Economy-wide impact of drought induced productivity losses

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Abstract

Purpose – The purpose of this paper is to investigate how a drought which initially affects agricultural productivity can ultimately affect an entire economy. The study aims to assess the magnitude of the impact as well as highlight key issues that can inform the implementation of drought mitigation programmes.
Design/methodology/approach – The paper presents the literature on the economic impact of drought and uses a computable general equilibrium model where productivity shocks are applied to the agricultural industries following which the resulting impacts on the rest of the sectors of the economy are obtained.
Findings – The findings show that the key macroeconomic variables, namely, real GDP, industry output, employment, the trade balance and household consumption are negatively affected by the drought shock.
Practical implications – The results point to the fact that in the absence of drought mitigation mechanisms, the occurrence of even a short drought as modelled in this paper can impose substantial socioeconomic losses.
Originality/value – First, a general equilibrium framework which uses climate and economic data when evaluating the social-economic impacts of drought is used. Most studies employ partial equilibrium analysis in analysing drought impacts on specific sectors or crops within a limited geographical area. Others use global or multi-regional models which impose averages on the observed impacts. The current study provides valuable insights on the potential damage which droughts can impose on a single economy. This gives a basis for decision making to support drought mitigation policies and programmes.

Keywords Drought, Environmental change, Water management, Economic impact, Water resources, Climate change impacts, Economics of climate change
Paper type Research paper

1. Introduction and rationale

Climate change is projected to increase drought intensity and frequency worldwide as a result of changes in precipitation patterns and rising temperature (Wanders and Wada, 2015). Lack of precipitation causes meteorological drought and agricultural drought, further propagating into hydrological drought via the drainage network (Sheffield *et al.*, 2012). Droughts impose significant adverse effects on water resources, agricultural sector performance and the overall economic performance of many developing countries[1]. Climate models predict that extreme weather events will become more frequent in the twenty-first century (see e.g. Hertel *et al.*, 2010; IPCC, 2014). Globally, a number of regions are experiencing some of the worst drought conditions on record (Freire-González *et al.*, 2017). Africa continues to be among the highest hit

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regions as well as having the most deaths resulting from droughts (Masinde *et al.*, 2018). In developing economies, there is a strong link between drought and economic performance as such economies depend on rain-fed agriculture which accounts for over 70 per cent of food production, employment and income generation (Masinde *et al.*, 2018). Thus, the importance of estimating the impact of drought is key in developing drought mitigation and adaptation policies (Logar and van den Bergh, 2013).

This paper seeks to investigate and document how drought impacts which initially affect the agricultural sector end up permeating the different sectors of the economy. This is critical given the fact that for many developing countries, drought-related policies are largely focussed on short-term responsive actions such as food aid, rather than proactive planning and long-term mitigation strategies. Ding *et al.* (2011) note that whereas responsive actions are critical for smoothing out short-term disturbances, they are incapable of providing long-term social-economic resilience to future drought impacts. Preparedness with respect to sustainable interventions is therefore fundamental for mitigating future drought risks.

This study adds to the literature on drought impacts in three ways. First, we use a general equilibrium framework in which data from climate and economic models are integrated when evaluating the social-economic impacts. Most studies employ partial equilibrium analysis to estimate the effects of drought on specific sectors or crops within a limited geographical area (see Schlenker and Lobell, 2010). However, partial equilibrium analysis holds the potential effects on other sectors as constant, hence the preference for general equilibrium analysis as it allows for the investigation of the economy-wide impacts of any given shock. It is therefore possible to trace the consequence on other sectors of an expansion or contraction in any given sector.

Second, a number of CGE-based studies use global or multi-regional models, e.g., the GTAP-W (Calzadilla *et al.*, 2014; Berrittella *et al.*, 2007); TERM-H2O (Wittwer, 2012; Horridge and Wittwer, 2008), IMPACT (Zhu *et al.*, 2008) and IMPLAN (Giesecke, 2011). The aggregation and assumptions which are made when developing such models quite often dictates that analysis is based on regional averages. As a result, differences between countries in the same region are not accounted for as local effects are averaged out. The use of a representative developing country model is thus vital as it helps to shed light on the potential impact of a drought on a single economy.

