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The economic costs of droughts

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Abstract. The paper reviews the literature on the economic costs of droughts. It notes the main results obtained and identifies the gaps in our knowledge about such droughts. Comparisons with other disasters are provided.

Keywords. Drought – Direct costs – Indirect costs – Resilience.

Les coûts économiques de la sécheresse

Résumé. *Cet article passe en revue la bibliographie concernant les coûts économiques de la sécheresse. Les principaux résultats obtenus sont soulignés et les lacunes concernant notre connaissance de ces sécheresses sont idenfitiées. Des comparaisons avec d'autres catastrophes sont présentées.*

Mots-clés. *Sécheresse - Coûts directs - Coûts indirects - Résilience.*

I – Introduction[1]

The economic assessment of natural hazard-induced losses[2], particularly those of droughts, is a difficult and under researched topic, fraught with uncertainty, intrinsic complexity, methodological challenges and different conceptualisations of losses. The available literature on macroeconomic effects of natural disasters focuses mainly on rapid-onset, typically geophysical hazards. Slow-onset hazards such as drought require a different methodology. Moreover, most studies focus on property damages and less so on higher-order, and intangible (non-market, environmental and social) impacts. The few studies which try to disentangle the economy-wide impacts do so mostly for a single hazard event and pay little attention the cumulative consequences of a series of events (Benson and Clay, 2003). More often than not, the ensuing assessments provide an order-of-magnitude estimate only and are not cross-comparable (Handmer, 2003). The rising costs of natural hazards (Scheuren *et al.*, 2008) make it a high priority to improve the quality and reliability of the assessment exercises, so as to inform mitigation and risk management policies. The limitations of the current loss assessment practice and methodologies tend to favour structural, water-supply oriented projects to water-saving and demand management.

II – Categories of losses

Droughts are natural, human exacerbated disasters. From an economic point of view, they engender exogenous, internal or external (if international trade is affected) supply shocks to economies with far-reaching ripple effects, touching almost every aspect of economic life. Compared to other natural hazards, droughts cause not as much *structural* losses as they do *non-structural* losses such as land value decline or agricultural yield failure.

Moreover, *indirect* or *higher-order* impacts[3] of droughts may outweigh the *direct* losses. The latter pertain to water-use sectors hit by a drought such as agriculture, hydro- and cooling-water dependent energy production, water navigation, water-intensive manufacturing and households. Water is at the same time an important input to production, a crucial lifeline utility service and a means of transport for good and passengers. During drought events, the directly hit sectors are likely to curtail their activities and production, collect less revenues, lay-off staff, and postpone all but critical investments. These direct losses set off a sequence of "up"- and "downstream" reactions that affect their suppliers and customers. For example, losses in hydroelectricity production due to low river flows are direct effects, whereas the production losses due to constrained electricity supply are higher-order effects.

The impacts, either direct or higher-order, may be measured in terms of either economic stocks and/or flows. *Stocks* such as land, machinery or inventories are economic variables which are built up and depleted over time. *Flows*, such as annual crop yield or energy produced, are services or outputs of stocks measured per unit of time. Capital stocks increase by the flow of new investments and are depleted by the flow of depreciation.

Direct stock losses may include land value reduction, failure of perennial crops (e.g., orchards, groves, vineyards), soil degradation by wind erosion and/or damage to any productive capital damaged as a direct consequence of water shortages. Examples of *higher-order stock losses* can include fire-destroyed property, depleted savings, or over-abstraction of aquifer.

Direct flow losses can include reduction of farm outputs, drought-forced downturn in tourism, and/or losses due to business interruption[4]. An example of the latter is the necessity to close down a high-rise office building for fire-safety reasons (Rose, 2004a). The *higher-order flow losses* can include decline in investments not related to drought mitigation, drop in national income, opportunity costs of drought-related budget expenditure, increase in food imports, etc.

