Determinants of farmers' resilience towards ENSO-related drought: Evidence from Central Sulawesi, Indonesia

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1. Introduction

Crop production in the tropics is subject to considerable climate variability, which is mostly attributable to the ENSO (El Niño - Southern Oscillation) phenomenon (Salafsky, 1994; Amien et al., 1996; Datt and Hoogeveen, 2003). In Southeast Asia, El Niño is associated with comparatively dry conditions: in four El Niño years between 1973 and 1992, the average annual rainfall amounted to only 67% of the 20 year average in Java, Indonesia, depressing rice yields by 50% (Amien et al., 1996). There is evidence that, in concert with global warming, the frequency and severity of extreme climatic events will increase during the 21st century and the impacts of these changes will notably hit the poor (McCarthy et al., 2001 pp. 6-7).

While several macro-scale studies model the impact of climate variability and climate change on crop production in the Asia-Pacific region (see Zhao et al., 2005, for a review), very little is known about specific climate variability impacts at the household level. The Intergovernmental Panel on Climate Change identified the "quantitative assessment of the sensitivity, adaptive capacity, and vulnerability of natural and human systems to […] climatic variation" as one of the high research priorities with respect to policymaking needs (McCarthy et al., 2001 p. 17). Against this background, the objective of this paper is to measure household resilience towards ENSO-related drought in a rainforest margin area in Indonesia, and to identify its influencing factors in order to derive policy recommendations.

2. Methodology

Characteristics of the research area and data collection

The research area encompasses the Palu River watershed in Central Sulawesi, Indonesia. Its mountainous topography results in a distinct rainfall gradient, with the coastal zone receiving only 600 mm of rain p.a., while precipitation rates exceed 3,000 mm at higher elevations

(WWF, 1981). Irrigated rice and cocoa are the two most important crops grown. To account for the variation in local climatic conditions, data were collected in a stratified random sample of 228 farm households in eight villages located at different elevation levels; the data relate to the most severe drought period experienced by a household.

Measuring drought resilience

Resilience is defined to be "the ability of a system to absorb change" (Ellis, 1998 p. 14). Since household risk management aims at smoothing consumption (Morduch, 1995), we measure the resilience of a household towards drought as the observed degree of drought-induced expenditure reductions for basic necessities; to capture the impact on the consumption of home-produced food, we also account for absolute differences in the consumption of selected food items between the 'normal' and the drought situation. A household is regarded to be fully resilient if all indicators listed in Table 1 (section 3) remain unaffected. We apply Principal Component Analysis (PCA) to aggregate the indicators into a Drought Resilience Index (DRI), which serves as the dependent variable in a regression model to identify its influencing factors. A substantial share of households was found to be fully resilient; hence, the distribution of the DRI is censored (compare Figure 2), and an ordinary least squares regression would yield biased estimates. Therefore, we employ a model proposed by Tobin (1958) that accounts for the qualitative difference between limit and non-limit observations and uses the maximum likelihood (ML) method for parameter estimation. The 'Tobit' model expresses the observed outcome (DRI) in terms of an underlying latent variable as follows:

$$y_i^* = \beta_0 + \sum_{j=1}^{k} \beta_j x_{ij} + \varepsilon_i \qquad (1a)$$

$$DRI_i = \min\left(y_i^*, 1\right) \qquad (1b)$$

where

y^* = Latent dependent variable 'Drought Resilience'

i = Household index (i = 1,…,N)

x_j = Vector of explanatory variables (j = 1,…,k)

β = Vector of parameters to be estimated

ε = N (0, σ^2) distributed random error term

DRI = Observed dependent variable 'Drought Resilience Index'

The latent dependent variable y^* in equation (1a) satisfies the classical linear model assumptions[1].