Third, most of these studies have been undertaken in different contexts, and for different motivations. For instance, most studies have been undertaken for developed or upper-middle income countries (see e.g. Calzadilla *et al.*, 2014, for South Africa; Reilly *et al.*, 2003, for the USA; Falloon and Betts, 2009, for Europe). Some studies focus on virtual water trade in specific sectors (Hoekstra and Hung, 2005); while others focus on specific crops within the agricultural sector (Pauw *et al.*, 2011; Hertel *et al.*, 2010; Skjeflo, 2013). Even for single country general equilibrium models that analyse the impacts of droughts beyond agriculture, some tend to limit their analysis to specific components of the agricultural sector. In addition, the shocks which are imposed on the productivity of primary factors are not based on actual estimates from climate, and econometric models on yield productivity losses (see e.g. Horridge *et al.*, 2005). Therefore, the resulting analysis may present a less accurate picture of the potential economy-wide effects of a drought.

1.1 Objectives

The paper uses a CGE model to analyse the impact of drought on the economy in the short-run. Specifically, the paper:

(1) establishes the extent of output losses that result from the decline in agricultural productivity as a result of a drought;

(2) estimates the resulting output decline on the downstream industries such as the agro-processing component of the manufacturing sector;

(3) determines how the losses emanating from the decline in agricultural sector productivity in turn affect the key macroeconomic variables (GDP, household consumption, employment, import, exports, etc.); and

(4) highlights possible interventions which could be employed to mitigate the resulting adverse impacts on the economy.

2. Quantifying the economic impact of a drought

While the pathways through which drought impacts the economy are many, the primary trigger is loss in production. Various approaches have been used to assess impacts of drought on the economy. See Meyer *et al.* (2013), Chumi and Dudu (2008), Ding *et al.* (2011), Logar and van den Bergh (2013) for a meticulous compilation of the important elements of such drought-related studies in the literature. Methodologies range from linear programming models, surveys, econometric models, input-output (I-O) models, CGE models, through to hybrid models (Cochrane, 1997).

Logar and van den Bergh (2013)[2] contend that market valuation techniques are the most suitable for assessing direct tangible costs that result from drought shocks. However, the I-O and CGE models are the most favoured for quantifying the macroeconomic impacts of drought induced losses. Logar and van den Bergh (2013) and Meyer *et al.* (2013) assert that despite their limitations with respect to the huge data requirements as well as the assumption of perfect adjustment towards the equilibrium, economy-wide approaches that use applied general equilibrium modelling are the most complete methods for analysis that has far-reaching socioeconomic implications. This is because they take all sectors of the economy into account and are therefore capable of capturing both direct and indirect effects (Freire-González *et al.*, 2017).

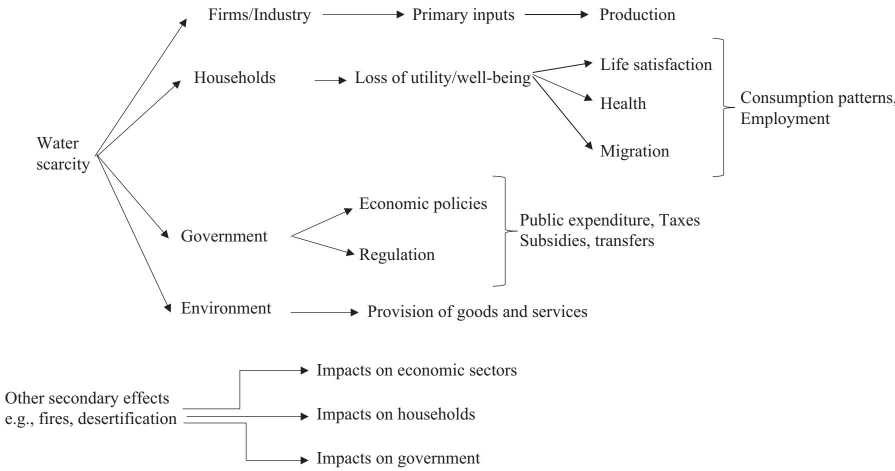
Several studies that analyse the economy-wise impact of drought exist in the literature (see Horridge *et al.*, 2005; Berrittella *et al.*, 2007; Boyd and Ibarrarán, 2009; Pauw *et al.*, 2011; Wittwer and Griffith, 2010). To ensure robustness, CGE models have several validation mechanisms for their results. The most favoured is the back-of-the-envelope (BOTE) technique used to explain results from a particular application of a full-scale model (Dixon and Rimmer, 2013). BOTE construction provides a mechanism for demonstrating that the computations have been performed correctly. Finally, by modifying and extending the BOTE calculations, the reader is able to obtain a reasonably accurate idea of how some of the projections would respond to various changes in the underlying assumptions and data (Dixon *et al.*, 1977, pp. 194-195).

