Food and Agriculture Organization of the United Nations

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Summary

Measuring households' resilience and the determinants of such resilience, or "resilience capacities," has become an urgent task as households across the globe face an increasingly challenging set of shocks, including climate, economic and geo-political shocks. The United Nations Food and Agriculture Organization (FAO) and Technical Assistance to NGOs, International (TANGO) have gained extensive experience providing measurement support to resilience-strengthening programs implemented in developing countries. This paper explores similarities and differences between FAO's and TANGO's measurement approaches. The organizations employ the same procedure for measuring resilience itself, both using an indicator of "realized resilience", which compares households' food security before and after specific, well-defined shocks. However, the procedures used to calculate indexes of resilience capacity, which in contrast measure households' intrinsic capacity to withstand shocks they may face in the future, differ. TANGO employs factor analysis (using only indicators of resilience capacity) while FAO employs the Multiple Indicators Multiple Causes (MIMIC) estimation procedure (using indicators of resilience capacity and food security). Data collected in nine shock-prone areas of Sub-Saharan Africa and Asia are utilized to compare the indexes in two key empirical applications informing resilience programming: ranking population groups for targeting purposes and analysis of the relationship between resilience capacity and realized resilience. More often than not, the FAO and TANGO indexes are found to yield similar policy implications despite the different measurement approaches. Along with realized resilience, both are useful components of the growing set of resilience measurement tools needed by implementing agencies, researchers, governments, and international donors for informing resilience programming.

1. Introduction

Measuring resilience has become an urgent task as climate change, ecosystem fragility and geo-political instability have led to increasingly unpredictable risks. The well-being of the world's poor is now subject to a more challenging series of shocks and stressors (Constas, Frankenberger and Hoddinott 2014). The response to assist households dealing with these shocks depends not only on accurate measurement of resilience to such shocks and stressors itself, but also on accurate measurement of their "resilience capacities"—the underlying determinants of resilience. These capacities, which are the programming and policy levers for enhancing resilience, are a set of economic, social, and even psychological resources that enable households to be resilient in the face of shocks.

In 2013 the Resilience Measurement Technical Working Group (RMTWG) comprised of experts in resilience measurement was established under the auspices of the Food Security Information Network.[1] The primary objectives of the working group were to "secure consensus on a common analytical framework and guidelines for … resilience measurement, and to promote adoption of agreed principles and best practices" (FSIN 2016a). In March 2016, members of the RMTWG held a workshop to bring together the resilience measurement teams of the Food and Agriculture Organization of the United Nations (FAO) and Technical Assistance to NGOs, International (TANGO). These organizations have gained extensive experience measuring both resilience and resilience capacity in various settings across the developing world; they are heavily involved in providing resilience measurement support to programs funded by the United States Agency for International Development (USAID) and the European Union. The purpose of the workshop was to "deepen participants' understanding of the methods and strategies used by the different resilience measurement teams and to navigate a way forward to improve harmonization of approaches" (FSIN 2016b).

The workshop participants reached consensus that some degree of harmonization of measurement approaches is important and that significant progress in "conceptual harmonization" and "operational harmonization" has been reached.[2] There was a perceived need for consistency in the procedures used to construct measures of household resilience and resilience capacity. Since the 2013 RMTWG meeting, however, there has been a proliferation of efforts to measure various aspects of resilience and resilience capacity, as demonstrated at the November 2018 Resilience Measurement, Evidence and Learning Conference.[3] There is growing recognition that embracing variety in approaches to measurement, including both qualitative and quantitative approaches, can help gain insight into different aspects of resilience in different shock environments and among different populations.

Given this background, the purpose of this paper is to explore similarities and differences between TANGO's and FAO's measurement approaches—their conceptual underpinnings, measurement procedures, and as they compare in empirical applications to inform resilience policy and program design. The empirical applications are, firstly, targeting populations most in need of resilience-strengthening interventions and, secondly, using regression analysis to understand how households' resilience capacity affects their ability to

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[1] The Food Security Information Network (FSIN) is a global initiative co-sponsored by FAO, WFP and IFPRI to strengthen food and nutrition security information systems for producing reliable and accurate data to guide analysis and decision-making. See more at http://www.fsincop.net/home/en/.

[2] Conceptual harmonization refers to common understanding on the definition of resilience and its conceptual basis. Operational harmonization, specifically *measurement* operationalization, refers to common understanding regarding the types of indicators used as inputs into measurement and their properties.

[3] See http://www.measuringresilience.org/conference/.

recover from shocks. It is hoped that understanding these similarities and differences will help users make informed choices about which is appropriate to specific applications and settings.

The paper focuses on three measures. The first two are TANGO's and FAO's indexes of resilience capacity calculated using data reduction techniques falling under the umbrella of "Structural Equations Modeling" (sometimes known as "latent variable modeling"). TANGO's index is constructed based only on indicators of resilience capacity that are combined using factor analysis. FAO's index is constructed based on indicators of resilience capacity and food security that are combined using the Multiple Indicators Multiple Causes (MIMIC) model.[4] The third measure, "realized resilience", is a measure of resilience itself founded on tracking households' food security over the course of an actual shock. TANGO and FAO use the same measurement procedures to construct this measure. Note that the choice of and validity of the *indicators* of resilience capacity and food security used to construct these measures is addressed elsewhere (e.g., Frankenberger et al. 2013; Vaitla et al. 2017).

Section 2 of the paper first provides the definitions of resilience and resilience capacity on which the paper's analysis is based. Section 3 then describes and compares the three measures from conceptual and measurement standpoints. In Section 4, the empirical applications—targeting and analysis of the relationship between resilience capacity and resilience—are undertaken using nine data sets representing 28,637 developing-country households. The sets contain data on indicators of households' resilience capacities and food security as well as the data needed on their exposure to a wide variety of shocks, from droughts and floods to price hikes. The paper concludes with discussion of the similarities and differences found and the underlying reasons for any differences.

[4] The index is part of FAO's RIMA II (Resilience Index Measurement and Analysis-II) approach to resilience measurement (FAO 2016).

2. Definitions

Resilience

The definition of resilience adopted by the Resilience Measurement Technical Working Group (RM-TWG, 2016) is: "Resilience is the capacity that ensures adverse stressors and shocks do not have long-lasting adverse development consequences." This broad definition is consistent with those used by FAO and TANGO which are, however, more instructive when it comes to measurement.

> FAO's definition is as follows: Resilience is "the capacity of a household to bounce back to a previous level of well-being (for instance food security) after a shock" (FAO 2016, p. 1).
>
> TANGO has relied on the USAID definition of resilience, which is: "The ability of people, households, communities, countries, and systems to mitigate, adapt to, and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth" (USAID 2012). Its operational definition is "the ability of a household to manage or recover from shocks and stresses" (Smith et al. 2019).

In short, a household that is resilient is able to maintain or recover its well-being when faced with shocks and stressors. Measurement of resilience itself thus centers on tracking how households' well-being, for example food security, changes over the course of an actual shock.

It is important to note that while resilience is related to the concept of vulnerability, it is not merely its inverse. Vulnerability is a set of conditions that prevents households from managing adverse events; it views households as passive, vulnerable "victims" of events. Resilience, by contrast, is about the actual ability of households to manage adverse events—to anticipate them and adapt, and to respond to them when they hit. Rather than passive victims, it views households as active agents making informed decisions that have an effect on the course of their lives (see Constas et al. 2014, Béné et al. 2014, 2015).

Resilience capacity

While the word resilience is used to describe those situations where a shock or stressor has been managed, resilience *capacities* are a set of underlying determinants of resilience that enable households to withstand shocks and stresses. An overall indicator of a households' resilience capacity would thus measure a households' current *capacity* to achieve resilience to the shocks it may face in the future.

TANGO's measurement practice has relied on a conceptual framework supported by the RMTWG (RM-TWG 2014) whereby resilience capacities are broken down into three dimensions:

> (1) Absorptive capacity—The capacity to minimize exposure to shocks and stresses (*ex ante*) where possible and to recover quickly when exposed (*ex post*);
>
> (2) Adaptive capacity—The capacity to make proactive and informed choices about alternative livelihood strategies based on changing conditions; and
>
> (3) Transformative capacity—System-level enabling conditions for lasting resilience, such as governance mechanisms, policies/regulations, infrastructure, community networks, and formal

safety nets that are part of the wider system in which households and communities are embedded (Frankenberger et al. 2013; Béné et al. 2016).

While FAO acknowledges the theoretical validity of this framework (FAO 2016), in practice it breaks resilience capacity into four "resilience pillars":

(1) Access to basic services—a proxy for the possibility for the household to access an enabling institutional and public service environment;

(2) Assets—income and non-income related assets that enable a household to make a living;

(3) Social safety nets—the network upon which a household can rely when and if faced with a shock; and

(4) Adaptive capacity—"Household ability to adapt to the changing environment in which it operates" (FAO 2016, p. 14).

All four of these pillars fall under at least one of the three capacity types of TANGO's conceptual framework.

