016. Economic Impact of Erath County's Dairy Industry. *Texas Journal of Agriculture and Natural Resources.* 19:8–22. DOI: https://txjanr.agintexas.org/index.php/txjanr/article/view/107

Jahn, M. 2015. Economics of extreme weather events: Terminology and regional impact models. *Weather and Climate Extremes*. 10(B):29-39. DOI: https://doi.org/10.1016/j.wace.2015.08.005.

Janse van Vuuren, P.F. 2015. Regional Resource Flow Model Social Accounting Matrix Analysis. March 2015. Cape Town: GreenCape. DOI: 10.13140/RG.2.2.10498.68802

Jappelli, T. and Pistaferri, L. 2010. The Consumption Response to Income Changes. *Annual Review of Economics.* 2020(2):479-506. DOI: 10.1146/annurev.economics.050708.142933

Jones, L.P. 1973. The Measurement of Hirshmanian Linkages. *Quarterly Journal of Economics*. 90(2):323-333.

Jones, P.G. and Thornton, P.K. 2003. The Potential Impacts of Climate Change on Maize Production in Africa and Latin America in 2055. *Global Environmental Change.* 13:51-59. DOI: https://doi.org/10.1016/S0959-3780(02)00090-0

Jordaan, A. J., Sakulski, D. and Jordaan, A. D. 2013. Interdisciplinary drought risk assessment for agriculture: the case of communal farmers in the Northern Cape Province, South Africa. *South African Journal of Agricultural Extension.* 41:1-16.

Josling, T. 1985. Markets and prices: links between agriculture and the general economy. *European Review of Agricultural Economics*. 38:243–256.

Koks, E.E. and Thissen, M. 2016. A Multiregional Impact Assessment Model for disaster analysis. *Economic Systems Research.* 28:4. 429-449. DOI: 10.1080/09535314.2016.1232701

Kundzewicz, Z. 2003. Water and climate – The IPCC TAR perspective. *Nordic Hydrology*. 34(5):387-398.

Kuwayama, Y., Thompson, A., Bernknopf, R., Zaitchik, B. and Vail, P. 2019. Estimating the Impact of Drought on Agriculture Using the U.S. Drought Monitor. *American Journal of Agricultural Economics.* 101:193-210. DOI: https://doi.org/10.1093/ajae/aay037

Lobell, D., M. Burke, C., Tebaldi, M., Mastrandea, W.F. and Naylor, L. 2008. Prioritising Climate Change Adaptation needs for Food Security. *Science*. 319:607–610.

Lomborg, B. 2021. Data contradicts climate-alarmist reporting. *Business Day* [Online]. Available: https://www.businesslive.co.za/bd/opinion/2021-09-13-bjorn-lomborg-data-contradicts-climate-alarmist-reporting/ [2022, December, 21]

Mainar-Causapé, A.J., Ferrari, E. and McDonald, S. 2018. Social accounting matrices: basic aspects and main steps for estimation. JRC Technical Reports (EUR 29297 EN). Luxembourg: Publications Office of the European Union. DOI:10.2760/010600

Maluleke, I. 2020. The effects of drought on agriculture. *Grain SA* [Online]. Available: https://www.grainsa.co.za/the-effects-of-drought-on-agriculture [2021, December 12]

Mann, K. H. and Lazier, J.R.N. 2006. *Dynamics of Marine Ecosystems: Biological-Physical Interactions in the Oceans*. 3rd edition. Oxford: Blackwell Publishing Ltd.

McDonald, S. and Punt, C. 2002. Supply constraints, export opportunities and agriculture in the Western Cape of South Africa. *Studies in Economics and Econometrics.* 26(1). DOI: https://hdl.handle.net/10520/EJC21793

Meza, I., Siebert, S., Döll, P., Kusche, J., Herbert, C., Eyshi, E., Rezaei, H., Nouri, H. et al. 2020. Global-scale drought risk assessment for agricultural systems. Natural Hazards and Earth System Sciences. 20(2020):695-712. DOI: 10.5194/nhess-20-695-2020

Mkentane, L. 2019. SA's drought is costing the agriculture sector billions of rand. *Business Day* [Online]. Available: https://www.businesslive.co.za/bd/national/science-and-environment/2019-11-12-sas-drought-is-costing-the-agriculture-sector-billions-of-rand/ [2022, September 2]