3. Methodology

3.1 Conceptual framework for analysing the impact of a drought

Assessment of the economic impacts of drought requires a framework that can account for its unique characteristics. This paper follows the conceptual framework by Freire-González *et al.* (2017) for assessing the economic impacts of droughts. Essentially, the framework emphasises how policy decisions, responses and planning can interact in the wake of such a climatic shock. An important ingredient of the framework is the recognition that drought is a complex phenomenon with numerous and economy-wide socioeconomic implications (see Figure 1).

In Figure 1, we present the different pathways to the economic impacts which are primarily triggered by losses in production. It is vital to note that the pathways are interrelated given that economies are complex systems with many feedback loops. Figure 1 differentiates between two types of impacts. The first is related to how a lack of water affects different economic agents such as industry, households, government and the environment. The second refers to the secondary effects of a drought from fires,



Source: Freire-González *et al*. (2017)

Figure 1. Economic impacts of drought

desertification, migrations, etc. Detailed analysis of each of the secondary effects can be undertaken using a specific framework of economic analysis, beyond the effects of the lack of water on the economic systems.

3.2 Modelling framework

This section provides the theoretical underpinnings of the economy-wide model used as well as the database structure. These are followed by the articulation of its implementation.

Uganda Applied General Equilibrium (UgAGE) theory and database. We use a single country CGE model known as the UgAGE model. UgAGE is an ORANI-style CGE model built on a database for Uganda (Dixon *et al.*, 1982; Horridge, 2001)[3]. It constitutes of 37 industries and commodities, including 25 within the broader agriculture sector (see Roos *et al.*, 2015). It also features theory and data linked to the demand and supply of taxable water in the economy, similar to that used in the UPGEM model (Blignaut *et al.*, 2008)[4]. The detailed agricultural sector in the model allows for a deeper analysis of how industries and commodities are affected by a drought.

The model's core theoretical structure is typical of most comparative-static CGE models and consists of blocks of equations that describe: industry demand for produced inputs and primary factors; industry supply of goods and services; investor demand for inputs to capital formation; household demand; export demand; government demand; the composition of final purchasers prices that detail the relationship between basic costs, trade and transport margin costs and taxes; market clearing conditions for commodities and primary factors; and numerous other macroeconomic variables and price indices. The model is implemented and solved using the GEMPACK® suite of software programmes[5].

3.3 Model closure

We simulate the impact of a drought by setting up the model's policy closure to reflect a short-run time horizon. This choice of closure is a modified version of the standard Dixon-Parmenter-Sutton-Vincent closure (see Dixon *et al.*, 1982, Chapter 19). It is designed to reflect our interest in the near-term impacts of a drought given that a single drought episode is typically restricted to only a couple of years. In line with typical short-run economic theory, the assumptions of our short-run policy closure restrict any change in capital stock levels and real wages, but allow endogenous movements in employment, and the rate-of-return on capital by industry relative to the baseline.

On the expenditure side, aggregate real investment is set to be exogenous while the investment slack variable is endogenous, in order to shift the supply curve for capital. Keeping investment as exogenous is informed by the expectation that a typical drought does not drag on long enough to alter aggregate investment decisions over a short-run period. Aggregate real consumption and trade balance (in real terms) are endogenous while the ratio of household consumption to GDP is exogenous. In this regard, aggregate real consumption can hence be interpreted as the aggregate index of household welfare. In addition, all tax rates, preference variables and technical change variables are held exogenous in the policy closure. The nominal exchange rate is set as the numeraire.