Flow losses may or may not be a consequence of stocks being damaged. Stock losses on the other hand are always associated with flow losses. The value of a stock is the discounted flow of net future returns from its operation (Rose, 2004a). Thus counting both stock and flow losses would mean that the losses are double-counted. For example, summing up the reduction of agriculture land value and net foregone return flows from that land is a double-counting of the same loss. Similarly, some flows are mirrors of other flows. For example, the lost revenues reflect the costs of production such as wages or interest payments. To sum them up with salaries of lay-off staff would again involve double-counting (BTE, 2001).

Intangible impacts refer to other impacts, non-internalised in economic terms. These include *inter alias* effects related to lifestyle and health, social tension and disruption, social capital accumulation, and environmental impacts (Alstone and Kent, 2004; Drought Policy Review Expert Social Panel, 2008).

The relationships between direct, higher-order and intangible impacts are not easy to capture (BTE, 2001). In case of droughts the later two categories may be of the same magnitude or larger than the direct losses.

1. Pattern of loss spread throughout economy

Much of the discussion in disaster economics concerns whether the disasters have positive or negative net effects on macroeconomic variables (e.g. GDP, employment), how these effects evolve in a short and long term, and whether they are transitory or permanent (Benson and Clay, 2003; Baade *et al.*, 2005). Different characteristics of geophysical *vs* hydro-meteorological, and rapid- *vs* slow-onset disasters confound the debate. The macroeconomic consequences of low-probability geophysical hazards (such as earthquakes) are better researched. There is evidence that post-disaster reconstruction and relief payments may generate a boom in the economy and at the regional level, to some extent offsetting the hazard losses (Albala Bertrand, 1993). In addition, replacement of capital provides opportunity for productivity-rising innovations. The recurrent hydro-meteorological disasters, which include droughts, pose different methodological challenges and there is some disagreement about their cumulative effect on long-term economic development. In the short-term, disasters negatively affect income generation, investment, consumption, production, employment and financial flows, and these losses are usually manifested through a decline of macroeconomic variables such as GDP (Benson and Clay, 2003).

In welfare economics, the losses are measured according to value of resource used or destroyed, determined at prices which represent their efficient allocation (Rose and Lim, 2002). Social costs of disasters represent the total burden imposed by a disaster, that is the value lost to society including the opportunity costs of resources deployed for reconstruction and relief, [for more detail see Dore and Etkin (2000) and EPA (2008)]. In this respect the social costs of a disaster are not accurately represented by the change in GDP and GDP is a misleading measure of welfare. For example, while drought abatement expenditures are counted for in social cost assessment, at least part of them will at the same time be included positively in the calculation of GDP (EPA, 2008).

Hazard impacts are not borne proportionally: the losses of some agents may to some extent be offset by the gains of others. Farms outside of drought-hit areas may benefit from higher crop prices; railroads may benefit from reduced water transportations; and the sales of technologies for well drilling, weather modification, and chemicals for suppressing evaporation can be boosted by droughts (Riebsame *et al.*, 1991). Therefore, the net effects of disasters will vary across the scales of aggregation: individuals, firm, community, region, nation (Scanlon, 1988; Cochrane, 2003). A drought impact assessment exercise should thus include an assessment of distributional effects of drought losses and policies to mitigate them. Net regional losses (NRL) which include all direct and higher-order effects are partly offset by inflow of payments from outside the region IOR (e.g. rebuilding stimulus, unemployment compensations, other aid) and by transfer of production within the region. The net national losses (NNL) consists of NRL and IOR, reduced by the benefits transferred outside of the impacted region (e.g. tourism offset or recaptured lost production) (Cochrane, 2003).

The magnitude of the losses is co-determined by the ability of affected individuals and communities to "absorb or cushion against damage" (Rose, 2004b), a concept referred to as *resilience*.