Nelson, G. 1992. Equatorial wind and atmospheric pressure spectra as metrics for primary productivity in the Benguela system. *South African Journal of Marine Science*. 12:19–28. DOI:10.2989/02577619209504687

Northern Cape Provincial Government. 2021. *Northern Cape Socio-economic Review and Outlook – 2021*. Kimberley: Northern Cape Provincial Government Available:

http://www.ncpt.gov.za/Portals/0/NC%20Socio%20Economic%20Review%20and%20Outlook%202021.pdf?ver=QnfVoKugQ8RDzLHVwzSEHA%3d%3d

Okuyama, Y. 2003. Critical Review of Methodologies on Disaster Impact Estimation. Global Facility for Disaster Reduction and Recovery (GFRR).

Okuyama, Y. and J.R. Santos. 2014. Disaster Impact and Input-Output Analysis. *Economic Systems Research*. 26:1–12.

Organization for Economic Co-operation and Development. 2021. Consumer Price Index: All Items for South Africa. retrieved from Federal Reserve Bank of St. Louis Available: https://fred.stlouisfed.org/series/ZAFCPIALLMINMEI

Pyatt, G. 1988. A SAM Approach to Modelling. *Journal of Policy Modelling*. 10(3):327-352.

Pyatt G. and Round, J.I., Eds. 1985. Social Accounting Matrices: A Basis for Planning. Washington, D.C.: The World Bank.

Qukula, Q. 2019. Northern Cape drought causing severe distress to local economy. *Cape Talk* [Online]. Available: https://www.capetalk.co.za/articles/362212/northern-cape-drought-causing-severe-distress-to-local-economy [2021, November 12]

Reinert, K. A. and Roland-Holst, D.W. 1997. Social Accounting Matrices. In *Applied Methods for Trade Policy Analysis: A Handbook.* J. F. Francois & K. A. Reinert, Eds. Cambridge: Cambridge University Press. 94-121.

Roberts, D. 1990. A comparison of input-output methods for analysis in agricultural economics. Manchester Working Papers in Agricultural Economics (WP90/03). U.K.: University of Manchester.

Rose, A. 2004. Economic Principles, Issues, and Research Priorities in Hazard Loss Estimation. In *Modeling Spatial and Economic Impacts of Disasters.* Y. Okuyama & S. Chang, Eds. Heidelberg: Springer. 13-36.

Round, J. 2003. Social Accounting Matrices and SAM-based Multiplier Analysis. In *The impact of economic policies on poverty and income distribution: Evaluation techniques and tools*. F. Bourguignon, & L. A. Pereira da Silva, Eds. Washington, DC: World Bank and Oxford University Press. 301–320.

Samuels, M.I., Allsopp and Knight, R.S. 2007. Patterns of resource use by livestock during and after drought on the commons of Namaqualand, South Africa. *Journal of Arid Environments.* 70(4):728-739. DOI: 10.1016/j.jaridenv.2006.11.006

Santos, J.R. and Haimes, Y.Y. 2004. Modelling the demand reduction input-output (I-O) inoperability due to terrorism of interconnected infrastructures. *Risk Analysis: An International Journal.* 24(6):1437-1451.

Schaub, S. and Finger, R. 2020. Effects of drought on hay and feed grain prices. *Environmental Research Letters.* 15(3). DOI: https://doi.org/10.1088/1748-9326/ab68ab

Shannon, L.V., Boyd, A.J., Brundrit, G.B. and Taunton-Clark, J. 1986. On the existence of an El Nino-type phenomenon in the Benguela system. *Journal of Marine Research*. 44:495-520.

Shreiner, B.G., Mungatana, E.D. and Baleta, H. 2018. Impacts of Drought Induced Water Shortages in South Africa: Economic Analysis. *Water Research Commission.* WRC Report No. 2604/1/18. http://www.wrc.org.za/wp-content/uploads/mdocs/2604%20Vol%201.pdf

Siddig, K.A. 2011. *Impacts of climate change on agriculture*. UNU WIDER Conference: Impacts of Climate Change on Agriculture. Rabat, Morocco, 6-7 December 2011. New York: United Nations.

