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A Review of the Literature on Resilience Measurement

Elena Serfilippi[1] and Gayatri Ramnath[2]

Abstract
The lack of consensus and consistency in measuring resilience undermines the development aid community's ability to objectively monitor and verify the effects of programs that are intentionally designed to build resilience. In this paper we compare conceptual and analytical models of resilience used by various development organizations, critically evaluating their strengths and weaknesses from a program implementation and measurement point of view. We provide the reader with a clear synthesis of the literature and a classification system for these resilience models. Finally, we bridge the "measurement gap" by mapping each resilience model to its set of indicators from a list of indicators and metrics we have directly distilled from the literature and classified using SMART filters.

Keywords: Resilience, Shock, Risk, Vulnerability, Sustainability, Well-Being
JEL: Q12, Q18, I32, I38

[1] Committee on Sustainability Assessment (COSA), 502 6th Street Mt. Gretna PA 17064. E-Mail: es@thecosa.org; University of Namur (CRED), Rempart de la Vierge 8, 5000, Namur, Belgium. E-Mail: elena.serfilippi@unamur.be
[2] Committee on Sustainability Assessment (COSA), 502 6th Street Mt. Gretna PA 17064. E-Mail: gr@thecosa.org

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Introduction

Increasingly, the international development community has embraced the concept of resilience as a proxy for sustainable, long-term growth. Resilience to adverse shocks is crucial for individuals and communities to stay on the path of long-term sustainability. Such resilience prevents them from falling into recurring cycles of poverty that erode progress made toward development and well-being.

This understanding of resilience is articulated in Target 1.5 of the United Nations' 2015 Sustainable Development Goals (SDGs): "Build the resilience of the poor and those in vulnerable situations, and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters by 2030."

Although the concept of resilience is better understood among development practitioners than in the past, there is still a lack of consensus regarding its definition as well as consistency in its measurement. The absence of a common language and standardized metrics for measurement undermines the ability of the development aid community to objectively monitor and evaluate resilience-building programs.

In this paper, we aim to fill these gaps through a careful review of the definitions and models of resilience used by various development practitioners. In doing so, we seek to harmonize a highly dispersed field of study and provide the reader with a clear synthesis of literature and a classification system for resilience models, providing a critical evaluation of the strengths and weaknesses of those models both as concepts and by how they measure resilience. The latter is particularly important because, despite progress made in conceptual understanding of resilience, not all existing models translate to easily measurable indicators and metrics. We have therefore developed a list of indicators that are critical to measure resilience. These indicators are pragmatic, actionable, and have been drawn from an exhaustive review of scientific literature and best practices among leading institutions.

The rest of the paper is divided into five sections. The first section offers an overview of competing resilience definitions commonly found in the scientific and development literature. We also synthesize the features of these definitions into a unique definition of resilience that meets generally agreed-upon scientific attributes. The second section offers a detailed analysis of the concepts of resilience, vulnerability, and sustainability. In the third section, we describe the principal resilience models in use today, dividing them into descriptive, causal, and analytical resilience models while evaluating their strengths and benefits from a measurement point of view. The fourth section builds upon our understanding of the resilience models to advance a measurement system that clearly specifies indicators and metrics for each of the resilience dimensions. The fifth section presents our conclusion.

Section 1: Definitions of Resilience

The definition of resilience has evolved across disciplines and over time. Some of the literature suggests that the concept of resilience was first developed within mathematics and physics (Bodin and Wiman, 2006), whereas others attribute it to research conducted by psychologists in the 1940s (Waller, 2001; Manyena, 2006). Increasingly, "resilience" has been used in the social sciences to identify how human societies, communities, and organizations react to shocks like economic, social, or environmental disturbances where the system, represented by either human society or other organizational structures, develops a set of dynamic capabilities to maintain core functions while coping with shocks (Borda Rodriguez and Vicari, 2015).

These systems are inherently more complex and dynamic when compared with resilience in other fields of study. They include not only interactions between people, society, and the environment, but also complex reciprocal feedback systems between human behavior and surrounding ecosystems (Levin et al., 1998), the framework to which we refer to when resilience is applied to development economics. In this regard, Barrett and Constas (2013) define development resilience as "the capacity over time of a person, household, or other aggregate unit to avoid poverty in the face of various stressors and the wake of myriad shocks. If and only if that capacity is and remains high over time, then the unit is resilient."