3. Measurement methods

TANGO's and FAO's resilience capacity indexes both rely on the latent variable approach whereby multiple *observed* indicators are combined to measure a single, latent *unobserved* variable. In particular they can be ascribed to the category of Structural Equations Modeling (SEM), a tool to measure such latent variables with multiple indicators (using a "measurement model") and, if desired, to also understand relationships between observed and latent variables (using a "structural model") (Shumacker and Lomax 2010; Lei and Wu 2007). Both organizations' indexes are ex-ante (forward-looking) indicators of households' intrinsic ability to recover from future shocks.

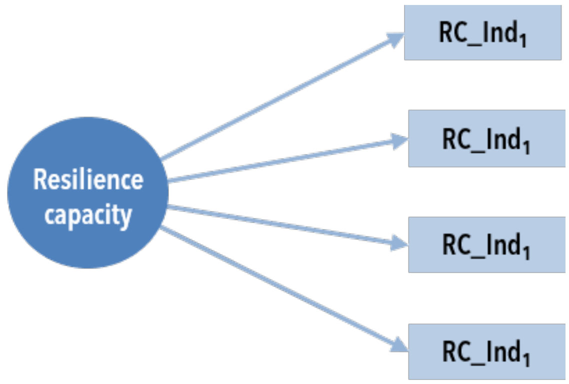
In this section we first lay out the SEM models employed to calculate indexes of resilience capacity starting with the most simple, that used by TANGO. Following, we discuss calculation of the resilience measure used by both organizations that was introduced above, termed "realized resilience." Finally, we compare all three measures from meaning and methodological perspectives.

3.1 TANGO's measure of household resilience capacity (factor analysis)

To construct an index of resilience capacity TANGO employs factor analysis, one of the most basic SEM techniques that only relies on a "measurement model" within the broader SEM structure. Factor analysis reduces the starting number of observed variables in an analysis to a smaller number of unobserved variables by formulating linear combinations of the observed variables that contain most of the information (STATA 2016). More intuitively, it produces an index that best summarizes the inter-correlations among a set of variables.

Figure 1 is a "path diagram" of a factor analysis model applied to resilience capacity with four observed variables, denoted RC_Ind_1 - RC_Ind_4, and one latent variable. The latent variable is circled, and the observed variables are in the squares. The arrows from the latent variable to the indicators signify that variation and covariation among the observed variables is partially determined by the latent variable.

Figure 1. Path diagram for Factor Analysis as applied to measurement of resilience capacity



To calculate an index for the latent variable, factor analysis finds one or more common factors that linearly reconstruct the observed variables by predicting their correlation matrix. It then calculates factor loadings for possibly multiple common factors. These loadings are used to identify which common factor appears to be the one representing the concept being measured. Such identification takes place by examining the signs and magnitudes of the loadings (STATA 2016).[5] After identification of a common factor, the loadings are used to calculate the desired index, a weighted average as follows:

$$index = \gamma_1 X_1 + \gamma_2 X_2 + \gamma_3 X_3 + \gamma_4 X_4. \quad (1)$$

The X's are the observed indicators (in standardized values), and the γ's are scoring coefficients derived from the factor loadings.

TANGO employs the principle-factors method for conducting factor analysis and the "regression scoring" method for calculating the scoring coefficients. The Kaiser-Meyer-Olkin (KMO) measure is employed to determine whether the observed variables have enough in common to warrant a factor analysis (STATA 2016). In practice, indexes of all three dimensions of resilience capacity—absorptive capacity, adaptive capacity and transformative capacity—are first calculated and then combined into an overall index of resilience capacity, again using factor analysis.

[5] There is a strong and wide literature on the exact number of factors to retain (see for example, Preacher et al. 2013). In practice, TANGO almost exclusively uses the first common factor, which accounts for the highest proportion of variance and typically has factor loadings of the appropriate sign.

3.2 FAO's measure of household resilience capacity (MIMIC model)

As mentioned in the introduction, in addition to indicators of resilience capacity, FAO's measurement approach includes indicators of arguably the most important well-being outcome for households in the shock-prone environments in which it works: food security. The approach conforms to guidance from Constas, Frankenberger and Hoddinott (2014), which states that "Resilience is a capacity that should be indexed to a given development outcome (e.g., food security, poverty, health) with a normative threshold" (p. 7). FAO incorporates the development outcome directly into its measurement using the Multiple Indicators-Multiple Causes (MIMIC) SEM model.

It is important to note that while the guidance from Constas, Frankenberger and Hoddinott (2014) references the use of a normative threshold, it also recognizes that such measurement may include "positive trajectories toward acceptable levels of well-being" (p. 7, fn 6). Specifying a normative threshold is not necessary and most often not appropriate for the populations to which FAO and TANGO apply resilience measurement. The large majority of households in these shock-prone environments fall below well-being thresholds both before and after being exposed to a shock. While acknowledging the importance of normative thresholds as targets, both organizations' measures related to resilience do not specify a normative threshold as a necessary condition for the achievement of resilience.

The FAO MIMIC model is focused on measuring an underlying latent variable, "resilience", that is hypothesized to have multiple indicators (food security indicators) as well as multiple causes (resilience capacities). In contrast to the TANGO method, both measurement and structural models are included. The observable variables are divided into correlates of the latent variable (corresponding to "causes" in the title of the model) and indicators of the latent variable. The correlates feed into the structural part of the model while the indicators feed into the measurement part of the model.[6] The relationship between observable variables and the latent variable is modeled by minimizing the distance between the sample covariance matrix and the covariance matrix predicted by the model. More intuitively, the FAO MIMIC model combines factor analysis (of the indicators of food security) and regression analysis (linking the resilience capacity indicators and the latent variable) to produce the desired index.[7]

Figure 2 is a path diagram of the FAO MIMIC model (D'Errico et al. 2016). Here the indicators of resilience capacity are considered correlates of the latent variable. The arrows from the indicators of resilience capacity to the latent variable signify that the resilience capacity indicators are correlates of resilience. Those from the latent variable to the food security indicators signify that variation and covariation among the indicators of food security are partially determined by the latent variable.

[6] Classical SEM distinguishes between two types of measurement models: reflective and formative (Edwards and Bagozzi, 2000). A reflective model sees a latent variable as the cause of observed variables; the formative model sees the observed variables as the causes of a latent variable. This important distinction is reflected in the way a model is visualized (see Figure 2) and estimated.

[7] See Joreskog and Goldberger (1975, cited in Dell'Anno and Schneider 2006), Breusch (2005) and Lee, Cadogan and Chamberlain (2013) on the regression interpretation of the MIMIC model. The MIMIC model can be reproduced using Ordinary Least Squares regression with the dependent variable being the factor analysis index of food security and independent variables the resilience capacity indicators.

Figure 2. Path diagram of the MIMIC model as applied to measurement of resilience capacity

Mathematically, the above MIMIC model is as follows:

$$Y_1 = \lambda_1 \eta + \varepsilon_1 \qquad (2)$$

$$Y_2 = \lambda_2 \eta + \varepsilon_2 \qquad (3)$$

$$\eta = \gamma_1 X_1 + \gamma_2 X_2 + \gamma_3 X_3 + \gamma_4 X_4 + \xi, \quad (4)$$

where η represents the latent variable, Y_1 and Y_2 are indicators of the latent variable (food security indicators), the X's are its correlates (resilience capacity indicators), and ε_1, ε_2 and ξ are error terms.

The RIMA-II model parameters are estimated using Maximum Likelihood on the assumption that the error terms ε_1, ε_2 and ξ are joint normally distributed. Model fit is assessed using fit indices calculated in order to measure the discrepancy between the sample covariance matrix and the covariance matrix predicted by the model.[8]

[8] In particular, the Root Mean Square Error of Approximation (RMSEA), the Comparative Fit Index (CFI), and the Tucker-Lewis Index (TLI) are employed (FAO 2016). The linearity assumption is partially removed by including not only the first factor but also all those required to explain (at least) 90% of the variance; this is in order to include the long-term effect of some variables. Note also that predicted values of the index are calculated in STATA using the "xblatent" option.

3.3 Realized resilience: Measuring resilience by tracking food security during shocks

Consistent with the operational definition of resilience as the ability to recover from shocks and stresses, measurement of realized resilience tracks the well-being of households as it evolves over the course of an actual period of shock exposure.[9] The measure is termed "realized resilience" because it is a post-shock (ex-post, or backwards-looking) depiction of how households actually fared over the course of a shock. Measurement only relies on indicators of well-being outcomes—in typical applications, indicators of food security.