Taljaard, P.R. 2007. THE MACRO ECONOMY AND IRRIGATION AGRICULTURE IN THE NORTHERN CAPE PROVINCE OF SOUTH AFRICA. Philosohiae Doctor dissertation. University of the Free State.

Thornton, P.K., Ericksen, P.J., Herrero, M. and Challinor, A.J. 2014. Climate variability and vulnerability to climate change: a review. *Global Change Biology.* 20(11):3313-3328. https://doi.org/10.1111/gcb.12581

Trade and Industrial Policy Strategies. 2016. Provincial Review 2016: Northern Cape. Available: https://www.tips.org.za/images/The_REB_Provincial_Review_2016_Northern_Cape.pdf

United Nations. 1999. *Handbook of input-output table compilation and analysis*, (Studies in methods, Series F, No 74). New York: United Nations.

UNDRR. 2009. Chapter 6: Special Section on Drought. In *Global Assessment Report on Disaster Risk Reduction 2019.* New York: United Nations.

Van Leeuwen, E.S., Nijkamp, P. & Rietveld, P. 2005. Regional Input-Output Analysis. In *Encyclopedia of Social Measurement*. K. Kempf-Leonard, Ed. Oxford: Elsevier. 317-323.

Van Seventer, D. 1999. The estimation of a system of provincial input-output tables for South Africa. Studies in Economics and Econometrics. 23(2):55-75. DOI: 10.1080/03796205.1999.12129258

Van Seventer, D., Bold, S., Gabriel, S. and Davies, R. 2019. A 2015 social accounting matrix for South Africa. SA-TIED Working Paper #35. March 2019.

Waldron, H. N. and Probyn, T. A. 1992. Nitrate supply and potential new production in the Benguela system. *South African Journal of Marine Science*. 12:29–39. DOI:10.2989/02577619209504688

Walker, C., Milton, S.J., O'Connor, T.G., Maguire, J.M. and Dean, W.R.J. 2018. Drivers and trajectories of social and ecological change in the Karoo, South Africa. *African Journal of Range & Forage Science.* 35(3-4):157-177. DOI: https://doi.org/10.2989/10220119.2018.1518263

Webster, D. 2020. Seven lean years in the Northern Cape. *Mail and Guardian* [Online]. Available: https://mg.co.za/article/2020-02-18-seven-lean-years-in-the-northern-cape/ [2022, January 12]

Wu, J., Li, N., Hallegatte, S., Shi, P., Hu, A. and Liu, X. 2012. Regional indirect economic impact evaluation of the 2008 Wenchuan Earthquake. *Environmental Earth Sciences.* 65(1):161-172.

Ziolkowska, J.R. 2016. Socio-Economic Implications of Drought in the Agricultural Sector and the State Economy. *Economies.* 2016(4). DOI: https://doi.org/10.3390/ECONOMIES4030019

XI) Appendices

Appendix A. Summary of author's SAM aggregations
Author's aggregation of activities and commodities accounts:

Agriculture - Commercial	**Agriculture**
Agriculture - Subsistence	
Diamond mining	**Mining**
Iron ore mining	
Other mining	
Meat, Fish, Fruit, Vegetables, Oils and Fat Products	**Consumer Goods**
Dairy products	
Grain Mill, Bakery and Animal Feed Products	
Other food products	
Beverages and tobacco products	
Textiles, Clothing, Leather Products and Footwear	
Wood and Wood Products	
Furniture	
Paper and Paper Products	
Publishing and Printing	
Chemicals & Chemical Products (incl. Plastic Products)	**Intermediate Goods**
Rubber Products	
Non-Metallic Mineral Products	
Basic Metal Products	**Metal Products**
Structural Metal Products	
Other Fabricated Metal Products	
Machinery & Equipment	**Capital Goods**
Electrical Machinery & Apparatus	
Communication, Medical and other Electronic Equipment	
Manufacturing of Transport Equipment	
Handcrafts & curios - Informal	
Other Manufacturing & Recycling	
Other manufacturing - Informal	
Electricity	**Electricity**
Water	**Water**
Buildings	**Construction**
Other construction	
Construction - Informal	
Trade	**Private Services**
Accommodation	
Trade, accommodation & entertainment - Informal	
Transport services	