Given the conceptual complexity of "resilience" in the social sciences, it is not surprising to find several variations of its definition in use by the development community, specifically international development agencies, Non-Governmental Organizations (NGOs) and academia; Table 1 reports the principal definitions in use. While in some contexts resilience is interpreted as "resistance," implying a system's capacity to retain its original state when faced with disturbances, the development aid community primarily emphasizes the ability of individuals and communities to recover from losses after shocks and to transform over time to achieve long-term resilience and sustainability.

In this paper, we adopt the following definition of resilience:

Resilience is the capacity of people, communities, or systems to prepare for and to react to stressors and shocks in ways that limit vulnerability and promote sustainability.

This definition ecapsulates core attributes common to the definitions used by key development agencies. It also reflects the attributes generally agreed upon in the scholarly literature by leading theoreticians such as the Resilience Measurement—Technical Working Group (RM-TWG)[3], namely:

[3] The Resilience Measurement Technical Working Group is composed of leading experts in resilience measurement. For further details, please refer to their website: http://www.fsincop.net/topics/resilience-measurement/technical-working-group/en/.

Multiple scales: Resilience is observed at different levels, ranging from individuals to households, communities, and nations;
Multiple capacities: Resilience is a combination of different capacities—the capacity to recover after a shock, the capacity to adapt to a changing environment, and the capacity to transform;
Disturbance specificity: Resilience is a reaction to a specific shock and stressor, where shocks can be idiosyncratic (experienced only by a given individual, household, or community) or covariate (affecting a large group of individuals, households, or communities);
Temporal Sensitivity: Outcomes at different scales are likely to occur at different rates and account for long-term developmental results and growth; and
Vulnerability and Sustainability: Resilience is not an end in itself but a means to limit vulnerability and promote long-term sustainability. We discuss this in more detail in the following section.

Table 1: Definitions of Resilience

Institution	Definition of resilience
United Nations Development Programme (UNDP)	A transformative process of strengthening the capacity of women and men, communities, institutions, and countries to anticipate, prevent, recover, adapt, and/or transform from shocks, stressors, and change (UNDP, 2013).
European Union (EU)	Resilience is the ability of an individual, a household, a community, a country or a region to withstand, to adapt, and to quickly recover from stressors and shocks (EU, 2016).
United States Agency for International Development (USAID)	Ability of people, households, communities, countries, and systems to mitigate, adapt to, and recover from shocks and stressors in a manner that reduces chronic vulnerability and facilitates inclusive growth (USAID, 2013a).
Department for International Development (DFID)	Resilience is the ability of countries, communities, and households to manage change, by maintaining or transforming living standards in the face of shocks or stressors— such as earthquakes, drought or violent conflict—without compromising their long-term prospects (DFID, 2011).
Food Agriculture Organization (FAO)	The ability to prevent disasters and crises as well as to anticipate, absorb, accommodate or recover from them in a timely, efficient and sustainable manner. This includes protecting, restoring and improving food and agricultural systems under threats that impact food and nutrition security, agriculture, and food safety/public health (FAO, 2013).
Resilience Measurement Technical Working Group (RM TWG)	The capacity that ensures stressors and shocks do not have long-lasting adverse development consequences (FSIN, 2014a).
Lutheran World Relief (LWR)	The capacity of a system (e.g., a community) to absorb the impacts of shocks and stressors, to adapt to change and to potentially transform, in a manner that enables the achievement of development results (e.g., sustainable livelihoods, well-being, poverty alleviation) (LWR, 2016).
Barrett and Costas	Development resilience is the capacity over time of a person, household, or other aggregate unit to avoid poverty in the face of various stressors and in the wake of myriad shocks. If and only if that capacity is and remains high, then the unit is resilient (Barrett and Constas, 2013).
Mercy Corps	The capacity of communities in complex socio-ecological systems to learn, cope, adapt, and transform in the face of shocks and stressors (Petryniak et al., 2015).