3.4 Simulation design

We impose exogenous shocks on the economy that are representative of the direct impacts of a drought. The literature identifies two main types of shocks associated with a drought scenario: a reduction in primary factor productivity of agricultural industries that are dependent on rainfall, and a partial and temporary closure of downstream manufacturing industries. Productivity shocks in agriculture were generated based on a synthesis of values from the literature on yield losses under different temperature and precipitation scenarios for different commodity groups (see Hertel *et al.*, 2010). These values are consistent with previous studies on the magnitude and geographical patterns of yield impacts of Cline (2007) and Tebaldi and Lobell (2008). The values of crop yield losses were then used to determine the magnitude of productivity loss. It is these corresponding values of productivity shocks that were applied as technological shock parameters values for each agricultural commodity in the model.

Analysis the impact on the downstream sectors is based on the fact that manufacturers have to cope with lower supplies of inputs following a drought (Wittwer and Griffith, 2011). However, solving for inward farm supply shifts in order to simulate a drought induced shock would result in implausibly large farm output prices. In addition, such a shift in farm supply is associated with spurious terms of trade gains that tend to dominate the scenario. Whereas farm output prices increase in response to drought, such price hikes tend to be small relative to output declines (Wittwer and Griffith, 2010). As the closure condition is short-run, we impose a modelling mechanism that permits a temporary reduction in capital utilisation in response to the deteriorating economic conditions. This is the theory of sticky capital adjustment of Dixon and Rimmer (2009) which evolves as follows: industries operate at full capital so that used capital is equal to existing capital. With a sticky rental adjustment assumption, the rental rate is a profit mark-up on variable costs. This mark-up will thus adjust slowly downwards in response to excess capacity. The capital demand equation is thus modelled as a decreasing function of operating capital.

The sticky rental adjustment mechanism for the downstream agro-processing industry was used in the simulation. This means that operating capital falls relative to existing capital. Instead of responding to reduced farm output by paying much higher input prices, processors reduce capital utilisation (Wittwer and Griffith, 2011). This is equivalent to an inward movement in the agro-processing supply curves and an accompanying reduction in demand for farm inputs. While this has little impact on the agro-processing sector output prices, it reduces the demand for and moderates scarcity-induced price hikes of farm inputs and consequently moderates the fall in the rate-of-return on capital in the agro-processing sector. In turn, smaller farm output price hikes moderates the associated terms of trade effects. In the long-run as the drought impacts clear, the industry resumes full capacity utilisation.

4. Results and discussion

In this section, we present the results from our analysis, first, with the macro-level results, followed by the sectoral results.

4.1 Macro results

Table I presents results for the macroeconomic effects of a drought simulated using the UgAGE model under a short-run closure environment.

From the results, the drought causes GDP to decline. The exogenous shocks imposed due to the drought directly lower productivity across various agriculture industries, thereby reducing the level of agricultural output. This in turn leads to a temporary shutdown of capital in the downstream manufacturing industries. From the results, GDP declines by 4.6 per cent in the short-run, relative to a business-as-usual baseline. With the assumption of sticky real wages and fixed capital stock[6] in the short-run, the loss in GDP from the supply side stems from reduced employment, lower effective capital stock weighted for the shock to the manufacturing industry, and the resulting deterioration in primary factor productivity. Employment weighted by the wage bill declines by 5.1 per cent. Given the relatively low wages which characterise employment in many sectors of developing economies, such a decline in employment can imply higher job losses, induced by the agricultural sector productivity losses.

Household consumption recorded a decline of 4.6 per cent, underscoring the welfare impact of a drought. Furthermore, to highlight the extent of loss which a drought imposes on an economy, the decline in household consumption is in line with that of real GDP. Typically, it would have been expected that the resulting welfare gains from the terms of trade improvement of 2.7 per cent would mitigate the reduction in household consumption to the extent that it does not fall as much as real GDP. However, this is found not to be the case. The terms of trade improved on account of domestic price increases, resulting in a decline in exports by 5.2 per cent.