Transport - Combi-taxi	
Communications	
Insurance	
Real estate	
Business activities	
Other services - Informal	
Health and social work	
Activities/services	
General Government	**Government Services**

Author's aggregation of factor accounts:

Legislators, senior officials and managers	**Skilled Labourers**
Professionals	
Technical & associate professionals	
Clerks	**Semi-skilled Labourers**
Service workers, shop & market sales workers	
Skilled agricultural and fishery workers	
Craft and related traders workers	
Plant and machine operators & assemblers	
Elementary occupations	**Unskilled Labourers**
Domestic workers	
Occupation unspecified[11]	
All capital accounts	**Capital**

Aggregation of Institutional Accounts:

All household accounts	**Households**
All government accounts	**Government**
All capital accounts	**Capital**
All Rest of World (SA) accounts	**Rest of World (SA)**
All Rest of World (International) accounts	**Rest of World (International)**
All enterprise accounts	**Enterprises**

[11] No entries are recorded for 'Occupation unspecified'

Appendix B. Derivation for the unconstrained multiplier formula:
The formulae given below are adapted from equations (4.1) through to (4.11) in Breisinger et al. (2009:18-19) and serve as the basis for the derivation of the unconstrained multiplier formula in the methodology of this study.

We can express the SAM entries as letters or symbols, where:

X is the gross output of each activity (i.e. X_1, X_2)

Z is total demand for each commodity (i.e. Z_1, Z_2)

V is total factor income

Y is total household income

E is exogenous components of demand

Each column cell in the SAM is divided by its column total to derive the coefficients matrix, known as the M-matrix, that excludes the exogenous demand components, where:

a is technical coefficients (input/intermediate shares in production)

b is the share of domestic output in total demand

v is the share of factor income (or value-added) in gross output

l is the share of the value of total demand from exports or commodity taxes

c is the expenditure shares of household consumption

s is household savings as a share of total household income (i.e. the household savings rate)

Using the representative symbols in the SAM, total demand (Z) in each sector is the sum of intermediate input demand, household consumption demand, and other exogenous sources of demand (E).

(4.1)

$$z_1 = a_{11}X_1 + a_{12}X_2 + c_1Y + E_1$$

$$z_2 = a_{21}X_1 + a_{22}X_2 + c_2Y + E_2$$

Gross output (X) is only a part of total demand (Z), as shown in Equations (4.2).

(4.2)

$$X_1 = b_1Z_1$$

$$X_2 = b_2Z_2$$

Household income depends on the share of factors' earning in each sector, as shown in Equation (4.3).

(4.3)

$$Y = v_1 X_1 + v_2 X_2$$

We find the following identity for total income Y by substituting Equation (4.2) into (4.3).

(4.4)

$$Y = v_1 b_1 Z_1 + v_2 b_2 Z_2$$

We replace the X and Y terms in Equations (4.1) using Equations (4.2) and (4.4).

(4.5)

$$Z_1 = a_{11} b_1 Z_1 + a_{12} b_2 Z_2 + c_1 (v_1 b_1 Z_1 + v_2 b_2 Z_2) + E_1$$

$$Z_2 = a_{21} b_1 Z_1 + a_{22} b_2 Z_2 + c_2 (v_1 b_1 Z_1 + v_2 b_2 Z_2) + E_2$$

We arrange Equations (4.5) to move all terms, except for exogenous demand E, onto the left-hand side.

(4.6)

$$Z_1 - a_{11} b_1 Z_1 - c_1 v_1 b_1 Z_1 - a_{12} b_2 Z_2 - c_1 v_2 b_2 Z_2 = E_1$$

$$-a_{21} b_1 Z_1 - c_2 v_1 b_1 Z_1 + Z_2 - a_{22} b_2 Z_2 - c_2 v_2 b_2 Z_2 = E_2$$

We group together the Z terms.

(4.7)

$$(1 - a_{11} b_1 - c_1 v_1 b_1) Z_1 + (-a_{12} b_2 - c_1 v_2 b_2) Z_2 = E_1$$

$$(-a_{21} b_1 - c_2 v_1 b_1) Z_1 + (1 - a_{22} b_2 - c_2 v_2 b_2) Z_2 = E_2$$

We then use matrix algebra to convert Equations (4.7) into matrix format.