Oxfam	The ability of women and men to realize their rights and improve their well-being despite shocks, stressors, and uncertainty (Oxfam, 2015).
Rockefeller Foundation	Resilience is the capacity of individuals, communities, and systems to survive, adapt, and grow in the face of stress and shocks, and even transform when conditions require it. (Rockefeller Foundation, 2017).
Tulane University	Resilience is the capacity of the affected community to self-organize, learn from, and vigorously recover from adverse situations stronger than it was before (Tulane University, 2012).
OECD	Resilience is the ability of households, communities, and nations to absorb and recover from shocks, whilst positively adapting and transforming their structures and means for living in the face of long-term stressors, change, and uncertainty (OECD, 2014).

Section 2: Resilience, Vulnerability, and Sustainability

Vulnerability and sustainability are closely related to resilience, except that resilience is not an end in itself, but a means to limit vulnerability and promote sustainability.

Resilience and Vulnerability

The Inter-Governmental Panel on Climate Change (IPCC, 2001) defines vulnerability as ‘‘the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity.’’

According to IPCC, “exposure” can be explained as the “extent to which something is subject to a stressor,” particularly “the nature and degree to which ecosystems are exposed to environmental change.” Meanwhile, “sensitivity” marks the extent to which something will change if exposed to a stressor (i.e., “the degree to which a human-environment system is affected, either adversely or beneficially, by environmental change”). In this framework, adaptive capacity is defined as “the combination of the strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities” (IPCC, 2012).

The approach followed by IPCC is known as an Integrated Assessment Approach, and combines both socioeconomic and biophysical approaches to vulnerability. The biophysical approach assesses the damage that a given environmental stressor causes to both social and biological systems, emphasizing the vulnerability or degradation of biophysical conditions (Tesso et al., 2012). The socioeconomic-vulnerability approach focuses on the socioeconomic and political status of individuals or social groups. According to Tesso et. al (2012), variations in vulnerability levels among individuals in one community often vary depending on education, gender, wealth, health status, access to credit, access to information and technology, formal

and informal (social) capital, political power, and so on. According to Füssel and Klein (2006), the biophysical approach (the risk-hazard framework) corresponds most closely to "sensitivity" in IPCC terminology, while the adaptive capacity of the IPCC definition is broadly consistent with the socioeconomic approach.

While definitions for vulnerability and resilience are clear, there is no reasonable consensus on the relationships between the two. These relationships have been written about extensively (Adger, 2006), and the issue of how best to represent the relationship remains a topic of debate (Alinovi et al., 2010, 2008; FAO, 2016). For some researchers, resilience is an integral part of adaptive capacity (Cutter et al., 2008; Adger, 2006; Birkmann, 2006a; Folke, 2006), while for others, adaptive capacity is a principal component of vulnerability (Burton et al., 2002; O'Brien et al., 2004; Smit et al., 1999). A third perspective sees resilience and vulnerability as either simply nested concepts (Cutter et al., 2008) or nested concepts within an overall vulnerability structure (Gallopin, 2006; Turner et al., 2003).

In our view, resilience and vulnerability are nested and complementary. In the absence of adequate resilience capacities, a system is likelier to take the "path of vulnerability" versus a "path of security." In Béné et al. (2014), the authors contend that resilience goes beyond vulnerability in two important ways. First, an analysis of resilience identifies underlying capacities (absorptive, adaptive, and transformative) and the actor's response to shocks and stressors. This is largely absent in the general analysis of vulnerability. Second, resilience theory recognizes that individuals make informed decisions that shift them from being "passive" recipients to "active" agents in the face of shocks.

This relationship is represented in literature in three ways. Some approaches advocate assessing vulnerability independently from resilience and making vulnerability a function of exposure, sensitivity, and adaptive capacity (International Found for Agricultural Development (IFAD), 2015; Department For International Development (DFID), 2011); others consider vulnerability as the likelihood that at some time in the future, the welfare of an individual, or group of individuals, will fall below some norm or benchmark (Hoddinott and Quisumbing, 2010). In this regard, Hoddinott and Quisumbing specify three key approaches to assessing vulnerability: vulnerability as expected poverty; vulnerability as low expected utility that minimizes future well-being; and vulnerability as uninsured exposure to risk (Hoddinott and Quisumbing, 2010). All of these approaches econometrically estimate some form of measuring welfare and calculate the probability of falling below a certain threshold, usually the poverty line or some proxy for food security (Hoddinott and Quisumbing, 2010). Finally, some approaches consider vulnerability as a function of people's exposure to risks and their resilience to these risks (FAO, 2004); this approach assesses the role of an estimated resilience index in measuring vulnerability (Alinovi et al., 2009).