The decline in household consumption is expected to result in a substitution between the now expensive domestically produced output with the relatively cheaper imported versions of the same. The interaction of this income and substitution effect results in an increase in import volumes, by only 1.7 per cent relative to the baseline. In the absence of any other information, with real GDP and consumption falling, our first guess may have been that

Table I. Results of a drought on the key macroeconomic variables (per cent change deviation)

Variable description	Percentage change
Contribution of the balance of trade to GDP	−1.14
Employment	−5.12
Investment slack variable	−19.12
Terms of trade	2.67
Average land rental	17.74
Investment price index	0.24
Capital stock	−0.96
Consumer price index	1.31
Exports price index	2.67
Export volume	−5.20
Import volume	1.70
Real GDP	−4.59
Primary factor use	−2.37
Household consumption	−4.61
Government expenditure	−4.61

Source: Authors' computations from the UgAGE model imports should also fall by approximately that amount in order to reflect the impact of the drought in dampening domestic demand.

However, the resulting increase in imports by only 1.7 per cent is mainly due to household and industry demands switching away from expensive domestic goods to relatively cheaper imported versions, as predicted by the Armington nests in the theoretical structure of industry and household demand[7]. Among the key export commodities, Maize registered the largest decline in output of 11.9 per cent followed by Beans (11.5 per cent). Output in the manufacturing sector as a whole declined by 13.2 per cent, on account of the partial shutdown of industry capital in the model and the resulting rise in input costs due to the drought. Not surprisingly, imports of tradedables such as beans and manufactured goods increased relative to the baseline following the Armington substitution effect, thereby registering increases of 11.2 and 1.3 per cent, respectively.

4.2 Losses in industry output

In Table II, we present results for the impact of a drought on output for the selected industries. Output for the agricultural industries declined dramatically with coffee being the worst affected. The negative downstream effects are seen in the manufacturing sector via the decline in agro-processing activities within the sector.

It is worth noting that the large negative effects on output are not matched with similar reductions in employment except for coffee farming which registered a decline in labour input of 17 per cent. Indeed employment, especially in the agriculture industries declined but not to the same degree as the decline in output. This is due to the fact that a considerable proportion of the decline in output emanates from reduced productivity of both inputs. With fixed capital, as per the short-run closure rules, the loss in employment defined by effective labour input is minimal. In fact, Horridge *et al.* (2005) in their study of drought in Australia also found minimal declines in employment as defined by physical labour units. This was attributed to the fact that the agricultural sector in Australia is characterised by owner-operators. In the developing economies, changes in employment have a direct impact on household welfare via its effect on households' earning potential. The effect of a drought on household welfare can also be linked to changes in the consumer price index. Indeed, as the results in Table I indicate, household consumption is affected. This implies that the rise in prices has implications for household welfare as most agricultural households often have lower incomes, with equally lower possibilities of compensating through off-farm income generating activities.

Table II. Results of sectoral changes in output(per cent changes)

Commodity	% change	Category		
		Export	Staple	Agro-processing
Maize (*Zea mays*)	−11.90	*	*	*
Millet (*Eleusine coracana*)	−11.88		*	
Beans (*Phaseolus vulgaris*)	−11.35	*	*	
Wheat (*Triticum aestivum*)	−7.04			*
Matoke (*Musa sapientum*)	−10.62		*	
Simsim (*Sesamum indicum*)	−10.35	*	*	*
Sorghum (*Sorghum bicolor*)	−6.93		*	
Cassava (*Manihot esculenta*)	−6.93		*	
Potato (*Ipomoea batatas*)	−7.07		*	
Groundnuts (*Arachis hypogaea*)	−8.08		*	*
Coffee (*Coffea spp.*)	−13.25	*		*
Agro-processing	−13.25			

Source: Authors' computations from the UgAGE model

Finally, it is interesting to note that the impact of a drought on industry output is driven mainly by its direct impact on the productivity losses than the short-run elasticity. For example, a commodity such as groundnuts with a higher short-run supply elasticity of 0.32 registered a lower decline in output of 8.1 per cent compared to maize with a lower short-run elasticity of 0.25, but with output losses of 11.9 per cent. This is due to the capital-labour ratio requirements for each of these industries. Results show that industries with higher capital-labour ratios were more severely affected by this productivity shock than those with lower ratios. The sectoral impact of a shock depends on the extent to which industries can substitute their inputs. In particular, the impact of a shock on a given industry hinges on the capital-labour intensity and how elastic, each industry can substitute between its inputs and also vary its quantities. For instance, capital is fixed in the short-run. In this instance, a drought alters the relative prices of each good which causes each industry's input cost share to vary. In addition, studies on crop yield show that different crops are affected differently by drought even when it is of the same magnitude (Hertel *et al.*, 2010). These differences were accounted for in the implementation of the shock and also partly explain the observed differences in the results.