III – Economic resilience

The conceptualisation of economic resilience (*ER*) differs widely. Briguglio *et al.* (2008) for example defines resilience as "policy-induced ability of an economy to withstand or recover from exogenous shocks". *Ability to recover* refers to ability to deploy discretionary policy tools (e.g. tax cuts) to curb the effects of shocks. *Ability to withstand* is a measure of how well the shocks are absorbed, for example by shifting human capital resources to unaffected sectors enjoying higher demand. The economic variables which they deploy to quantify resilience include macroeconomic stability (e.g. fiscal deficit, unemployment and inflation rates), microeconomic market efficiency (e.g. trade freedom), state's governance and social development (e.g. literacy rate, life expectancy). Cardona *et al.* (2008) associate *ER* with internal and external funds available to a government to face the hazard losses (e.g. ability to deploy new taxes, budget reallocation margins, external and internal credit, aid funds and donations). Bruneau *et al.* (2003) take into account also the ability to mitigate the effects of hazard beforehand. They conceptualise *ER* in terms of robustness, redundancy, resourcefulness and rapidity (to restore functionality). Rose (2007) distinguishes static/dynamic, and inherent/adaptive resilience. *Static* resilience is aligned with efficient allocation of resources (that is measures are taken to satisfy demand of high value water users first). By this means alone one is able to substantially reduce the losses. *Dynamic* resilience includes long-term investments and institutional changes. *Inherent* resilience is the ordinary ability to deal with crises, for example by tapping groundwater in cases the water delivery from surface water sources cannot be guaranteed. *Adaptive* resilience refers to refers to extra-efforts and makeshift solutions to the disaster calamity. Figure

1 shows how individual and market resilience influence the drought impacts on individual businesses and regional economy.

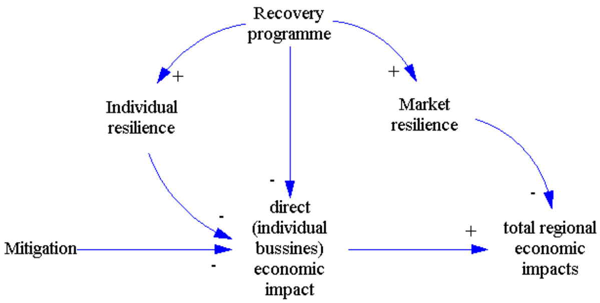

Fig. 1. Economic resilience and its offsetting role on drought losses [adopted from Rose (2007)].

Drought aid policies may have positive or negative effects on resilience. In Australia, the farm management deposit (FMD) scheme helped to smooth farmers' income in high- and low-yield years (RBA, 2006). In contrast, the review of the Exceptional Circumstances (EC) interest rate subsidies were found ineffective and damaging the farmers' self-reliance and drought preparedness (Productivity Commission, 2008).

The relationship between the vulnerability to natural disasters, including droughts, and the stage of countries' economic development seems to follow the inverted-U curve pattern (Benson and Clay, 1998). While simple economies are better able to contain the economic effects of droughts, the intermediate economies become more vulnerable to shocks as the community ties break down, and labour force and agriculture production become more specialised. In highly developed economies the vulnerability declines with the fading share of agriculture on Gross Domestic Product (GDP). One thing, however, is clear: damages in terms of deaths and share of GDP lost are much greater in low income countries than in high income ones.

IV – Existing studies of drought related economic costs

There are only a few studies documenting the extent of economic losses of droughts. These studies differ in their scope and methodology used. The scope may be as different as determination of liability, assessment of the worthiness or comparison of different hazard mitigation policies, or exploring the vulnerability and resilience to hazard. The methodologies applied include linear programming models, surveys, econometric models, input-output (IO) models, computable general equilibrium models (CGE), and hybrid models (Cochrane, 1997). The IO and CGE models are most suitable for macroeconomic assessments of drought losses. The former does not account for behavioural changes and input substitutions, thus their results may be seen as an upper bound estimate of the losses. The CGE models on the other hand assume perfect adjustment to equilibrium which may lead to over-resilient responses. Therefore, the CGE model results may be seen as a lower-bound estimate of economic impacts (Rose, 2004a; Rose and Liao, 2005).