With several different definitions and techniques to measure resilience and vulnerability having been proposed, the development community still needs to find a common understanding of how best to represent the relationship between resilience and vulnerability.

Resilience and Sustainability

The theoretical literature linking resilience and sustainability is sparse, and some authors recommend keeping the two theoretical constructs separate (Redman, 2014); their rationale is that while resilience theory focuses on adaptive capacity without assuming anything about outcomes, sustainability theory incorporates normative values and outcomes into a scientific framework. Those who adopt a less theoretical perspective argue that resilient communities should also be sustainable communities and vice versa (Saunders, 2015).

While there may be theoretical justifications to keep resilience theory and sustainability theory separate, from a practitioner's point of view we believe they are inextricably linked. The causal relationships run both ways: unsustainable practices amplify the negative impacts caused by environmental and other types of disasters (Cutter et. al, 2008), and systems that lack resilience will slip into undesirable, unsustainable development pathways. Resilience programming should, therefore, incorporate normative sustainable thinking based on outcomes, and implementations should focus on long-term program and policy impacts.

From a measurement perspective, resilience and sustainability share a vast number of metrics that are assessed at various points in time. An example introduced in the next section demonstrates how the capacities approach of resilience theory can be integrated with the multi-dimensional framework of sustainability.

Capital and Capacity: Static and Dynamic Dimensions of Resilience

Designing a measurement system for resilience requires incorporating indicators that capture both its static and dynamic dimensions. Agencies working on resilience often focus on only one side of this equation (whether they state this explicitly or not): static or dynamic, depending on their vision, organizational core capacity, and theory of change. This reflects the highly dispersed nature of the literature and dialogue surrounding the concept of resilience. In this section, we describe the components of resilience and the terminology frequently used to introduce these core elements.

The terminology commonly used to describe the static dimension of resilience is "capital" and the dynamic dimension is referred to as "capacities." The static dimension, capital, is explained as snapshots of assets (e.g., human, social, financial, physical, and natural) over which stakeholders have control and that can be measured at any given point in time. Typically, resilience models consider capital before a shock (i.e., the starting condition or endowment possessed by stakeholders in a system), and capital after the shock. In several models, starting conditions influence significantly the probability of vulnerability to future shocks and the magnitude of the consequences.

The Sustainable Livelihood Framework (SLF) proposed by the Department for International Development (DFID, 2000) provides an example of a framework that focuses on capital. Capital here refers to a "range of assets" that are essential for people to achieve desirable livelihood outcomes, and the SLF proposed by DFID

identifies five types of assets or capital upon which livelihoods are built: human (set of skills, knowledge, ability to work, and good health); socio-political (quantity and quality of social resources as networks and access to wider institutions in society); natural (factors that affect households' livelihoods through climate change variables, such as land degradation and erosion, and through human activity, such as conservation); physical (infrastructure, services, and productive assets that enable people to maintain safety and enhance their relative level of well-being); and financial (cash and other liquid resources, such as savings, credit, remittances, and pensions).

Although the SLF is crucial to analyzing sustainability, an accurate resilience analysis requires encompassing all the measurement indicators associated with capital and integrating them with dynamic capacity indicators. The dynamic capacity indicators denote the strategies employed by households to cope with stressors and shocks, including their ability to expand and contract capital in response to shocks, stressors, or changes; and to rely on skills and linkages to adapt in positive ways. It follows that in the resilience framework, capital and capacities are integrated to describe a chronological sequence of events related to the occurrence of an external shock to a system.

Béné et al. (2012) provide a commonly accepted way to look at capacities that is found in most discussions on resilience, identifying absorptive, adaptive, and transformative capacities. Absorptive capacity represents the ability to reduce both risk of exposure to shocks and stressors (preparedness) and to absorb the impacts of shocks in the short term (mitigation); while adaptive and transformative capacities constitute longer-term responses to social, economic, and environmental changes (e.g., livelihood diversification, asset accumulation, and improved social and human capital). Transformational responses are represented by major changes in the system's structure and function when the adaptive capacities of the household, community, or ecosystem are overwhelmed by the magnitude of the shocks.