4.3 Decomposition analysis of the changes in industry output

Table III presents the Fan decomposition[8] analysis of the resulting changes in industry output (see Zheng and Fan, 1999). If we take maize, for example, we see that the predicted changes in domestic output are derived from three effects:

(1) the local market effect, i.e., changes in domestic demand for maize, whether domestically produced or imported;

(2) the domestic share effect, i.e., a shift in local usage of agricultural maize, from the imported to the domestically produced; and

(3) the export effect, i.e., an increase in the export demand for maize.

In most cases, these effects tend to work in different directions. However, the results show that the effects of a drought adversely affect output thereby reducing all the components of the decomposition. The essence of the Fan decomposition is to show the relative magnitudes

Table III. Results for the impact of a drought on the shares of industry output

Industry	Local market	Domestic share	Export	Total
Maize (*Zea mays*)	−5.16	−1.83	−4.91	−11.90
Rice (*Oryza sativa*)	−13.05	0.01	0[a]	−13.05
Wheat (*Triticum aestivum*)	−11.99	4.42	0.53[a]	−7.04
Cassava (*Manihot esculenta*)	−6.96	0	0.03[a]	−6.93
Potato (*Ipomoea batatas*)	−7.07	−0.01	0.001[a]	−7.07
Tobacco (*Nicotiana tabacum*)	−0.16	−0.003	−0.03	−0.20
Groundnuts (*Arachis hypogaea*)	−8.52	−0.05	0.48[a]	−8.08
Millet (*Eleusine coracana*)	−5.25	0	−6.64	−11.89
Sorghum (*Sorghum bicolor*)	−3.00	−0.89	−3.05	−6.93
Beans (*Phaseolus vulgaris*)	−4.75	−0.06	−6.55	−11.35
Coffee (*Coffea spp.*)	−13.26	0.01	0[a]	−13.24
Tea (*Camellia sinensis*)	−2.25	−0.01	−5.05	−7.31
Vanilla (*Vanilla planifolia*)	−0.004	0	−0.16	−0.16
Matoke (*Musa sapientum*)	−10.80	0	0.18	−10.62
Agro-processing	−3.30	−6.65	−3.08	−13.03

Note: [a]Denotes industries whose output is classified as non-tradable in the model
Source: Author's computations from the UgAGE model

of these three contributions to output change. Table III presents a breakdown of the changes in shares in total industry output for some selected industries.

We select a few strategic industries for our analysis. For the selected industries, the local market contribution largely explains the reduction in overall output for all the industries. This highlights the impact of a drought in depressing overall demand for agricultural-related commodities through the resulting increase in prices. Among the key export commodities, beans registered the largest decline in export demand of 6.6 per cent, contributing to the fall in overall industry output of 11.4 per cent. Similarly, maize had a decline of 4.9 per cent in exports.

In terms of a shift from the usage of local output from domestic to imported, a drought induces a decline in the usage of the relatively expensive local output resulting in an increase in the amount of imported versions of the good, except for wheat. This is explained by the cost of the intermediate agro-inputs as well as output declines which the manufacturing sector has to contend with in the production of its final outputs. In this case, the drought only compounds the constraints to the performance of the manufacturing industry. This has serious policy implications since economic transformation of many of the agro-based economies from agrarian to industrial has been premised on the development and improvement of agro-processing as a starting point. The results underscore the adverse effects of a drought on the domestic and external sectors of the economy. At a micro level, household welfare gets compromised resulting from a decline in output and the rising prices, especially of staple commodities. At a macro level, higher prices hamper exports which affect foreign exchange earnings.

In the foregoing analysis, it is also important to be mindful of the model limitations. Specifically, the UgAGE model assumes that producers are profit maximising price takers and that households have access to well-functioning markets. In most developing countries, however, there are high transaction costs in the agricultural sector, and limited access to credit markets. In practice, these factors can compound the impact of a drought on an economy. Such factors in turn curtail the adaptive capacity of an economy at a micro level. In instances where multiple markets for goods fail, production decisions become intertwined with consumption decisions (de Janvry *et al.*, 1991; Skjeflo, 2013).