The realized resilience measure is calculated by both TANGO and FAO as follows:

$$\Delta Y = Y_1 - Y_0, \quad (5)$$

where Y is the level of food security, and the subscripts indicate initial food security (t=0) and food security after the shock period (t=1). Note that this measure is highly dependent on the level of food security before the onset of the shock period (Y_0). The higher is this initial value, the lower is realized resilience and vice-versa. This "regression to the mean" (Trochim 2020; Dalliard 2017) can be partly due to random measurement error, but has another source here: the bounds imposed on *changes* in food security by upper and lower bounds on measures of food security, which represent its finite nature. Households that have relatively low initial food security have more room to increase it (and little to decrease it) compared to those with higher levels and vice-versa. Thus, when comparing the measure across groups of households or time it is important to interpret any differences in light of differences in their initial food security.[10]

3.4 Summary: Comparing the measures from meaning and methodological perspectives

The three measures considered here have distinct meanings. TANGO's factor analysis –based resilience capacity index measures households' capacity to withstand shocks and stressors they might face. FAO's MIMIC-based resilience capacity index has a somewhat different interpretation, measuring households' capacity to withstand shocks as it relates to their food security. Realized resilience measures households' actual ability to recover from specific shocks.

The TANGO and FAO indexes are based on data collected at one point in time regardless of whether households are experiencing shock exposure. They measure households' more intrinsic capacity to withstand shocks. The realized resilience measure, by contrast, is measured before and after shock periods, focusing on how households recover from specific, well-defined shocks.

A third difference is in regards to the type of data used for construction of the measures. The factor analysis index relies only on indicators of resilience capacities (X). The MIMIC index relies on indicators of resilience

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[9] TANGO also uses measures of food security stability over the course of a shock and a subjective measure termed "ability to recover" to measure resilience. The latter is based on data collected from households on their perceived ability to recover from each shock they experienced during a specified recall period (Smith et al. 2018).

[10] Valid comparisons across groups can also be undertaken by statistically adjusting the realized resilience measure for initial food security using OLS regression with realized resilience as the dependent variable and the initial value (as well as a group identification dummy variable) as an independent variable, a type of "Analysis of covariance" or ANCOVA (e.g., Barnett et al. 2004; Linden 2013) (See, for example, Smith and Frankenberger 2020).

capacities and indicators of food security, an outcome measure (both X and Y). The measure of realized resilience only relies on indicators of food security (Y).

With regards specifically to the FAO and TANGO resilience capacity indexes, a notable difference is in the estimation and interpretation of the coefficients in equations (1) and (4). The factor analysis coefficients (γ) are estimated using the intercorrelations among all of the resilience capacity indicators. They can be interpreted as the weight given to each indicator in the estimation of an overall index of resilience capacity, with greater weights given to those indicators that correlate more highly with the index. The MIMIC coefficients (β) are estimated using the statistical relationship between each resilience capacity indicator and food security. They can be interpreted as the amount by which food security would change with a one unit change in each resilience capacity indicator (a partial derivative). For the four-indicator example, the conditions under which the two models would yield the same index are:

$$\gamma_j = \beta_j = \frac{\partial \hat{Y}}{\partial x_j},\ j = 1 \ldots 4. \quad (6)$$

It is also important to consider that, empirically, the relationship between resilience capacity and food security will depend strongly on the validity of the indicators employed as measures of food security.

The next section looks at differences in the three measures from an empirical standpoint, and the results are interpreted in light of these basic differences in meaning and methodology.

4. Quantitative comparison of the measures in empirical applications

This section compares the measures described in the last section from an empirical standpoint, starting with descriptive comparisons of their means, associations, and probability distributions. It then looks at differences in how TANGO's and FAO's resilience capacity indexes rank groups of households for targeting purposes, including geographical areas of residence and socio-economic groups. Lastly, it compares them in regression analysis examining the relationship between households' resilience capacities and their realized resilience.

4.1 Data and indicators of resilience capacity and food security

4.1.1 Data sets

Table 1 contains information on the nine data sets employed for this analysis, including dates of data collection, sample size, nature of shocks households were exposed to, and the organization conducting the data analysis, whether TANGO or FAO. All of the data sets were collected in highly shock-prone regions within countries, five from East Africa, one from Central Africa, two from West Africa, and one from South Asia. Each data set contains cross-sectional data that will be used for calculating the Factor Analysis and MIMIC indexes. Six also contain panel data, for which data collection took place at two points in time during a shock period for the same households. These data are used for calculating the measure of realized resilience.

4.1.2 Indicators of food security

From Section 3, food security indicators are used for two purposes in this paper. The first is to calculate the MIMIC index. The second is for calculating realized resilience (the change in food security over a shock period). Box 1 lists the food security indicators employed for at least one of these purposes. Appendix A lists which specific food security indicators are employed for the TANGO and FAO data sets.

4.1.3 Indicators of resilience capacity

FAO's indicators of resilience capacity fall under the four "resilience pillars" mentioned above:

(1) Access to basic services
(2) Assets
(3) Social safety nets and
(4) Adaptive capacity.

The indicators used to measure each for the FAO data sets can be found in Appendix B (Table B1).

TANGO's index of resilience capacity is built from indexes of the three dimensions of resilience capacity: absorptive capacity, adaptive capacity, and transformative capacity. These indexes in turn are calculated from a set of individual indicators that varies by location. The indicators employed for each of the TANGO data sets can be found in Appendix B (Table B2). Examples of the indicators are disaster preparedness and bonding social capital (absorptive capacities), livelihood diversity and access to financial services (adaptive capacities), and access to markets and women's empowerment (transformative capacities).

Box 1. Food security indicators

Number of months of adequate food. Ranging from 0 to 12, the measure is the number of months in which the household indicated having adequate food to meet family needs.

Household Food Insecurity Access Scale (inverse of). The HFIAS is an An index based on nine questions regarding respondents' experiences of food insecurity in the last 30 days, including the frequency with which they experienced events and feelings associated with hunger and food insecurity.

Household Hunger Scale. An index constructed from the responses to three questions regarding people's experiences of acute food insecurity in the last 30 days.

Dietary Diversity Score. The total number of food groups, out of 12, from which household members consumed food in the last day. The DDS is an indicators of dietary quality.

Per capita calorie consumption. Per capita calorie consumption is the total calorie content of the food consumed by household members daily divided by household size.

Food Consumption Score. A composite score based on dietary diversity, food frequency, and the relative nutritional importance of different food groups. The FCS is calculated using the frequency of consumption of different food groups consumed by a household in the last 7 days.

Simpson Index. A measure of dietary diversity based on the proportion of food groups in households' total calorie consumption.

Table 1. Information on the data sets employed

Data set	Cross section or panel?	Dates of data collection	Number of households	Geographical area of data collection	Nature of shocks	Organization conducting data analysis and reference for further information
Bangladesh	Cross section Panel	2014 2012, 2014	8,415 358	Chars and Haors (in the north) and Coastal flood plains (in the south).	Flooding.	TANGO (Smith 2015)
Burkina Faso/Niger	Cross section Panel	2017 2013, 2017	2,492 360	Burkina Faso: Eastern, Northern Central and Sahel regions. Niger: Zinder, Maradi and Tillabery zones	Drought, flooding, insect invasions, animal disease outbreaks, food price inflation.	TANGO (Smith et al. 2016)
Chad	Cross section	2014	6,949	Barh el gazal, Batha, Chari baguirmi, Guera, Hadjer lamis, Kanem, Lac, Logone occidental, Logone oriental, Mandoul, Mayo kebbi-est, Mayo kebbi-ouest, Moyen chari, Ouaddai, Salamat, Sila, Tandjile, Wadi fira, Ennedi oust, Ennedi est	Drought, animal disease, human epidemics, income related shocks, food price inflation, input price inflation.	FAO (FAO 2019)
Ethiopia	Cross section Panel	2013 2013, 2014	2,609 366	Borena zone in Oromiya and Jijiga zone in Somali.	Drought, livestock and crop disease, food price inflation, input price inflation, conflict.	TANGO (Smith et al. 2014; Frankenberger and Smith 2015).
Mauritania	Cross section	2015	1,514	Assaba, Brakna, Tagant, Guidimagha.	Drought, livestock and crop disease, food price inflation, input price inflation.	FAO (FAO 2015)
Somalia I	Cross section	2016	1,280	Northern Sanaag Region in Somaliland; Three regions of southern Somalia; and Luuq district.	Drought, flooding, livestock disease, food price fluctuations, conflict, trade disruptions.	TANGO (Langworthy et al. 2016)
Somalia II	Cross section Panel	2016 2014, 2016	230 230	Burco and Odweyne districts.	Domestic violence, gender violence, conflicts, land grabbing, income related shocks, agricultural related shocks, weather shocks.	FAO (World Bank and FAO 2018)
Tanzania	Cross section Panel	2011 2010, 2011	2,855 2,855	Dodoma, Arusha, Kilimanjaro, Tanga, Morogoro, Pwani, Dar es salaam, Lindi, Mtwara, Ruvuma, Iringa, Mbeya, Singida, Tabora, Rukwa, Kigoma, Shinyanga, Kagera, Mwanza, Mara, Manyara, Kaskazini, Unguja, Kusini Unguja, Mjini/Magharibi Unguja, Kaskazini Pemba, Kusini Pemba.	Drought, flooding, food related shocks, food price inflation, input price inflation, livestock and crop disease	FAO (D'Errico, Romano and Pietrelli 2018)
Uganda	Cross section Panel	2011 2010, 2011	2,129 2,129	Kampala, Central without Kampala, Eastern, Northern, Western.	Drought, livestock and crop disease,income shocks.	FAO (D'Errico, Romano and Pietrelli 2018)

4.2 Statistical comparison: Means, correlations and distributions

4.2.1 FAO versus TANGO indexes of resilience capacity (RC)

Table 2 reports the means of the FAO (MIMIC) and TANGO (Factor analysis) RC indexes, as well as their correlations. The original indexes produced using the two methods are scaled from 0 to 100 to facilitate comparison. Graphs comparing their full distributions are presented in Figure 3. According to Kolmogorow-Smirnov(K-S) tests for equality of distributions, the FAO and TANGO index distributions diverge significantly ($p<0.05$) for all nine data sets (Table 2, last column).