(4.8)

$$\begin{pmatrix} 1 - a_{11} b_1 - c_1 v_1 b_1 & -a_{12} b_2 - c_1 v_2 b_2 \\ -a_{21} b_1 - c_2 v_1 b_1 & 1 - a_{22} b_2 - c_2 v_2 b_2 \end{pmatrix} \begin{pmatrix} Z_1 \\ Z_2 \end{pmatrix} = \begin{pmatrix} E_1 \\ E_2 \end{pmatrix}$$

The first term in Equation (4.8) is the identity matrix (I) minus the coefficient matrix (M).

(4.9)

$$\begin{pmatrix} 1 - a_{11}b_1 - c_1v_1b_1 & -a_{12}b_2 - c_1v_2b_2 \\ -a_{21}b_1 - c_2v_1b_1 & 1 - a_{22}b_2 - c_2v_2b_2 \end{pmatrix} = I - M$$

Renaming the other two vectors Z and E, we express Equation (4.8) as Equation (4.10).

(4.10)

$$(I - M)Z = E$$

By rearranging the terms in Equation (4.10), we find the multiplier formula given as Equation (4.11).

(4.11)

$$Z = (I - M)^{-1}E$$

Appendix C. Reduced 2004 Northern Cape SAM adapted from Conningarth Economists (2005).

Reduced SAM (from Left to Right):

SAM - [R millions, 2021 Prices]

		Activities										
		aAgriculture	*aMining*	*aConsumerGoods*	*aIntermediateGoods*	*aMetalProducts*	*aCapitalGoods*	*aElectricity*	*aWater*	*aBuildings*	*aPrivateServices*	*aGovernmentServices*
Activities	*aAgriculture*	-	-	-	-	-	-	-	-	-	-	-
	aMining	-	-	-	-	-	-	-	-	-	-	-
	aConsumerGoods	-	-	-	-	-	-	-	-	-	-	-
	aIntermediateGoods	-	-	-	-	-	-	-	-	-	-	-
	aMetalProducts	-	-	-	-	-	-	-	-	-	-	-
	aCapitalGoods	-	-	-	-	-	-	-	-	-	-	-
	aElectricity	-	-	-	-	-	-	-	-	-	-	-
	aWater	-	-	-	-	-	-	-	-	-	-	-
	aConstruction	-	-	-	-	-	-	-	-	-	-	-
	aPrivateServices	-	-	-	-	-	-	-	-	-	-	-
	aGovernmentServices	-	-	-	-	-	-	-	-	-	-	-
Commodities	*cAgriculture*	553.02	2.35	1 413.74	16.47	0.22	26.79	1.14	-	0.47	155.22	4.66
	cMining	25.70	244.33	19.20	286.33	3.72	13.19	225.87	26.80	69.45	50.74	3.32
	cConsumerGoods	966.49	142.26	1 422.95	49.78	2.68	38.99	9.28	12.66	67.11	2 537.36	47.07
	cIntermediateGoods	1 363.99	2 391.73	296.31	438.70	13.31	75.76	16.51	68.63	707.78	4 165.79	96.61
	cMetalProducts	60.50	461.21	51.79	56.71	154.49	182.34	15.23	17.77	211.77	170.55	5.57
	cCapitalGoods	486.67	2 133.58	102.51	49.28	8.73	378.58	110.01	118.26	326.03	4 141.37	201.90
	cElectricity	51.70	1 193.38	39.09	23.87	2.63	4.65	140.30	57.43	9.32	502.79	4.16
	cWater	14.64	321.31	7.59	2.04	0.11	0.51	4.21	318.61	1.87	97.59	2.13
	cConstruction	36.93	123.55	0.06	-	-	-	114.89	-	531.33	641.49	18.77
	cPrivateServices	1 510.55	5 147.61	801.13	429.91	18.10	83.21	130.71	127.18	566.06	19 521.49	310.59
	cGovernmentServices	-	-	-	-	-	-	0.40	-	-	161.77	217.36
Factor Payments	*Skilled Labourers*	149.47	2 198.48	163.89	66.03	14.21	48.46	110.64	37.71	87.95	6 477.03	352.38
	Semi-skilled Labourers	448.91	5 687.10	238.76	93.94	23.17	59.16	165.24	47.35	231.05	4 475.74	766.49
	Unskilled Labourers	467.86	1 302.50	73.70	23.24	3.01	9.43	13.73	17.12	123.43	896.95	107.87
	Capital	3 309.41	14 973.96	575.36	321.70	19.66	75.34	431.89	213.34	351.46	13 455.12	172.84
Institutions	*Enterprises*	-	-	-	-	-	-	-	-	-	-	-
	Households	-	-	-	-	-	-	-	-	-	-	-
	Government	3.59	33.94	5.18	4.70	1.16	3.06	1.29	0.36	5.63	70.41	2.62
	Capital Account	-	-	-	-	-	-	-	-	-	-	-
	RoW - SA	-	-	-	-	-	-	-	-	-	-	-
	RoW	-	-	-	-	-	-	-	-	-	-	-
	Total	9 449.43	36 357.28	5 211.27	1 862.69	265.19	999.47	1 491.35	1 063.22	3 290.71	57 521.40	2 314.32