The interaction between the three capacities guarantees the stability, flexibility, and change of a given system. For example, according to Norris et al. (2008), the ideal outcome of absorptive capacity after a crisis is resistance to a shock. When the absorptive capacity is exceeded, individuals will then exercise their adaptive capacity (Cutter et al., 2008), and if the adaptation is not enough to overcome the shock, the system will develop transformational changes, guaranteeing stability of the system.

Section 3: The Evolution of Resilience Frameworks: Descriptive, Causal, and Analytical Models

As with the resilience definitions, there are several conceptual resilience models that vary predominantly by their focus area and purpose, many developed either by NGOs or development agencies. In this section, we offer a classification of these models from an analytical point of view: i.e., their ability to translate the core idea of resilience into measurable empirical outcomes and to guide programs and theories of change.

Broadly, we classify resilience into descriptive, causal, and analytical models inspired by the Common Analytical Approach developed by the Food Security Information Network (FSIN) in their technical series for resilience measurement (FSIN, 2014a; FSIN 2014b, FSIN 2016), based on three central criteria in developing measurement tools for program interventions. These criteria represent the ability of the resilience model to capture: (i) the temporal dimension; (ii) causal relations between dimensions; and (iii) aggregation and analytical needs. The first criterion refers to the model's ability to capture resilience changes over time, while the second considers the model's capacity to define relations between the different resilience components as shocks, capacities, and well-being. The third criterion responds to aggregation needs of the different resilience indicators (e.g., resilience index) and specific econometric needs due to the presence of variables that measure both resilience and well-being (e.g., food security). In this regard, the measurement needs have been compared by Cisse' and Barret (2016) to Sen's poverty aggregation needs: poverty "identification" (i.e., identifying who is poor) and "aggregation" (i.e., defining how characteristics of the poor can be combined into an aggregate indicator).

Admittedly, evaluating these models using these criteria creates a bias in favor of a quantitative-econometric-evaluation approach, but we believe that the overall approach helps to analyze pros and cons associated with each model, and guarantees their applicability to measurement.

Descriptive models

Descriptive models of resilience attempt to identify the key determinants of a resilient system without necessarily considering a clear sequence of chronological events and causal relationships[4], and are thus lacking in all three resilience facets described above (temporal dimension, causal relations between dimensions, and aggregation and analytical needs). These models primarily offer a classification system that describes in detail a system's components as they relate to resilience.

A good example is the Oxfam resilience model (Oxfam Great Britain (GB), 2013) in which resilience is broken down into five dimensions that contribute to building a resilience index: Livelihood viability (livelihood strategies to face shocks, stressors, and uncertainty); Innovation potential (ability to take appropriate risks and positively adjust to change); Contingency resources and support access (access to backup resources and appropriate assistance in times of crisis); Integrity of the natural and

[4] Frankenberger and Constas (2014) refer to these models as characteristic approaches.

built environment (health of local ecosystems, soundness of natural resource management practices, and robustness of essential physical infrastructure); Social and institutional capability (access to formal and informal institutions to reduce risk, support positive adaptation, and ensure equitable access to essential services in times of shock/stress).

Although this model accounts for the aggregation needs, it considers resilience as a mix of capitals, ignoring the capacity dimension, and it does not identify which of the five dimensions are actually relevant when a shock occurs (Frankenberger and Nelson, 2013). In other words, the model only focuses on the description of the resilience components and their aggregation in a resilience index, but it does not include any shock-related variable or its relationship with resilience, and it tends to ignore any temporal dimension and causal relation between the different components.[5] The absence of the temporal dimension and insights into causal links and relationships limits the broader applicability of this framework—and similar ones—for use in programs, impact evaluations, and certain types of econometric analyses where the purpose of measurement is to establish causality.

Causal and Analytical Models

Most resilience frameworks belong to the category of causal models, where a significant feature is a focus on a sequence of events that illustrates causal links between shocks, resilience capacities, and outcomes, lending itself well to developing interventions and designing theories of change. In this category, the principal models are those developed by the Department For International Development (DFID, 2011) and the Technical Assistance to NGO (TANGO, 2012).