Table 2. Comparison of FAO and TANGO indexes of resilience capacity: Means, correlations and distributions

Data set	N	Means			Correlation a/	K-S test for equality of distributions b/
		FAO (MIMIC)	TANGO (Factor analysis)	Difference		
Bangladesh	8,415	25.5	31.5	-6.0	0.891	0.000 ***
Niger	2,492	60.0	41.1	18.9	0.770	0.000 ***
Chad	6,949	15.3	27.8	-12.5	0.753	0.000 ***
Ethiopia	2,609	56.5	48.0	8.5	0.809	0.000 ***
Mauritania	1,514	52.9	49.0	3.9	0.903	0.000 ***
Somalia I	1,339	35.7	30.4	5.3	0.685	0.000 ***
Somalia II	230	59.3	47.4	11.9	0.738	0.000 ***
Tanzania	2,867	25.8	25.5	0.3	0.874	0.043 **
Uganda	2,129	29.0	27.8	1.2	0.779	0.000 ***

Notes: All means are weighted, taking into account survey sampling designs. The indexes are placed on a 0-100 scale to facilitate comparisons.

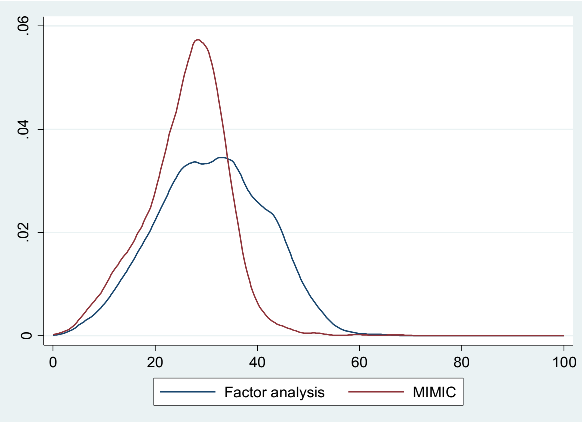
a/All correlations are statistically significant at the 1 percent level.

b/Kolmogorow-Smirnov test (p-values). Stars indicate statistical significance of the difference at the 5%(**) and 1% (***) levels.

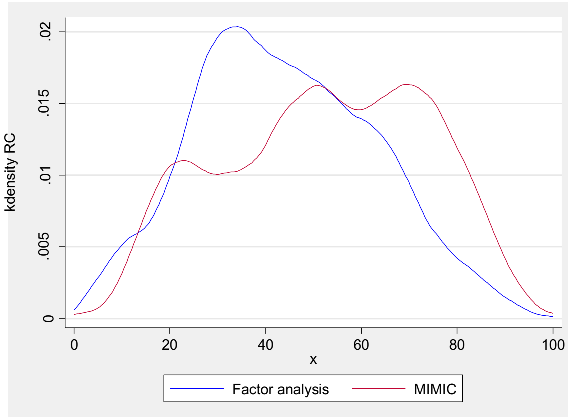
Based on comparison of means and correlations, the indexes appear to differ little for five data sets– Bangladesh, Ethiopia, Mauritania, Tanzania and Uganda. In these cases, means are quite close, index correlations are high (ranging from 0.78 to 0.90). While visually the distributions for the Bangladesh and Ethiopia data sets show divergences, those for Mauritania, Tanzania and Uganda are very similar. Means and distributions differ substantially for Burkina Faso/Niger, Chad, and Somalia II, despite moderately high correlations (ranging from 0.738 to 0.770). The FAO and TANGO indexes diverge the most for Somalia I, for whom the correlation is 0.685. Such correlational differences, even moderate ones, can have implications for population group rankings, for statistical analysis of the impact of resilience capacity on households' ability to recover from shocks (both examined further below), for statistical analysis of the impact of project interventions on resilience capacity, and for tracking changes over time, for example to track progress towards project goals.

Figure 3. Comparison of the distributions of FAO and TANGO resilience capacity indexes