Reduced SAM continued.

SAM - [R millions, 2021 Prices]

		Commodities										
		cAgriculture	*cMining*	*cConsumerGoods*	*cIntermediateGoods*	*cMetalProducts*	*cCapitalGoods*	*cElectricity*	*cWater*	*aConstruction*	*cPrivateServices*	*cGovernmentServices*
Activities	*aAgriculture*	9 315.93	-	-	-	-	-	-	-	133.50	-	-
	aMining	-	35 368.48	-	-	68.86	1.04	-	-	862.17	56.74	-
	aConsumerGoods	13.32	-	4 862.65	29.32	-	1.50	-	-	-	304.48	-
	aIntermediateGoods	-	-	1.05	1 765.33	-	1.73	-	-	-	94.58	-
	aMetalProducts	-	-	-	-	251.55	3.23	-	-	-	10.41	-
	aCapitalGoods	-	-	-	-	0.58	945.28	-	-	-	53.61	-
	aElectricity	-	-	-	-	-	-	1 443.23	-	45.97	2.15	-
	aWater	-	-	-	-	-	-	-	1 063.22	-	-	-
	aConstruction	-	-	-	-	-	-	-	-	3 225.74	64.97	-
	aPrivateServices	-	-	-	-	-	-	-	-	-	57 521.40	-
	aGovernmentServices	-	-	-	-	-	-	-	-	-	-	2 314.32
Commodities	*cAgriculture*	-	-	-	-	-	-	-	-	-	-	-
	cMining	-	-	-	-	-	-	-	-	-	-	-
	cConsumerGoods	-	-	-	-	-	-	-	-	-	-	-
	cIntermediateGoods	-	-	-	-	-	-	-	-	-	-	-
	cMetalProducts	-	-	-	-	-	-	-	-	-	-	-
	cCapitalGoods	-	-	-	-	-	-	-	-	-	-	-
	cElectricity	-	-	-	-	-	-	-	-	-	-	-
	cWater	-	-	-	-	-	-	-	-	-	-	-
	cConstruction	-	-	-	-	-	-	-	-	-	-	-
	cPrivateServices	-	-	-	-	-	-	-	-	-	-	-
	cGovernmentServices	-	-	-	-	-	-	-	-	-	-	-
Factor Payments	*Skilled Labourers*	-	-	-	-	-	-	-	-	-	-	-
	Semi-skilled Labourers	-	-	-	-	-	-	-	-	-	-	-
	Unskilled Labourers	-	-	-	-	-	-	-	-	-	-	-
	Capital	-	-	-	-	-	-	-	-	-	-	-
Institutions	*Enterprises*	-	-	-	-	-	-	-	-	-	-	-
	Households	-	-	-	-	-	-	-	-	-	-	-
	Government	87.20	45.18	1 664.14	1 594.86	37.80	1 010.23	90.29	22.23	592.06	1 610.30	22.98
	Capital Account	-	-	-	-	-	-	-	-	-	-	-
	RoW - SA	90.45	844.90	5 270.58	6 586.65	1 083.45	12 429.10	1 288.39	47.95	4 203.26	11 428.18	246.08
	RoW	23.71	221.53	1 381.90	1 726.96	284.07	3 258.80	337.81	12.57	1 102.06	2 996.36	64.52
	Total	9 530.60	36 480.08	13 180.32	11 703.12	1 726.31	17 650.92	3 159.72	1 145.97	10 164.77	74 143.18	2 647.90

Reduced SAM continued.