Determinants of drought resilience

This section derives the explanatory variables to be included in equation (1a). Modifying the conceptual framework employed by Webb and Harinarayan (1999), our analysis of determinants of drought resilience is based on the following functional relationship:

DRI = f (H, RM) (2)

where,

H = Hazard

RM = Risk management

H and RM are in turn functions of the following general formula:

H = f (Prob, Press, Pred) (2a)

where,

Prob = Probability of occurrence of a hazardous event

Press = Pressure exerted by the hazardous event, i.e., the intensity of impact

Pred = Predictability of the hazardous event, i.e., the degree of warning available

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[1] In particular, it has a normal, homoscedastic distribution with a linear conditional mean.

and

RM = f (AB, RA) (2b)

where,

AB = Asset base

RA = Risk attitude

According to the livelihoods resources pentangle, the asset base can be subdivided into natural, physical, financial, human, and social capital (Devereux, 2003). However, a distinction between physical and financial resources is often difficult, especially if an asset is easily liquidated; we therefore adopt the classification proposed by Scoones (1998), which combines the two types to form a single category of 'economic and financial capital'. Apart from idiosyncratic factors, a household's attitude toward risk largely depends on its asset base (Morduch, 1995). Because of this endogenous nature, we do not attempt to measure RA explicitly, but we assume it to be indirectly reflected by AB.

We measure drought resilience in households that have already been exposed to drought; thus, the probability of drought does not enter our model. Combining the above structural equations into one, the following reduced-form model of determinants of drought resilience can be estimated:

DRI = f (Press, Pred, NC, EFC, HC, SC) (3)

where,

NC = Natural capital

EFC = Economic and financial capital

HC = Human capital

SC = Social capital

The definitions of all variables included in the model and their hypothesized direction of relationship with drought resilience are provided in Table 2. The variable meaneff in the category of human capital deserves some elaboration: Technical efficiency (TE) in agricultural production reflects a farmer's know-how regarding crop management; technical inefficiency exists if for a given set of inputs and a given production technology a household fails to attain the maximum possible ('frontier') output (Farrell, 1957). For the two primary crops in the research area, irrigated rice and cocoa, we estimate separate household-specific levels of TE employing a stochastic frontier model specified by Battese and Coelli (1995). A high level of TE is hypothesized to enhance resilience by facilitating the accumulation of reserves during times of 'normal' climatic conditions that can be used to smooth consumption during drought. Following Battese (1997), the dummy variables dasset, doff, dcred and dorg in the bottom section of Table 2 correct for potential bias caused by 'zero-observations' in the variables liqasset, offinc, maxcred and numorg.

3. Results

The effect of drought on household consumption

Among the 228 respondent households, 188 (82%) have ever been negatively affected by drought; on the average, the most severe drought experienced depressed the total annual household income by one-third. Because of lacking access to ENSO forecasts risk management was confined to ex-post coping strategies, especially the tapping of additional sources of income (43% of households), among them the illegal sale of rattan from an adjacent National Park (10%), and the borrowing of money from informal lenders (21%) at excessive interest rates. A total of 116 drought-affected households (62%) were not able to smooth consumption with respect to basic necessities. Figure 1 provides an overview of the percentage of households that reduced different expenditure categories (fat bars); within each category, the thin bar shows the mean level the respective expenditures had to be reduced to.

(Figure 1.)

The 'Drought Resilience Index'

Table 1 lists the definitions and summary statistics of the consumption and expenditure related indicators which the Drought Resilience Index (DRI) is based upon. Furthermore, it indicates their expected direction of relationship with the DRI and their component loading derived by PCA.

(Table 1.)

All signs of the component loadings conform to our expectations. Only indicators with an absolute loading greater than 0.4 were retained in the final model, as suggested by Stevens (2002 p. 394). The Kaiser-Meyer-Olkin measure of sampling adequacy yields a value of 0.76, indicating a distinct and reliable first component. Because of the size of its Eigenvalue and the size and signs of its component loadings as compared to those of further components extracted, we conclude that the first principal component that explains 45.3% of the total variance in the data reflects drought resilience. The households' scores on this factor, which have a mean of zero and a standard deviation of one, were converted to the DRI $\in [0,1]$. Figure 2 displays its cumulative distribution function; its maximum value is attained by those 72 drought-affected households (38%) that were capable of smoothing consumption.

(Figure 2.)

Determinants of drought resilience

Table 2 lists the variables in the Tobit regression model and their summary statistics. Only 162 out of 188 drought-affected households were included because of missing values in the variables yieldsh (some farmers did not grow any crops during the drought) and meaneff (not all of the farmers grow rice and/or cocoa). Table 3 presents the ML estimates of the coefficients of the explanatory variables[2].

(Tables 2 and 3.)