Climate and weather influence a large proportion of economic activities. In the developed economies such as the US, the impacts pertain to about 25 percent of the GDP (NOAA, 2002), a figure is likely much higher in agriculture-dominated developing countries.

Below we briefly review some loss estimates in order to document the magnitude of drought-related costs. We focus on US and Australia, that is developed countries with economic conditions comparable to that in Europe.

Ross and Lott (2003) provide an overview of 10 drought in the US between 1980 and 2003 whose economic impact exceeded one billion US dollars (normalised to 2002 dollars). The reported losses range from over one billion up to over sixty billions. Riebsame *et al.* (1991) somehow controversial estimate (Hayes *et al.*, 2004) of the economic damage caused alone by the 1988 drought in central and eastern US amounts to $39.4 billion. Back in 1995, the Federal Emergency Management Agency (FEMA) estimated the average annual drought-related economic losses to some six to eight billion (NOAA, 2002). Hayes *et al.* (2004) have collected drought-loss estimates for the 2002 drought event which hit many States of the USA. Albeit incomplete and relying on different sources/methodologies, the total losses sum up to almost USD 13 billion. Howitt *et al.* (2009) have estimated that in short-run, the losses due to 2009 drought in California (Central Valley) may amount to USD 2.2 billion and some 80,000 jobs may have been lost.

The 2006/7 drought in Australia reduced the GDP by almost a one percent, but the farm GDP fell by around 20 percent (RBA, 2006). Albeit not as severe as the droughts in the 1940s or early 1980s, it came shortly after the 2002 drought and the limited recovery time in between conditioned resilience of agricultural sector. Still, output, inflation and employment were hardly affected. The opposite is true for rural exports which accounts for a fifth of total exports (RBA, 2006). The 2002 drought is believed to have lowered the GDP by 1.6 percent, with agriculture alone contributing with around 1.0 percent decline. Similarly, the drought is attributed the decline of around 1 percent in the employment and national real wage rate (Adams *et al.*, 2002). The difficulty of isolating drought impacts from other causes of farms' low net income is discussed in Thompson and Powell (1998).

Estimates of losses from different disasters by Okuyama and Sahin (2009) show that in a sample of 184 disasters over the last 47 years droughts have had the lowest damages in aggregate terms, both direct and indirect. In total the greatest losses came from geophysical disasters (earthquakes, with 40% of the total), followed by hydrological (floods 25%) and meteorological (storms 25%). Climatological disasters (principally droughts) accounted for only 10% of all damages. It is also interesting to note that meteorological disasters have the largest impact multiplier[5] (2.02), followed by geophysical (1.88), hydrological (1.80), and climatological (1.78).

Below *et al.* (2007) analysed the drought events contained in the EM-DAT. The consolidation of the data led to identification of 392 multiyear and multicountry events, with the reported economic losses amounting to USD 78 billions (for the reference period 1900-2004, with the caveat that only some 25% of reported events comprise information about the losses).

In Europe, the only existing large-scale study is based on a survey conducted by the Directorate General (DG) Environment in 2006-2007. The economic impacts of droughts for the past 30 years has been estimated to top 100 billion Eur. In the most recent years the annual costs climbed to over 6.2 billion Eur.

The DG ENV report emphasised the gaps in the collected data and the fact that MS might have interpreted the survey's questions differently. The report also concluded that "further cost-analyses are urgently needed in order to specify more precisely the impacts of water scarcity at EU level".

A recent study that serves as a case study for the assessment of the economic costs of such an event is one on the drought that affected Catalonia between 2007-2008 (Martín-Ortega and Markandya, 2009). This drought was the most severe of the last century, affecting the so-called Ter-Llobregat system which serves the Metropolitan area of Barcelona where most of the population is concentrated (approximately 5.5 million people).