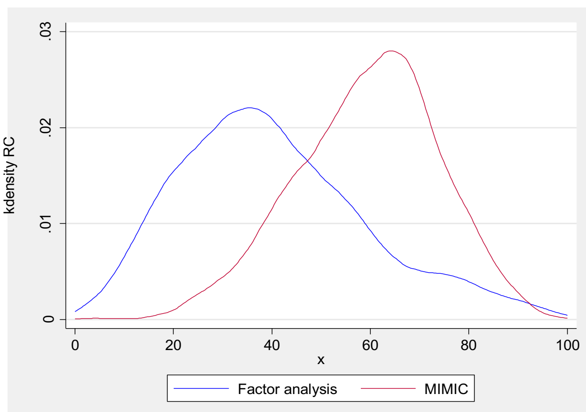
Bangladesh



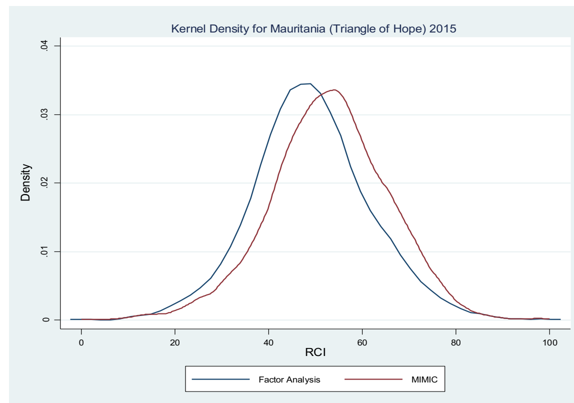
Ethiopia



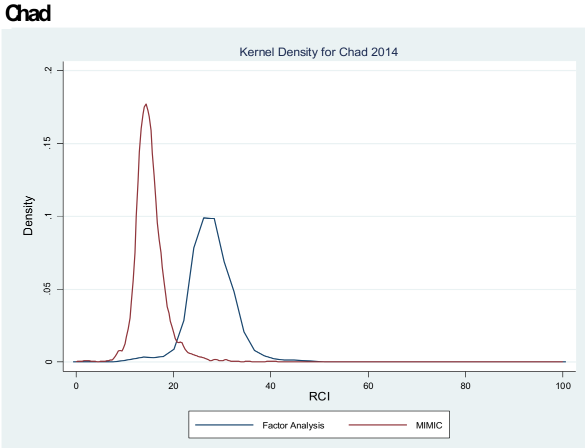
Burkina Faso and Niger



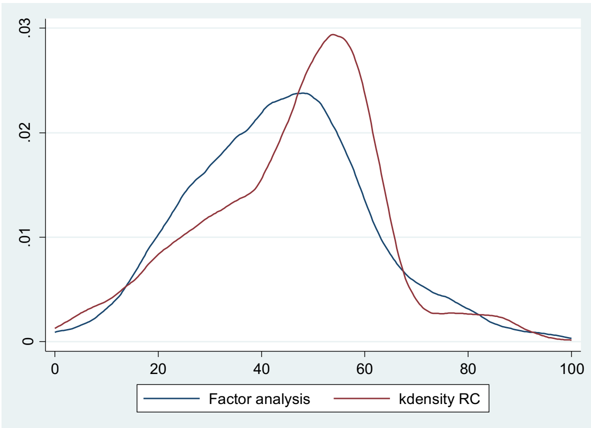
Mauritania



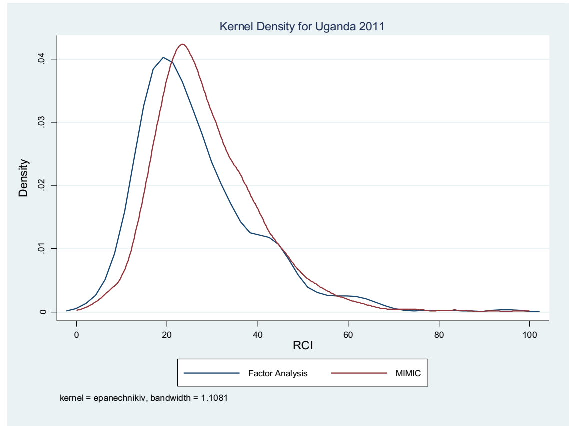
Chad



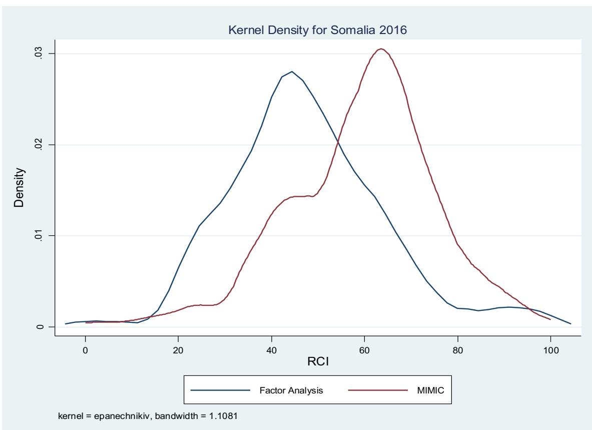
Somalia I



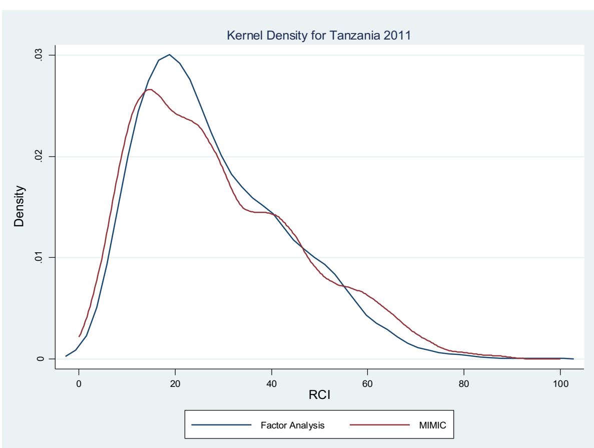
Uganda



Somalia II



Tanzania



As noted in Section 3.4 above, in the cases where the FAO and TANGO RC index distributions do markedly differ, the disparity can be attributed to underlying differences in the calculation of the index weights. The factor analysis weights are based on the inter-correlations between the resilience capacity indicators. MIMIC weights are based on the statistical relationship between the resilience capacity indicators and food security indicators. We can expect that in populations where the latter relationship is strong, the FAO and TANGO indexes will be more similar. Also note that divergences can occur if the particular food security indicators employed to estimate the MIMIC model do not capture food security well in a population.

4.2.2 FAO/TANGO indexes of resilience capacity versus realized resilience

Table 3 reports means, statistical associations, and tests for equality of distributions for the FAO and TANGO RC indexes compared with the measure of realized resilience for the six panel data sets. Because realized resilience is measured on a completely different scale than the RC indexes, we focus here on associations and distributional differences rather than differences in means. Rather than correlation coefficients, the associations between the measures are calculated as Ordinary Least Squares (OLS) regression coefficients where the dependent variable is realized resilience and, in addition to a resilience capacity index, initial-period food security is controlled for.[11] This approach is taken because the measure of realized resilience (a change in food security) is not comparable to the RC indexes without controlling for initial food security.

The K-S tests show that both the FAO and TANGO index distributions diverge significantly from that of realized resilience for all six data sets (see Table 3, last column). However, the associations are all positive and statistically significant at the 1 percent level. Comparing the TANGO and FAO index coefficients, they are very close for four of the data sets. For Bangladesh and Burkina Faso/Niger they are somewhat higher for the MIMIC index (differing from the TANGO indexes by 29.8 and 37.2 percent, respectively).

Note that while it is expected that resilience capacity and realized resilience have a positive relationship, as found here, they are not the same conceptually (see Section 3.4), and a number of factors can drive a wedge between empirical measures of them. Periods of shock are by their very nature times of great volatility. Many things are changing that affect the trajectory of households' food security besides their initial resilience capacities, for example, the amount of humanitarian assistance received and the state of households' physical environments. These changing conditions can affect the ability of households to draw on their initial

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[11] When initial food security, Y_0, is not controlled for, the measured relationship between realized resilience and resilience capacity is weaker and may even be negative (this is because, as mentioned in Section 3.3, households with lower initial food security have more room to increase it and vice versa). To see this mathematically, let the relationship between realized resilience, Z=$Y_1 - Y_0$, and resilience capacity be represented by the following equation:

$$Z = f\big(RC_o, Y_o(RC_o)\big),$$

where RC_o is resilience capacity at time zero. Then the relationship between RC_o and realized resilience is governed by the following derivative:

$$\frac{dZ}{dRC_o} = \frac{\partial Z}{\partial RC_o} + \frac{\partial Z}{\partial Y_o}\frac{\partial Y_o}{\partial RC_o}.$$

While $\frac{\partial Z}{\partial RC_o}$ and $\frac{\partial Y_o}{\partial RC_o}$ are positive, $\frac{\partial Z}{\partial Y_o}$ is negative, driving down the overall effect (if Y_0 is not controlled for).

resilience capacities to help them recover. Also affecting the relationship is the degree and nature of shock exposure. Households that have stronger resilience capacities to start but who are faced with multiple, strong shocks may not do as well as those with weaker capacities but who are less shock exposed. Finally, the greater the length of time between measurement of the resilience capacities and measurement of endpoint food security, the weaker the positive association is likely to be.

Table 3. Comparison of FAO/TANGO indexes of resilience capacity with measure of realized resilience

Data set	N	MIMIC index versus realized resilience				Factor analysis index versus realized resilience			
		Means		Assoc-iations	K-S test for equality of distributions a/	Means		Assoc-iations	K-S test for equality of distributions a/
		FAO (MIMIC)	RR			TANGO (Factor analysis)	RR		
Bangladesh	358	25.5	1.33	0.114 ***	0.000 ***	31.5	1.33	0.080 ***	0.000 ***
Niger	360	60.0	-0.98	0.239 ***	0.000 ***	41.1	-0.98	0.150 ***	0.000 ***
Ethiopia	366	57.0	-3.10	0.075 ***	0.000 ***	52.0	-3.10	0.064 ***	0.020 **
Somalia II	230	59.3	-0.84	0.002 ***	0.000 ***	47.4	-0.05	0.002 ***	0.000 ***
Tanzania	2,867	25.8	0.14	0.765 ***	0.000 ***	25.5	0.14	0.752 ***	0.000 ***
Uganda	2,129	29.0	0.58	0.589 ***	0.000 ***	27.8	0.58	0.579 ***	0.000 ***

Notes: All means are weighted, taking into account survey sampling designs. The indexes are placed on a 0-100 scale to facilitate comparisons.
a/Kolmogorow-Smirnov test for equality of distributions (p-values). Stars indicate statistical significance of the difference at the 5%(**) and 1% (***) levels.

4.3 Policy analysis: Targeting

In this section we compare rankings given by FAO's and TANGO's indexes of resilience capacity for geographical areas and socio-economic groups, the latter including gender-based groups and livelihood groups. The measure of realized resilience is not included here for the comparability reasons given in the last section. The number of data sets included in each comparison differs depending on whether the relevant data are available.

The rank comparison for administrative regions within the study areas is given in Table 4. Rankings are the same for Bangladesh and Uganda, and reasonably close for four other countries: Chad, Ethiopia, Mauritania, and Somalia I. In the case of Burkina Faso/Niger, the rank correlation is positive and moderately high, at 0.543. In the case of Tanzania, despite a fairly high correlation between the two indexes themselves (see Table 2 above), rankings are very different. Those for Somalia II are based on only two geographical areas, which are ranked opposite one another.

Table 5 gives comparisons for four of the countries based on locality types (urban, rural and in the case of Somalia II, peri-urban in addition). The rankings are the same for three of the four countries. For Somalia II, rural areas are consistently ranked number one by the FAO and TANGO indexes, but the urban and peri-urban areas are ranked opposite one another.

Table 4. Comparison of FAO and TANGO resilience capacity index rankings of geographical areas

Data set	Population group	FAO (MIMIC)		TANGO (Factor Analysis)		Rank difference
		Mean	Rank	Mean	Rank	
Bangladesh	Coast	25.2	1	24.3	1	0
	Haor	32.4	4	26.1	4	0
	Mid Char	29.7	2	25.0	2	0
	North Char	32.1	3	25.3	3	0
				Rank correlation		1.000
Burkina Faso/Niger	Sahel	59.4	4	38.7	5	-1
	Centre-Nord	62.2	2	45.2	1	1
	Est	65.5	1	40.0	4	-3
	Zinder	61.5	3	44.2	2	1
	Maradi	59.1	5	43.7	3	2
	Tillabery	47.8	6	30.7	6	0
				Rank correlation		0.543
Chad	Barh el gazal	14.8	13	25.2	17	-4
	Batha	14.5	14	26.0	15	-1
	Chari baguirmi	16.8	2	28.3	9	-7
	Guera	14.3	15	25.0	18	-3
	Hadjer lamis	15.9	6	27.4	11	-5
	Kanem	14.2	17	24.7	20	-3
	Lac	14.2	16	25.5	16	0
	Logone occidental	16.4	4	29.6	4	0
	Logone oriental	15.3	9	28.8	7	2
	Mandoul	15.2	10	28.4	8	2
	Mayo kebbi-est	15.4	8	28.8	6	2
	Mayo kebbi-ouest	17.4	1	31.4	1	0
	Moyen chari	16.4	5	30.8	2	3
	Ouaddai	13.9	19	27.6	10	9
	Salamat	14.9	12	26.8	12	0
	Sila	13.4	20	24.7	19	1
	Tandjile	16.8	3	30.2	3	0
	Wadi fira	14.1	18	26.5	14	4
	Ennedi ouest	15.0	11	26.7	13	-2
	Ennedi est	15.9	7	29.0	5	2
				Rank correlation		0.834
Ethiopia	Gursum	38.4	7	40.3	5	2
	Jijiga	41.8	5	27.8	7	-2
	Kebri Beyah	39.7	6	31.2	6	0
	Yabelo	65.8	1	60.2	1	0
	Teltele	61.6	3	48.5	3	0
	Dugdadawa	59.5	4	47.6	4	0
	Miyo	62.0	2	52.0	2	0
				Rank correlation		0.847

Continued.