4. Discussion

All of the test statistics related to the DRI indicate that for our data set PCA is an appropriate method for the construction of an index. Since the DRI is a relative measure, we will confine our discussion to the sign of the coefficients and their relative size if the associated variables are based on the same scale. The variables yieldsh and notplant correct for differences between individual households regarding the pressure exerted by the drought; thus, they also correct for differences in the type of irrigation facilities available. The higher the mean share of crop yields during the drought as compared to the 'normal' situation, the less pronounced the negative impact. Not being able to plant one or more crops due to the drought (notplant) has a substantial resilience reducing effect. No effect of prior knowledge of the likely incidence of a drought is supported by the data. The distinct rainfall gradient in the research area leads to a relatively low land productivity in low-lying areas (lowelev), thus reducing household resilience. The sign of the coefficient of the soil fertility proxy redsoil is contrary to our expectations, but it is not significantly different from zero; one reason for this may be that the use of mineral fertilizer is not taken into account.

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[2] They relate to the normally distributed latent dependent variable y^* ('Drought Resilience'), which is the actual variable of interest, rather than the observed variable dri whose share of censored observations depends on the severity of the drought experienced.

As expected, the possession of easily liquidated assets (liqasset) and access to credit (maxcred) enhance resilience. Since the two variables are based on the same scale we can further conclude that one monetary unit of liquid assets has a greater effect on drought resilience than one unit of available credit line. This is understandable since the interest and transaction costs of credit are likely to be considerably higher than the transaction costs involved in the sale of liquid assets. No influence of regular off-farm income is supported by the data, which is in line with Fafchamps et al. (1998) who found that, due to a collapse of the demand for local services and crafts, droughts adversely affected not only farm but also off-farm income.

The aggregate household labor capacity (labcap) and the level of TE in the cultivation of rice and cocoa (meaneff) are resilience enhancing factors, which confirms our hypotheses. The potential to increase productivity is particularly large in the case of the primary cash crop cocoa, a relatively new crop in the area, for which mean TE is estimated to be merely 37%, as opposed to 77% in rice cultivation. The data do not support a positive influence of the level of formal education (maxedu). Rather, the combined household labor capacity, which is a prerequisite to the implementation of labor-intensive coping measures, and the qualification of the household concerning proper crop management are of relevance.

Although the positive coefficient of numorg is as expected, the statistically significant positive coefficient of the 'zero-observation' dummy variable dorg is surprising. It implies that those households that do not participate in official village organizations have other types of informal social networks at their disposal.

5. Conclusions and policy recommendations

Despite the location in a rainforest area, farmers in Central Sulawesi face a substantial risk of recurring ENSO-related drought periods. The majority of the affected households have to cut expenditures to adapt to the drought-induced reduction of agricultural income; the drastic cuts in food expenditures are particularly alarming, suggesting that droughts seriously impair their nutritional status. Drought resilience is positively influenced by the possession of easily liquidated assets and access to credit. Furthermore, a high level of technical efficiency in agricultural production enhances resilience by facilitating the accumulation of reserves during non-drought years; particularly large increases in productivity could be achieved in the cultivation of cocoa, the primary cash crop in the area.

Our recommendations encompass the improvement of farmers' access to ENSO forecasts, the investigation of the agronomic and marketing potential of relatively drought tolerant crops, the promotion of formal financial institutions providing consumption credit at moderate interest rates, and the intensification of focused agricultural extension efforts in view of low productivity levels.

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Table 1. Expenditure and consumption related indicators from which the 'Drought Resilience Index' (DRI) for farm households in Central Sulawesi is constructed, including their summary statistics[a] and component loadings (hypothesized direction of relationship in parentheses)