A drawback of causal models is that they do not include analytical procedures that help transform graphical representations to measurement and estimation systems. Analytical models go one step further by offering a pathway to measurement through aggregation models, and solving specific econometric issues such as endogeneity and correlation problems. As noted in FSIN (2014b), “The end result of an analytical model for measurement is a causal model that leads to a set of indicators supported by technical criteria.” Analytical models provide more specific guidance on how to estimate and use actual indicators related to a given construct (FSIN, 2014b). (The main reference models are summarized in Table 2, along with a list of development practitioners adopting them.)

Table 2: Main Reference Models in Resilience Analysis

[5] Another issue specific to the OXFAM model is the use of arbitrary cutoffs and weight limits that restrict the broader applicability of its measurement technique.

Models	Organization
Descriptive	OXFAM (2013) OECD (2014)
Causal	DFID (2011) TANGO (2012) OECD (2014) IFAD (2015)
Analytical	FAO (Alinovi et al. 2008, 2010; FAO 2013, 2016) RM-TWG (FSIN, 2014a, 2014b, 2016) UNDP (2013) USAID (2013a, 2015) CIAT (2015) University of Florence (2013) Tulane University (2012) Mercy Corps (2015)

Causal Models

In this section, we describe the DFID (2011) and TANGO (2012) resilience models, which are similar due to their focus both on Disaster Risk Reduction (DRR) and resilience.

DFID's resilience approach mainly considers five key resilience pillars: Context (subjects and governance); Disturbance (shocks and stressors); Capacity to deal with disturbance; Sensitivity (degree to which a system will be affected by, or respond to, a given shock or stress); and Reaction to disturbance (recovery ability).

In practice, DFID's resilience model integrates the "assets pentagon" of the Sustainable Livelihoods Framework (social, human, physical, financial, and natural, (DFID, 2011)) with disturbance and resilience capacities. One limitation is that it focuses on resilience rather than household well-being, the final outcome of interest. DFID (2011)'s model is mainly followed by IFAD (2015)'s proposal of a simplified

version where the resilience of rural households is determined by access to the five capitals: natural, productive, financial, human, and social. Lack of these capitals undermines a household's resilience against climate related shocks.[6]

TANGO (2012)'s framework differs from DFID (2011) in making one additional step in the analysis of resilience, switching the outcome of interest from resilience to a household's well-being. Instead, resilience is an intermediate outcome required for achieving a more fundamental "longer-term developmental ambition" (Béné et al., 2014; Brown, 2013; UNDP, 2013), typically a measure of well-being as food security, health and nutrition status, and poverty (Constas et al., 2014).

With both approaches, a shared limitation is that they do not provide specifics on the main measurement requirements; namely, how to analyze causal links and measure outcomes, a gap that TANGO recently filled (TANGO 2016a, 2016b) by adopting a more analytical approach focused on the aggregation of the three capacities into a resilience index and evaluation of the effect of resilience-enhancing programs.

Another causal model, presented by the Organization for Economic Co-operation and Development (OECD, 2014), applies a risk management approach to resilience measurement that builds on traditional risk management tools, using both a capital and a capacity view and following the causal model framework. OECD identifies core program actions associated with each resilience capacity, offering a normative suggestion for resilience programs to consider in various contexts. Their toolkit describes the process for establishing a resilience system analysis, the main focus of which is to create a participatory workshop approach to building resilience programs. These participatory exercises serve to identify risks and core resilience components relevant to a particular context, further identifying key leverage points and stakeholders for implementation. Once core resilience components have been identified, an assessment of how risks affect each component individually, and the system as a whole, should be conducted. OECD's resilience indicators focus on capitals and capacities but do not provide specific guidance on how to choose relevant indicators when shocks occur.