Table 4. Continued.

Data set	Population group	FAO (MIMIC) Mean	FAO (MIMIC) Rank	TANGO (Factor Analysis) Mean	TANGO (Factor Analysis) Rank	Rank difference
Mauritania	Assaba	53.0	3	49.3	3	0
	Brakna	56.0	2	51.4	1	1
	Tagant	56.2	1	51.0	2	-1
	Guidimagha	48.1	4	45.2	4	0
				Rank correlation		0.800
Somalia I	Badhan	22.1	5	30.6	4	1
	Belet Xawa	32.7	4	20.4	6	-2
	Baidoa	14.6	6	28.5	5	1
	Afgooye	45.6	3	37.3	3	0
	Luuq	47.1	2	53.9	1	1
	Luuq (town)	55.2	1	51.8	2	-1
				Rank correlation		0.771
Somalia II	Burco	64.8	1	34.0	2	-1
	Odweyne	54.5	2	44.4	1	1
				Rank correlation		-1.000
Tanzania	Arusha	27.5	9	15.7	26	-17
	Dar Es Salaam	40.7	4	27.1	10	-6
	Dodoma	17.3	26	30.8	6	20
	Iringa	28.2	8	20.7	22	-14
	Kagera	20.3	23	29.0	8	15
	Kaskazini Pemba	36.8	5	24.5	14	-9
	Kaskazini Unguja	33.8	7	41.3	2	5
	Kigoma	22.8	19	21.6	20	-1
	Kilimanjaro	34.5	6	22.0	19	-13
	Kusini Pemba	43.3	2	22.6	18	-16
	Kusini Unguja	41.3	3	28.4	9	-6
	Lindi	22.1	20	25.4	12	8
	Manyara	24.7	14	25.1	13	1
	Mara	23.7	17	20.1	24	-7
	Mbeya	24.7	15	20.7	23	-8
	Mjini/Magharibi	50.7	1	23.9	16	-15
	Morogoro	26.6	10	22.7	17	-7
	Mtwara	23.4	18	21.1	21	-3
	Mwanza	25.2	12	26.5	11	1
	Pwani	25.0	13	23.9	15	-2
	Rukwa	19.8	25	19.9	25	0
	Ruvuma	20.1	24	29.1	7	17
	Shinyanga	24.1	16	35.6	4	12
	Singida	26.1	11	48.1	1	10
	Tabora	21.5	21	31.1	5	16
	Tanga	21.0	22	38.2	3	19
				Rank correlation		-0.138
Uganda	Kampala	46.6	1	47.4	1	0
	Central without kampal	33.2	2	32.6	2	0
	Eastern	25.9	4	23.4	4	0
	Northern	23.8	5	20.3	5	0
	Western	28.5	3	24.7	3	0
				Rank correlation		1.000

Notes: All means are weighted, taking into account survey sampling designs. The indexes are placed on a 0-to-100 scale to facilitate comparisons.

Table 5. Policy analysis: Comparison of FAO and TANGO resilience capacity index rankings of locality types

Data set	Group	FAO (MIMIC) Mean	FAO (MIMIC) Rank	TANGO (Factor Analysis) Mean	TANGO (Factor Analysis) Rank	Rank difference
Mauritania						
	Urban	55.7	1	52.2	1	0
	Rural	51.8	2	47.7	2	0
				Rank correlation		1.000
Somalia II						
	Rural	50.6	1	46.4	1	0
	Peri-urban	36.0	2	23.7	3	-1
	Urban	26.5	3	34.0	2	1
				Rank correlation		0.500
Tanzania						
	Urban	27.7	1	27.7	1	0
	Rural	24.7	2	23.7	2	0
				Rank correlation		1.000
Uganda						
	Urban	41.3	1	42.0	1	0
	Rural	26.7	2	24.3	2	0
				Rank correlation		1.000

Notes: All means are weighted, taking into account survey sampling designs. The indexes are placed on a 0-100 scale to facilitate comparisons.

Rank comparisons for gender-based groups are reported in Table 6. Gender of household head is the indicator for six of the countries, and whether the household is female adult-only is the indicator for three countries. The FAO and TANGO indexes rank the groups the same in six of the eight countries for which any differences by gender are apparent. For the other two, the indicator value differences across the gender groups are so small that the rank differences are not meaningful.

Finally, Table 7 compares rankings for livelihood groups in four of the countries. The rankings are the same or very similar in Bangladesh and Ethiopia. However they differ substantially for Burkina Faso/Niger and Somalia II, both countries for which the distributions of the indexes differ substantially and correlations are low (see Figure 3 and Table 2 above).

Table 6. Policy analysis: Comparison of FAO and TANGO resilience capacity index rankings of gender-based groups

Data set	Group	FAO (MIMIC) Mean	FAO (MIMIC) Rank	TANGO (Factor Analysis) Mean	TANGO (Factor Analysis) Rank	Rank difference
Bangladesh						
Gender of hhh	Female	21.5	2	26.7	2	0
	Male	26.2	1	32.3	1	0
				Rank correlation		1.000
Burkina Faso/Niger						
Female-only hh	Yes	44.6	2	31.3	2	0
	No	61.0	1	41.7	1	0
				Rank correlation		1.000
Chad						
Gender of hhh	Female	14.3	2	27.8	1	1
	Male	15.5	1	27.8	1	0
				Rank correlation		a/
Ethiopia						
Female-only hh	Yes	50.1	2	44.8	2	0
	No	57.2	1	48.4	1	0
				Rank correlation		1.000
Mauritania						
Gender of hhh	Female	54.3	1	50.4	1	0
	Male	52.4	2	48.5	2	0
				Rank correlation		1.000
Somalia I						
Gender of hhh	Female	58.7	2	45.0	2	0
	Male	59.6	1	48.4	1	0
				Rank correlation		1.000
Somalia II						
Female-only hh	Yes	27.6	2	21.2	2	0
	No	37.0	1	31.7	1	0
				Rank correlation		1.000
Tanzania						
Gender of hhh	Female	25.9	1	24.2	2	-1
	Male	24.8	2	24.3	1	1
				Rank correlation		-1.000
Uganda						
Gender of hhh	Female	28.3	2	28.5	1	1
	Male	29.3	1	26.4	2	-1
				Rank correlation		-1.000

Notes: All means are weighted, taking into account survey sampling designs. The indexes are placed on a 0-100 scale to facilitate comparisons.
a/ Not defined.

Table 7. Policy analysis: Comparison of FAO and TANGO resilience capacity index rankings of livelihood groups

Data set		Group	FAO (MIMIC) Mean	FAO (MIMIC) Rank	TANGO (Factor Analysis) Mean	TANGO (Factor Analysis) Rank	Rank difference
Bangladesh							
	Occupation of household head	Farming	34.0	2	28.3	1	1
		Agricultural labor	29.7	4	23.6	4	0
		Non-agricultural labor	29.3	5	23.6	5	0
		Salaried work	34.4	1	28.1	2	-1
		Self-employment	34.0	3	26.8	3	0
		Unpaid household work	27.8	7	22.8	7	0
		Other	28.9	6	23.1	6	0
					Rank		0.964
Burkina Faso/Niger							
	Livelihood group						
		Pastoralism	63.3	1	41.4	2	-1
		Agriculture	59.2	3	39.3	3	0
		Other	60.9	2	46.6	1	1
					Rank		0.500
Ethiopia							
	Livelihood group						
		Pastoralist	62.6	1	54.0	1	0
		Agro-pastoralist	56.8	2	47.3	2	0
		Non-pastoralist	46.5	3	40.2	3	0
					Rank		1.000
Somalia II							
	Livelihood group						
		Pastoralist	37.8	1	33.4	3	-2
		Agro-pastoralist	34.6	2	55.9	1	1
		Riverine	32.8	3	34.6	2	1
					Rank		-0.500

Notes: All means are weighted, taking into account survey sampling designs. The indexes are placed on a 0-100 scale to facilitate comparisons.