Variable description			Mean	St. Dev.	Min	Max	Comp. loading
Expenditure related indicators							
foodsh (+)	=	**Share of food exp. during drought as compared to 'normal' situation (%)**	**81.21**	21.75	20.00	100.00	**0.844**
clothsh (+)	=	**Share of clothing exp. during drought as compared to 'normal' situation (%)**	**70.15**	35.35	0.00	100.00	**0.837**
maintsh (+)	=	**Share of maintenance exp. (house) during drought as compared to 'normal' situation (%)**	**63.43**	44.11	0.00	100.00	**0.786**
socialsh (+)	=	**Share of exp. for social events during drought as compared to 'normal' situation (%)**	**83.99**	25.57	0.00	100.00	**0.744**
healthsh (+)	=	**Share of health exp. during drought as compared to 'normal' situation (%)**	**88.43**	24.07	0.00	100.00	**0.582**
Food consumption related indicators							
ricedif (-)	=	**Number of times rice is 'normally' served per month – this number during drought**	**13.04**	20.58	0.00	90.00	**- 0.703**
maizedif (+)	=	**Number of times rice mixed w/ maize is 'normally' served per month – this number during drought**	**- 5.46**	14.51	- 90.00	8.60	**0.549**
beefdif (-)	=	**Number of times beef is 'normally' served per month – this number during drought**	**0.12**	0.33	0.00	1.00	**- 0.438**
chickdif (-)	=	**Number of times chicken is 'normally' served per month – this number during drought**	**0.24**	0.52	0.00	4.30	**- 0.412**

[a] Summary statistics are based on 188 households whose agricultural production was negatively affected by drought.

Table 2. Hypothesized influencing factors of household (HH) drought resilience in Central Sulawesi, and their summary statistics[a] (hypothesized direction of relationship in parentheses)

Variable		Variable description	Mean	St. Dev.	Min	Max
Dependent variable						
dri	=	Drought Resilience Index	**0.75**	0.28	0.00	1.00
Hazard proxies						
yieldsh (+)	=	Logged mean percentage share of normal yield during drought, weighted by plot size[b]	**58.89**	25.44	0.00	137.67
notplant (-)	=	Dummy, = 1 if at least one crop could not be planted due to drought, 0 otherwise	**0.06**	0.23	0.00	1.00
Predictability proxy						
predict (+)	=	Dummy, = 1 if HH had prior knowledge of the likely occurrence of a drought, 0 otherwise	**0.10**	0.30	0.00	1.00
Natural capital						
lowelev (-)	=	Dummy, = 1 if elevation of village < 100 m above sea level, 0 otherwise	**0.43**	0.50	0.00	1.00
redsoil (-)	=	Dummy, = 1 if the predominant soil color is redish/yellowish, 0 if it is black/brown	**0.24**	0.43	0.00	1.00
Economic/financial capital						
liqasset (+)	=	Value of liquid assets per AE[c] (100,000 IDR[d])	**5.19**	7.92	0.00	46.51
offinc (+)	=	Regular off-farm income per AE (100,000 IDR)	**3.63**	6.65	0.00	58.84
maxcred (+)	=	Maximum amount of credit available per AE (100,000 IDR)	**2.46**	7.44	0.00	87.11
Human capital						
labcap (+)	=	Aggregate HH labor capacity in AE, excluding children < 10 years of age	**3.38**	1.44	0.66	7.35
maxedu (+)	=	Number of years of formal education of the most educated HH member	**8.75**	2.76	0.00	15.00
meaneff (+)	=	Mean technical efficiency in rice and/or cocoa cultivation, weighted by area share	**0.63**	0.23	0.06	0.98
Social capital						
numorg (+)	=	Number of organisations the HH is involved in	**1.62**	1.58	0.00	6.00
Dummy variables correcting for zero-observations in explanatory variables						
dasset (-)	=	Dummy, = 1 if value of liqasset is zero, 0 otherwise	**0.07**	0.25	0.00	1.00
doff (-)	=	Dummy, = 1 if value of offinc is zero, 0 otherwise	**0.37**	0.48	0.00	1.00
dcred (-)	=	Dummy, = 1 if value of maxcred is zero, 0 otherwise	**0.07**	0.26	0.00	1.00
dorg (-)	=	Dummy, = 1 if value of numorg is zero, 0 otherwise	**0.36**	0.48	0.00	1.00

[a] Summary statistics are based on 162 cases without missing values for any of the variables.

[b] For ease of interpretation, summary statistics are given for the unlogged variable.

[c] Adult equivalents based on caloric requirements, differentiated by gender and age (WHO/FAO, 1973).

[d] Indonesian Rupiah. 1 US$ = 8,900 IDR (February 2003).