SAM - [R millions, 2021 Prices]

		Factor Payments				Institutions						
		Skilled Labourers	*Semi-skilled Labourers*	*Unskilled Labourers*	*Capital*	*Enterprises*	*Households*	*Government*	***Capital Account***	***RoW - SA***	***RoW***	*Total*
Activities	*aAgriculture*	-	-	-	-	-	-	-	-	-	-	9 449.43
	aMining	-	-	-	-	-	-	-	-	-	-	36 357.28
	aConsumerGoods	-	-	-	-	-	-	-	-	-	-	5 211.27
	aIntermediateGoods	-	-	-	-	-	-	-	-	-	-	1 862.69
	aMetalProducts	-	-	-	-	-	-	-	-	-	-	265.19
	aCapitalGoods	-	-	-	-	-	-	-	-	-	-	999.47
	aElectricity	-	-	-	-	-	-	-	-	-	-	1 491.35
	aWater	-	-	-	-	-	-	-	-	-	-	1 063.22
	aConstruction	-	-	-	-	-	-	-	-	-	-	3 290.71
	aPrivateServices	-	-	-	-	-	-	-	-	-	-	57 521.40
	aGovernmentServices	-	-	-	-	-	-	-	-	-	-	2 314.32
Commodities	*cAgriculture*	-	-	-	-	-	301.06	20.26	-	6 128.43	906.77	9 530.60
	cMining	-	-	-	-	-	43.93	12.33	-	2 349.36	33 105.80	36 480.08
	cConsumerGoods	-	-	-	-	-	6 128.67	463.29	2.05	904.72	384.97	13 180.32
	cIntermediateGoods	-	-	-	-	-	1 044.82	596.62	2.05	361.43	63.10	11 703.12
	cMetalProducts	-	-	-	-	-	97.30	102.18	-	55.32	83.58	1 726.31
	cCapitalGoods	-	-	-	-	-	1 165.21	779.07	7 220.95	314.06	114.72	17 650.92
	cElectricity	-	-	-	-	-	411.85	714.64	-	-	3.91	3 159.72
	cWater	-	-	-	-	-	133.44	241.93	-	-	-	1 145.97
	cConstruction	-	-	-	-	-	-	489.96	8 200.87	-	6.92	10 164.77
	cPrivateServices	-	-	-	-	-	29 546.95	1 890.79	-	9 846.74	4 212.16	74 143.18
	cGovernmentServices	-	-	-	-	-	2 049.63	56.60	-	108.88	53.26	2 647.90
Factor Payments	*Skilled Labourers*	-	-	-	-	-	-	5 413.01	-	227.87	68.07	15 415.19
	Semi-skilled Labourers	-	-	-	-	-	-		-	374.58	111.89	12 723.37
	Unskilled Labourers	-	-	-	-	-	-	177.35	-	130.25	38.91	3 385.35
	Capital	-	-	-	-	-	-	-	-	436.74	145.58	34 482.40
Institutions	*Enterprises*	-	-	-	21 921.38	-	-	300.90	-	-	-	22 222.28
	Households	14 751.84	14 173.36	3 239.67	-	13 984.81	1 096.86	3 036.82	-	150.99	37.75	50 472.08
	Government	-	-	-	323.12	6 255.57	5 992.62	11 746.84	-	6.94	1.85	31 236.17
	Capital Account	-	-	-	9 351.32	788.61	2 283.65	3 106.26	-	-	-103.92	15 425.92
	RoW - SA	398.01	382.40	87.41	2 424.73	894.98	106.01	-	-	-	-26 416.20	21 396.31
	RoW	265.34	254.94	58.27	461.85	298.33	70.08	-	-	-	-	12 819.09
	Total	15 415.19	14 810.70	3 385.35	34 482.40	22 222.28	50 472.08	29 148.85	15 425.92	21 396.31	12 819.09	