4.4 Policy analysis: Do households' resilience capacities strengthen their ability to recover from shocks?

We turn next to policy analysis examining the relationship between households' resilience capacity and their resilience while controlling for other factors affecting their ability to recover from shocks, including their shock exposure and socio-demographic characteristics. Do estimates of the direction and strength of this relationship differ for the FAO and TANGO resilience capacity indexes? This type of analysis using the overall indexes informs as to whether efforts to improve households' own resilience capacities, as opposed to simply providing them with humanitarian assistance, for example, actually does enable them to recover from shocks and is thus worth investing in. A fully informative investigation would go deeper to look at indexes of the three dimensions of resilience capacity (for the TANGO measure) or the four resilience pillars (for the FAO measure) and, most importantly, at individual capacities that correspond to specific investments, for example, access to markets or support for disaster risk reduction.

Using data from the six data sets containing panel data, we examine the relationship between the resilience capacity indexes and realized resilience using a standard growth regression model (e.g., Yamano et al. 2015; Hoddinott and Kinsey 2001) as follows:[12]

$$Y_{i,1} - Y_{i,0} = \alpha + \beta_1 RC_{i,0} + \beta_2 SE_i + \beta_3 Y_{i,0} + \beta_4 X_{i,0} + \varepsilon_i. \quad (8)$$

In equation (8) the term $Y_{i,1} - Y_{i,0}$ represents realized resilience over the shock period, with t=0 indicating the time period before the shock occurred and t=1 after. The variable "RC" represents the TANGO or FAO index of resilience capacity. These indexes are measured before the shock occurred as well. Also controlled for are the degree of shock exposure, initial food security, and household and community characteristics at time t=0.

Table 8 contains the regression results. The measure of shock exposure employed is listed in the second column, with separate regressions run for each. The full list of household and community characteristics controlled for is given in the last column.

[12] This regression technique does not allow analysis of causal impacts of households' resilience capacities. Thus, the regression results should be considered exploratory and "suggestive evidence."

Table 8. Regression analysis of the relationship between the FAO/TANGO resilience capacity indexes and household resilience to shocks

Data set/Food security indicator	Measure of shock exposure	MIMIC index		Factor analysis index		N	Household characteristics controlled for
		Coeff-icient	t-stat	Coeff-icient	t-stat		
Bangladesh							
Change in number of months of adequate food	Number of flood-related shocks exposed to	0.030	2.67 ***	0.021	2.16 **	358	HH size/age-sex composition, gender, age, occupation and education of hh head, hh economic status, exposure to other (non-flood-related) shocks, and village of residence.
	Annual streamflow surplus	0.027	3.44 ***	0.019	3.28 ***	358	As above, but region (rather than village) of residence is controlled for.
Burkina Faso and Niger							
Change in food security score a/	Shock exposure index	0.000	0.02	-0.009	-0.41	345	Household adult equivalents/age-sex composition, education, female-adult-only hh indicator, pastoral status, index of asset ownership, and country of residence.
	Cumulative rainfall deficit	0.020	0.59	0.000	0.00	345	As above.
Ethiopia							
Change in food security score a/	Cumulative rainfall deficit	0.065	2.00 **	0.067	1.60	366	Household size/age-sex composition, education, female-adult-only hh indicator, pastoral status, index of asset ownership, project geographical area, and interaction terms between the resilience capacity index and project area, and between the shock exposure measure and project area.
	Cumulative soil moisture deficit	0.065	2.06 **	0.069	1.78 *	366	
	Cumulative vegetation deficit	0.068	2.12 **	0.071	1.69 *	366	
Somalia II							
Change in Food Consumption Score	Food shocks	0.083	2.82 ***	0.590	0.14	460	HH size, gender, age,average level of education in the HH
	Climatic Shocks	-0.006	0.26	1.351	1.26	460	
	Economic Shocks	-0.022	2.52 **	-0.448	0.41	460	
	HH shocks	0.009	0.45	0.63	0.65	460	
Tanzania							
Change in Food Consumption Score	Food shocks	0.090	0.09	0.049	0.05	2,855	HH size, gender, age,average level of education in the HH, hh if agriculture and region of residence.
	Climatic Shocks	1.383	1.29	1.339	0.5	2,855	
	Economic Shocks	-0.397	0.37	-0.051	1.32	2,855	
	HH shocks	0.683	0.7	0.03	0.31	2,855	
Uganda							
Change in Food Consumption Score	Food shocks	-2.506	2.3 ***	-3.326	3.06 ***	2,128	HH size, gender, age,average level of education in the HH, hh if agriculture and region of residence.
	Climatic Shocks	0.173	0.17	0.526	0.53	2,128	
	Economic Shocks	-0.629	0.58	-0.435	-0.4	2,128	
	HH shocks	2.575	1.06	2.84	1.17	2,128	

Note: The dependent variable is the change in food security over the shock period (realized resilience)
a/ Inverted Household Food Insecurity Access Scale

For five of the countries, the two indexes yield the same policy implications:

- Bangladesh and Ethiopia: For all shock measures, household's initial resilience capacity likely helped them recover from shocks[13]
- Burkina Faso/Niger and Tanzania: For all shock measures, households' initial resilience capacity, as measured at this aggregated level, did not help them recover from shocks
- Uganda: Both indexes yield mixed evidence regarding whether households' initial resilience capacity helped them recover (depending on the type of shock exposure controlled for).

In the case of the Somalia II data set, the FAO and TANGO indexes yield inconsistent results. For instance, when "food shocks" is the measure of shock exposure, the TANGO index indicates that resilience capacity did help households recover while the FAO index indicates no effect of household resilience capacity on realized resilience.

It is important to note that results indicating no effect of resilience capacity for this overall index cannot be interpreted as meaning that none of households' capacities assisted them in their recovery. TANGO's work in this area has shown that when an index of overall resilience capacity is not statistically significant, indexes of one of the three dimensions often is, and certainly some of the individual indicators making up the broader indexes (e.g., Smith, Frankenberger and Nelson 2018). For example, further analysis of the Burkina Faso/Niger data set indicates that households' absorptive capacities as well as seven specific capacities—bonding and bridging social capital, holdings of savings, availability of hazard insurance, disaster preparedness and mitigation, asset ownership, and access to financial resources—did likely help them recover from the shocks they faced (Smith et al. 2018).

[13] In the Ethiopia analysis, the one statistically insignificant coefficient (for the TANGO index and cumulative rainfall deficit measure of shock exposure) would likely be significant with a larger sample size.

5. Summary and conclusions

In this paper we have evaluated the relative behavior of three measures related to households' resilience: TANGO's measure of resilience capacity constructed using factor analysis, FAO's measure of resilience capacity constructed using the MIMIC model, and a measure of realized resilience that tracks how households' well-being fares over the course of a shock. TANGO and FAO use the same procedure for measuring realized resilience, the change in food security from the beginning to the end of a shock period, which requires panel data. They use different procedures for measuring resilience capacity. Table 9 summarizes the similarities and differences among the three measures.

Table 9. Summary comparison of the three measures

	TANGO index of resilience capacity	FAO index of resilience capacity	Realized resilience
Meaning	The capacity of households to withstand future shocks and stressors	The capacity of households to withstand future shocks and stressors as it relates to their food security	Households' actual ability to recover from a specific, well-defined shock
Measurement: Types of indicators employed	Indicators of resilience capacity	Indicators of resilience capacity and food security	Indicators of well-being (e.g., food security)
Measurement: Calculation procedure	Factor analysis (Based on the intercorrelations among indicators of resilience capacity)	MIMIC model (Based on the statistical relationship between indicators of resilience capacity and food security)	Subtraction: Difference between pre-shock and post-shock values of indicator of well-being

From a conceptual standpoint, the measures have distinct meanings. TANGO's resilience capacity index measures households' capacity to withstand shocks they might face in the future. FAO's resilience capacity index measures households' capacity to withstand such shocks as it relates to their food security. Realized resilience measures households' actual ability to recover from shocks.

The TANGO and FAO resilience capacity indexes are calculated using data collected at one point in time regardless of whether households are experiencing a shock. They measure households' intrinsic capacity to withstand shocks. The realized resilience measure, by contrast, focuses on how households recover from specific, well-defined shocks, a depiction of how they actually fared. While it is expected that resilience capacity and realized resilience have a positive relationship, a number of factors drive a wedge between empirical measures of them, including the degree and nature of shock exposure and the length of time between measurement of the resilience capacities and measurement of endpoint food security (i.e., the end of the shock period). For this reason, they are not directly comparable to one another in descriptive analyses, such as comparisons for the purpose of targeting.