Table 3. Parameter estimates of influencing factors of household drought resilience in Central Sulawesi (N = 162)

	Tobit estimates (ML)			
Variable	**Coefficient**	**t-value**[a]	**Mean**	**VIF**[b]
Constant	- 0.2943	- 1.55		
yieldsh	0.1163	5.19***	3.864	1.21
notplant	- 0.3261	- 3.30***	0.056	1.19
predict	- 0.1075	- 1.34	0.099	1.21
lowelev	- 0.1234	- 1.95*	0.432	1.42
redsoil	0.0474	0.67	0.241	1.12
liqasset	0.0162	3.73***	5.186	1.24
offinc	- 0.0045	- 1.40	3.634	1.39
maxcred	0.0134	2.29**	2.457	1.13
labcap	0.0552	2.51**	3.382	1.20
maxedu	0.0112	0.97	8.750	1.37
meaneff	0.4036	2.99***	0.627	1.23
numorg	0.0673	1.95*	1.617	3.18
dasset	- 0.0791	- 0.82	0.068	1.23
doff	- 0.0910	- 1.39	0.370	1.41
dcred	0.0135	0.13	0.074	1.13
dorg	0.1810	1.83*	0.364	2.80

LR χ^2 = 65.17***
Log likelihood = - 74.104
Pseudo R^2 = 0.305
Sigma = 0.324***
% censored observations (upper limit) = 40.1

*(**)[***] Statistically significant at the 10% (5%) [1%] level of error probability.

[a] t-values are based on the heteroscedasticity-consistent standard errors proposed by White (1980).

[b] Variance Inflation Factor.

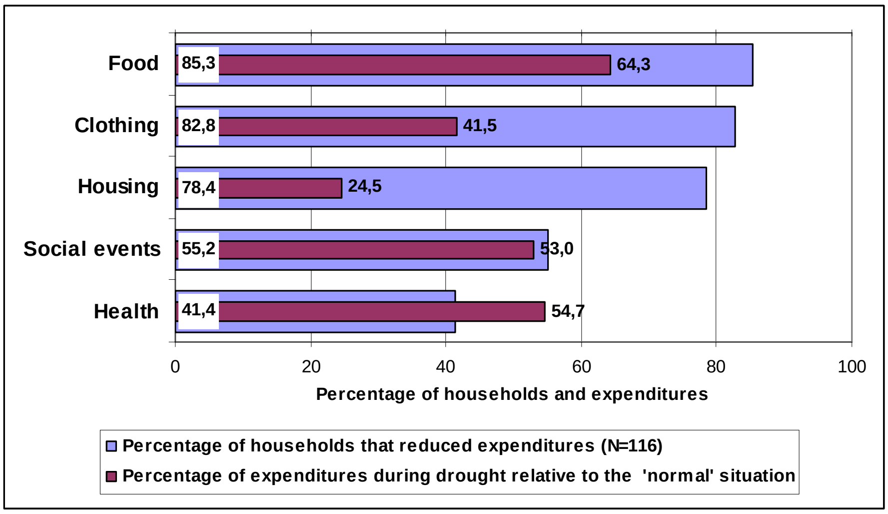

Figure 1. Reduction of household expenditures as a reaction to decreased agricultural income due to drought in Central Sulawesi.

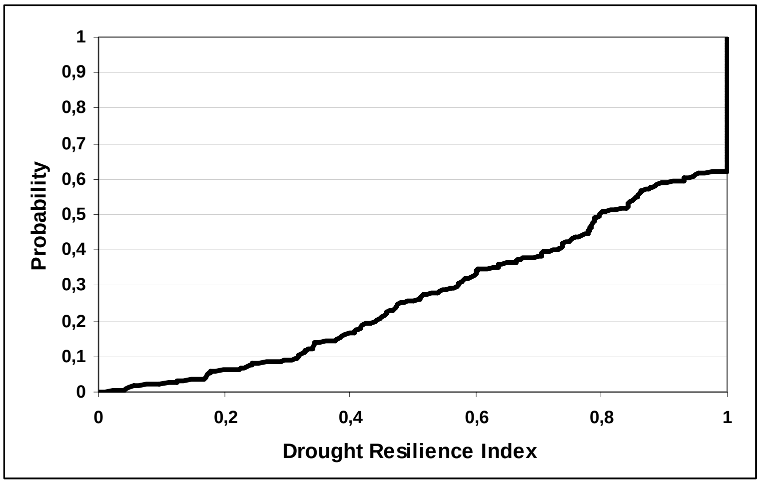

Figure 2. Cumulative distribution function of the ‘Drought Resilience Index’ (DRI) for farm households in Central Sulawesi (N = 188).