Analytical Models

The causal models previously discussed meet some of the criteria required for a good measurement system. At a conceptual level, they focus on temporal dimensions and offer a clear vision of cause-and-effect relationships; however, they do not go beyond a conceptual level to address both practical measurement requirements like aggregation needs (e.g., resilience index), and specific econometric issues like

[6] IFAD integrates climate-resilient questions to the Multidimensional Poverty Assessment Tool (MPAT), which measures 11 livelihood components and 31 subcomponents to describe the poverty context of a rural household more comprehensively. In the first MPAT, drafted in 2009, there were ten livelihood components; the eleventh has been recently added by IFAD for the specific purpose of measuring resilience to climate change.

correlation and endogeneity problems caused by the fact that some resilience elements are both input variables and outcomes of interest (e.g., food security).

Alinovi et al. (2008; 2010) pioneered analytical resilience models with the development of the Resilience Index Measurement and Analysis Model (RIMA I) for the Food and Agriculture Organization (FAO, 2013, 2014), recently updated to RIMA II (FAO, 2016). In their original framework, Alinovi et al. identified five principal dimensions of resilience integrating capital and capacity approaches. In particular, the resilience dimensions are separated into two categories: (i) physical dimension (income and food access, access to basic services, assets, and social safety nets), and (ii) capacity dimension (adaptive capacity and sensitivity).[7]

Their model mainly emphasizes the capitals and adaptive capacity, while ignoring transformative and absorptive capacities. The temporal dimension and the causal links are well defined; in practice, at a given moment, a household's resilience depends primarily on the options available to that household to make a living (access to assets, income-generating activities, public services, and social safety nets). Assuming that a shock (endogenous or exogenous) occurs, the household reacts by using an available response (adaptive capacities) to reach a new level of well-being in the next time period.

This model differs from the causal ones since it also satisfies resilience aggregation needs by introducing a resilience index. In practice, RIMA I adopts two-stage factor analysis (FA) to estimate each of the five resilience dimensions; resilience is then estimated through factor analysis of these dimensions. In this approach, the resilience latent variable is jointly estimated by its causes and indicators through a Multiple Indicator, Multiple Cause Model (MIMIC) model. This new technique overcomes RIMA-I's main limitations associated with endogeneity problems.

Many agencies have followed and readapted FAO's model developed by Alinovi et al. (2008, 2010). The United Nation Development Program (UNDP, 2013) integrates FAO's model identifying a system's possible pathways in reaction to a disturbance: from bouncing back better, bouncing back to the status quo, to bouncing back worse. The United States Agency for International Development (USAID, 2013a, 2015) uses FAO's model to identify a number of indicators under each resilience domain and re-classify them using a capacity approach. Apart from the quantitative focus on indicators, USAID highlights two other dimensions in making its resilience framework operational: supplementing quantitative data with qualitative information; and data collection methods.

In its latter approach, the agency highlights the use of existing data collection efforts like Feed the Future's population-based surveys, rather than relying on new survey

[7] In 2013, FAO added two previously ignored dimensions that account for the key role played by local and central authorities in reinforcing households' ability to cope with shocks (institutional environment) and factors affecting households' livelihood through climate change variables (natural environment).

data. The University of Florence (Ciani and Romano, 2013) expands FAO's five resilience dimensions to eleven resilience latent variables estimated through factor analysis: income and food access; access to basic services; agricultural assets; non-agricultural assets; household production technological level; public transfers; private transfers; adaptive capacity; physical connectivity; economic connectivity; and household demographics. The set of variables is richer than those presented in the FAO model and including additional characteristics enables assessment of which households are able to effectively adapt and absorb shocks. The International Center for Tropical Agriculture (CIAT, 2015) uses a resilience index approach inspired by FAO's model in the From Rust to Resilience Project (R2R), in collaboration with Catholic Relief Services (CRS). Tulane University (2012), in collaboration with the State University of Haiti (UEH), employed a multi-dimensional approach for analyzing resilience and the effects of humanitarian assistance on resilience outcomes in the aftermath of the 2010 earthquake. Their resilience model is similar to the one of Alinovi et al. 2008 and is based on seven components for which composite scores are calculated: community networks; human capital; coping behavior; debt and credit; wealth; psychosocial factors; protection and security.