Nine data sets containing resilience data for 28,637 households living in shock-prone areas were used to compare the FAO and TANGO resilience capacity indexes in policy applications. More often than not, they are found here to yield similar policy implications. Comparisons for the purposes of targeting were conducted by geographical area, locality type (urban/rural), gender-based groups, and livelihood groups. Rankings were close for 6/9 data sets in the case of geographical targeting, 3/4 by locality type, 6/8 by gender-based groups, and 2/4 by livelihood group. In regression analysis analyzing the relationship between resilience capacity and realized resilience, the conclusions reached were the same in 5 of the 6 countries for which panel data are available for analysis. Where differences are found, they can be attributed to (1) underlying conceptual differences—the fact that the two indexes are measuring different phenomena; (2) the use of different types of indicators: resilience capacity indicators only or resilience capacity *and* food security indicators; and (3) differences between calculation procedures of factor analysis and MIMIC model estimation.

In conclusion, this paper has helped to clarify the differences between three key measures related to the resilience concept. With respect to FAO's and TANGO's measures of households' resilience capacity—their capacity to withstand future shocks and stressors—it finds them both to be useful for providing important information supporting resilience-strengthening programming. They generally point in the same directions when it comes to implications for programming despite the different measurement approaches. Along with realized resilience, both are useful components of the growing set of resilience measurement tools needed by implementing agencies, researchers, governments, and international donors for addressing the increasingly challenging series of shocks and stressors faced by developing-country households.

Appendix A. Food security indicators employed

Table A1. Food security indicators used to calculate the MIMIC resilience capacity index and realized resilience

Data set	MIMIC index	Realized resilience
Bangladesh	* Number of months of adequate food in last year * Household Hunger Score (inverse of)	* Number of months of adequate food in last year
Burkina Faso/Niger	* Household food insecurity access scale (HFIAS) (inverse of)	* Household food insecurity access scale (inverse of)
Chad	* Food Consumption Score * Food expenditure	
Ethiopia	* Household food insecurity access scale (HFIAS) (inverse of) * Coping Strategies Index	* Household food insecurity access scale (inverse of)
Mauritania	* Food expenditure * Simpson Index * Food Consumption Score	
Somalia I	* Household food insecurity access scale (HFIAS) (inverse of)	
Somalia II	* Food Consumption Score * Food expenditure	* Food consumption score
Tanzania	* Food Expenditure * Simpson Index	* Food consumption score
Uganda	* Food Expenditure * Simpson Index	* Food consumption score

Descriptions of food security indicators

Number of months of adequate food in the last year.

Survey respondents were asked "Which were the months in the past 12 months in which you did not have enough food to meet your family's needs? This includes any kind of food, such as food you produced yourself, food purchased, food given to you by others, food aid, or food you borrowed." Following, enumerators listed the months and elicited a yes/no response for each. Ranging from 0 to 12, the measure is the number of months in which the household indicated having adequate food to meet the family's needs (Bilinsky and Swindale 2010).

Household Food Insecurity Access Scale (HFIAS) (inverse).

The HFIAS is an index constructed from the responses to nine questions regarding people's experiences of food insecurity. Responses range from worry about not having enough food to actual experiences of food deprivation associated with hunger. Respondents indicate whether or not they or another household member experienced the event or feeling in question and, if yes, how often in the last 30 days (rarely, sometimes or often). A score is then calculated based on these frequency responses (Coates, Swindale and Bilinsky 2007).

Household Hunger Score (inverse).

The second measure, the household hunger score, is an index constructed from the responses to three questions regarding people's experiences of acute food insecurity in the previous four weeks (Ballard et al. 2011). The experiences are:

1. There was no food to eat of any kind in the household because of lack of resources to get food;
2. Any household member went to sleep at night hungry because there was not enough food; and
3. Any household member went a whole day and night without eating anything because there was not enough food.

Survey respondents indicate whether or not they or another household member experienced the circumstance in question and, if yes, how often in the last 30 days (rarely, sometimes or often). A score ranging from 0 to 6 is then calculated based on these frequency responses. A prevalence of hunger can be calculated as the percentage of households whose score value is greater than or equal to two, representing "moderate to severe hunger."

Dietary Diversity Score.

The DDS reflects the quality of households' diets and is the total number of food groups, out of 12, from which household members consumed food in the last day (Swindale and Bilinsky 2006).

Coping Strategies Index.

The CSI is a scale taking into account both the frequency and severity of coping strategies employed to deal with food insecurity. The scale used here is based on nine coping strategies. Respondents are asked to report how many days in the last seven they employed each strategy. The index is calculated as a weighted average of the number of days a strategy was employed, where the weights reflect the severity of food insecurity associated with each strategy. It ranges from 0 to 217.7 (Maxwell and Caldwell 2008).

Per capita calorie consumption.

Per capita calorie consumption is the total calorie content of the food consumed by household members daily divided by household size. Calculation of this measure starts by estimating the quantities consumed by households of individual foods. Following, the energy contents of the edible portion of the quantities are summed, and the sum is divided by the number of days in the reference period for food data collection. Finally, this sum is divided by the number of household members (Smith and Subandoro 2007).

Food Consumption Score.

The Food Consumption Score is a composite score based on dietary diversity, food frequency, and the relative nutritional importance of different food groups. First, consumption frequencies over the last seven days of foods falling into seven specific food groups are calculated. Second, the consumption frequency for each group is multiplied its pre-determined food-group specific weight, with the weights chosen based on relative nutrient density. Finally, the weighted values are summed to arrive at the final score (World Food Program 2008).

Simpson Index.

The Simpson Index is a measure of dietary diversity based on the proportion of food groups in households' total calorie consumption. Total and food-group per-capita calorie consumption are used to calculate the proportion of total calories from each food group. Following, the Simpson Index is calculated as follows:

$$Index = 1 - \sum_{i}^{n} P_i^2$$

where the proportion for food group i is denoted P_i (e.g., Ecker 2018).

Appendix B. Resilience capacity indicators employed

Table B1 Indicators of resilience capacity used for constructing FAO's resilience capacity index

	Access to Basic Services	Assets*	Social Safety Nets	Adaptive Capacity
Chad	Access to improved sanitation	Per capita land owned	Transfers received	Household head can read and write
	Electricy as source of light	Per capita Tropical livestock unit	Assistance_index	Dependency ratio
	Electricity as source for coking	Per capita amount of cereal harvested (Tons)	Access to credit	Participation in Different source of income
	Having access to improved water			Fsi
	Average quantity of water used per person in the house, liter/person/day			
	Travel time to nearest town			
Mauritania	Electricy as source of light	TLU per capita	Received cash transfers per capita	Participation in different source of income
	Distance to water source (min.)	Cultivated land value per capita	Received in kind transfers per capita	Average (formal) education
	Distance to school (min.)	Wealth index	Participation in associations	Dependency ratio inverse (actives/non-actives)
	Distance to hospital (min.)	House value per capita		Perception of decisional process
	Distance to market (min.)	Agricultural inputs		
	Improved Sanitation			
Somalia	Access to improved water	Wealth Index	Number of networks or groups that a household reported being associated with	Participation Index
	Electricity as source of light	House Value	Transfers	Coping Strategy Index
	Access to improved toilet facilities	Total Annual Income Standardized	Access to Credit	Employment Ratio
	Access to waste disposal	Tropical Livestock Unit	Debt	Household Head Education
	Distance from School	Agricultural Input Index		Household's literacy rate
	Distance from Bus	Agricultural Assets Index		
	Distance from Market	Non farming enterprise		
		Food Consumption Score		
		Cultivated Land		
		Total Value of Durables		
Tanzania	Level of infrastructure	Agricultural welath index	Informal transfers	Participation in differt source of income
	Distance to primary school	Wealth index	Formal transfers	Household level of education
	Distance to agricultural Market	Per capita TLU		Dependency ratio
		Per capita land owned		
Uganda	Access to improved water	Agricultural welath index	Informal transfers	Participation in differt source of income
	Access to improved sanitation	Wealth index	Formal transfers	Household level of education
	Distance to veterinary services	Per capita TLU		Dependency ratio
	Distance to primary school	Per capita land used for crop production		
	Distance to secondary school			
	Distance to health services			
	Distance to hospital			
	Distance to agricultural inputs market			
	Distance to non-agricultural market			

* For Somalia the pillar is called Productive assets under the old way to model RCI

Table B2 Indicators of resilience capacity used for constructing TANGO's resilience capacity index

	Bangladesh	Burkina Faso/Niger	Ethiopia	Somalia I
Absorptive capacity				
Bonding social capital				
Cash savings				
Access to informal safety nets				
Availability of hazard insurance				
Disaster preparedness and mitigation				
Conflict mitigation support				
Asset ownership				
Adaptive capacity				
Bridging social capital				
Linking social capital				
Aspirations/confidence to adapt				
Livelihood diversity				
Access to financial resources				
Human capital				
Exposure to information				
Asset ownership				
Transformative capacity				
Bridging social capital				
Linking social capital				
Access to markets				
Access to basic services				
Access to livestock services				
Access to infrastructure				
Access to communal natural resources				
Access to formal safety nets				
Women's empowerment				
Governance				
Source of information on indicator measurement	Smith (2015)	Smith et al. (2016)	Smith et al. (2014)	Langworthy et al. (2016)

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