The 2007-2008 drought is a good illustrative case study due to its extreme severity and the availability of economic information both on the impacts (damages) and the measures taken. Among the latter were important communication campaigns that were put in place and that led to a significant reduction of demand and the setting up of mechanisms for public participation for future water management. The direct costs of the affected sectors, as well as indirect costs to the Catalan economy and non-market welfare losses due to the worsening of the environmental quality and restrictions on water supply to households due to scarcity conditions have been estimated in a recent study (Martín-Ortega and Markandya, 2009). The total losses are estimated in €1660 million (for a one year period), almost 1% of the Catalonian GDP. Of these the direct costs were estimated at about €540 million and the indirect costs at about €360 million. The rest is made up of non-market welfare losses, rising from the decline the ecological status of the river and the loss of welfare from the restrictions in water supply to households. These non-market welfare losses are often not accounted in studies of drought and yet, as this study shows, they can be of considerable importance. By designing measures appropriately policy makers can reduce the overall costs, but to do so they need the information on the components of the costs of alternative measures. To date this has often been missing.

1. Intrinsic uncertainty

The scope of the assessment and the deployed methodology has implications for data requirements of future studies. Usually, the available data are partial, approximated, and stem from different sources. Compound effects – that is other shocks an economy is exposed to – make it difficult to isolate impact of droughts in the aggregated macro-economic measures. For example, rising food prices may be a cumulative effect of droughts, floods (or other natural hazards) elsewhere, and agricultural or energy policies (EC, 2008). To tease out the effects of drought, it is necessary to build a scenario of how the economy would have fared in absence of drought. Thus, the loss assessment has to rely on assumptions in the base-line or counterfactual scenario. Other methodological choices confound the assessment: the choice of a discount rate for future flow losses, assumptions related to depreciation of stocks, etc. In general, direct or higher-order stock losses are less controversial than flow losses. Intangible impacts are most difficult to approximate they are completely omitted.

Hardly any of the existing studies accounts for the intrinsic uncertainty, making them difficult to compare. Ideally, the economic estimates of losses should be supplemented by a probability distribution function, expressing the likelihood of the total losses having a particular value. The second best case is to calculate a point estimate of losses and/or a range the "true" losses should fall between with a given probability. Further down the ladder of precision is estimates reflecting the order of magnitude of losses (says millions as opposite to tens of millions as opposite to hundreds millions). In this form, the estimates may still be useful for public policy if they help to determine the relative advantages of different hazard mitigation policies. It is not uncommon in politics that those with numbers prevail over those without (Economist, 2006). However, those numbers should be treated with care. The implications of all methodological choices and data quality issues should be made explicit to those who use these numbers for public and private policy making.

V – Summary and research gaps

Each drought event is unique in terms of drought intensity, impact on economy, and ability of individuals and society to cushion the losses. Thus, an assessment framework, however consistent, can only be applied as a guide (BTE, 2001) and not as an exact model.

First, it is necessary to harmonise different conceptualisations of losses. The existing guidance documents (NRC, 1999; Heinz Center for Science, 2000; BTE, 2001) apply different, ill-matched classifications of losses.

Second, the drought loss data collections should be standardised and institutionalised.

Third, any assessment of drought-related losses should be subjected to uncertainty analysis.

The consequences of (i) methodological choices and (ii) the implicit uncertainty in the loss data should be explored and commented on.

Fourth, further detailed studies are needed to advance the drought economics. Droughts are different from other hydro-meteorological hazards such as hurricanes, wind storms or floods. The deployed assessment techniques need to take into account the prevalence of higher-order and intangible impacts. The assessment exercises should cover larger time horizon [Benson and Clay (2003) suggest 18-24 months] to capture the propagation of losses in short- and medium-term. The cumulative assessment of multiple-event droughts is essential to understand the dynamic nature of resilience.

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Notes

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[2] Under losses we mean all negative economic impacts. Damages are physical equivalent of losses, see also NRC (1999).

[3] Hereafter we use the term "higher-order effects" for all indirect, second-order or induced effects, in the same way as in Rose (2004a).

[4] Counting losses due to business interruption as direct losses is an arbitrary choice but established practice (Rose and Lim, 2002).

[5] That is the amount by which each euro of direct losses is multiplied to account for total losses.