Recently, the Resilience Measurement Technical Working Group (FSIN, 2014a, 2014b; 2016) collected all global best practices emerging from the different resilience models in a global resilience conceptual and measurement framework, taking into account all the elements considered in the descriptive, causal, and analytical models and offering guidance for constructing variables and exploring relationships among them. Recognizing the multidimensionality and the input nature of resilience, RM-TWG in particular suggests aggregating resilience in an index and using Structural Equation Modelling (SEM) or Factor Analysis (FA) with a preference for SEM to overcome endogeneity problems. Mercy Corps (2015) has adapted the measurement framework developed by the RM-TWG in its Strategic Resilience Assessment (STRESS) process.

Section 4: Resilience Measurement

Although the importance of building resilience is widely understood, there are no pragmatic guidelines about how to optimally measure resilience and how best to measure the success of resilience programs. An important step would now be to create a widely recognized, pragmatic, and easily accessible resilience measurement system enabling development agencies and NGOs to enhance their resilience programming.

The first step toward this end is to create a unique set of resilience indicators, through a review of current global best practices and the growing literature on the topic. In this section we propose a set of resilience indicators carefully distilled from the resilience frameworks analyzed in the section above.

Resilience Indicators

We created a set of 76 resilience indicators that have been benchmarked to indicators used by leading organizations mentioned in the previous sections and appearing in some vulnerability studies such as the Livelihood Vulnerability Index (LVI), the Word Risk Index (WRI), the Environmental Performance Index (EPI) and the University of Notre Dame Global Adaptation Index (ND-GAIN).

This indicator library contains both qualitative and quantitative indicators and can be disaggregated into a core set of 27 resilience indicators that have been identified applying SMART filters, where SMART is an acronym for five filters ensuring that indicators meet the standards of **specificity** (so that people in different countries and contexts are comparing the same thing when they measure); **measurability** (data are required to support the indicator); **actionability** (a specific action should be undertaken thanks to the indicator); **realism** (the indicator isn't overly theoretical or naive); and **trackability** (indicators should measure changes over time). The indicators are flexible and can be re-adapted depending on local and/or national circumstances and a given intervention's priorities and resources.

The approach used to classify the indicators balances a multi-dimensional view based on dynamic resilience capacities (adaptive, absorptive, and transformative) with static social, environmental, and economic (SEE) dimensions in order to capture the complexity of factors relevant to measuring agricultural resilience. SEE elements are in turn disaggregated into commonly accepted capitals (human, physical, socio-political, financial, natural) of a resilience measurement system in line with the Sustainable Livelihood Framework devised by the Department for International Development (DFID, 2000).

Table 3 contains a detailed description of each indicator with an explicit reference to the benchmarking literature. The Table reports the core set of 27 indicators distilled from the comprehensive library of 76 indicators.[8]

[8] The full library can be provided by the authors on request but is also available at the following website: https://thecosa.org/working-with-us/measuring-resilience/

Conclusion

The adoption of resilience as a concept in the social sciences and particularly within the international development community has presented several challenges regarding use of appropriate definitions, models, and measurement frameworks. Originating in the physical sciences, ideas of resilience are not easily adaptable to human socio-ecological settings. The social sciences present a high degree of complexity because of free decision-making agents and complex feedback loops between agents and their environment.

Yet the idea of resilience, particularly as a programming tool in response to disaster and climate-change phenomena, has become increasingly prevalent in international development. Given the widespread use of the terminology in various fields and by various technical and non-technical actors, it is important to present a synthesized view of resilience and create a common language to advance core terms. It is particularly important to translate high-level concepts of resilience into actionable measurement metrics in order to implement, monitor, and evaluate resilience programs: the broad goals of this paper in which we have integrated diverse themes found in resilience literature under a unified measurement lens.

By presenting a synopsis of the definitions and models of resilience used by leading development agencies, this paper will be a useful resource for readers interested in exploring applications of resilience in the field of international development. At a conceptual level, we have harmonized several concepts in resilience that do not reach consensus in the literature, presenting a definition that integrates already dominant themes in international development, namely vulnerability and sustainability. Using a unified measurement lens, we present an approach that captures static endowments like capitals, as well as more complex dynamic elements like resilience capacities. At a measurement level, we define a list of indicators distilled from each resilience model. These indicators are pragmatic, actionable, and have been drawn from an exhaustive review of scientific literature and best practices among leading institutions. These indicators, when adapted to well-defined theories of change, can be used by development practitioners as a reference point to enhance resilience understanding and its measurement.

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