Given the increasing frequency and severity of drought, future studies should account for market imperfections, and risk within a dynamic framework. This is critical given the fact that microeconometric studies on adaptation to climate anomalies in Sub-Saharan Africa have found that farmers are already using a wide range of coping strategies to deal with such shocks (Stringer *et al.*, 2009). Coping mechanisms include the use of drought resistant crop varieties, livestock, tree planting; soil conservation methods and diversification of their economic activities (Below *et al.*, 2010). However, empirical evidence still shows that adaptation is still constrained by certain factors, such as access to credit, property rights with respect to land, and irrigation (Deressa *et al.*, 2009).

In Uganda, only 1 per cent of the arable land is under irrigation. Critical issues such as household adaptation through adjusting to changes in market prices are considered endogenous in computable general equilibrium modelling. Similarly, adaptation strategies such as adoption of drought resistant crop varieties, improved infrastructure and investment in irrigation, are not included in our model. A number of institutional and social structures which are critical to highlighting the true cost of a drought are not easily modelled using our approach. Adger (2006) suggests that quantitative assessments must be combined with qualitative studies that take into account much more complex social and institutional contexts. These include household adaptation through adjusting to changes in market prices. This is considered endogenous in a computable general equilibrium modelling environment. Similarly, adaptation strategies such as adoption of drought resistant crop varieties, improved infrastructure and investment in irrigation cannot be explicitly modelled in an economy-wide model.

5. Conclusion, policy implications and areas for further research

This paper presents an economy-wide analysis of the economic impacts of a drought. It further provides insights to guide public policy on the development of mitigation strategies in order to improve their level of preparedness against such shocks. The ultimate goal is to reduce societal vulnerability in the wake of climatic shocks. In this paper, we focussed on the short-run economy-wide costs of a drought. However, it is possible that the costs of a drought can easily persist into the medium to long term (IPCC, 2014; Fisher *et al.*, 2015). This implies that whereas a single drought episode might be short-lived, the increasing frequency can result in the effects of individual drought episodes to overlap, thereby amplifying the potential costs to the economy. At a micro level, risk of drought prevents especially the smallholder farmers from adopting profitable technologies and practices which they perceive as risky. This inhibits their capability to overcome hunger, malnutrition and poverty.

As the results suggest, covariate risk of drought often causes food shortages and inflation, reduction in agro-based exports, employment, foreign exchange shortages. Robust strategies and policy options are therefore needed to mitigate the micro and macro level vulnerabilities to climatic risk and to build the capability to manage drought induced shocks. Development of ground water sources, dams and large-scale rain water harvesting and storage coupled with irrigation remain key. Small-scale irrigation can have a high potential to alleviate the cost of a drought both at a micro and macro level (Mahmoud and van Ginkel, 2014). Irrigation can be adopted together with other land management practices that promote soil moisture conservation. This can help in converting more evaporation into transpiration thereby greatly increasing agricultural output without necessarily placing additional pressure on the existing water sources.

Future studies should therefore combine quantitative and qualitative dynamic microeconomic data in order to shed more light on the impacts of drought in a socioeconomic context.

Notes

1. The El Niño and La Niña weather phenomena have been cited as the principal causes.
2. For a thorough exposition on the analytical methods for drought assessment, see Logar and van den Bergh (2013).
3. ORANI is an applied general equilibrium model with variants that have been applied to economy-wide policy analysis in many countries globally. Log onto: www.copsmodels.com/oranig.htm for details on applied general equilibrium modelling.
4. University of Pretoria General Equilibrium Model is a general equilibrium model developed for policy analysis on the South African economy by the University of Pretoria, Department of Economics.
5. General Equilibrium Modelling PACKage (GEMPACK) is a suite of economic modelling software. It is especially suitable for computable general equilibrium (CGE) models, but can handle a wide range of economic behaviour.
6. These are exclusive of the exogenous temporary closure of some capital in the manufacturing industry.
7. Armington (1969) presents a thorough exposition on the adjustment processes.
8. Named after Fan Ming-Tai of the Academy of Social Sciences, Beijing Institute of Quantitative and Technical Economics.

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