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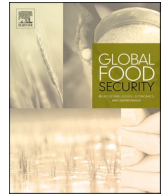
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Recovery without resilience? A novel way to measure nutritional resilience in Nepal, Bangladesh, and Uganda

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ABSTRACT

People in fragile environments face various shocks that negatively affect their nutrition. Many governments put policy mechanisms in place to promote recovery of households after adverse shocks; however, resilience is difficult to measure because some apparent recovery could be the result of statistical randomness and reversion to trends. This paper demonstrates a new approach to measuring nutritional resilience in a population. As our starting point, we use the common definition of resilience as ‘recovery after decline’, but also require that the degree of recovery should exceed stochastic expectations. Using maternal and child nutrition data from Nepal, Bangladesh, and Uganda, we find that observed recovery is not always statistically significant and does not always satisfy this definition of resilience. We identify household and community factors that are correlated with measurable nutritional resilience, and recommend points of entry for policies designed to enhance resilience in resource-constrained settings.

1. Introduction

Development and humanitarian professionals have long equated resilience with damage limitation and risk mitigation. That is, resilience-enhancing investments are typically designed to protect household assets, consumption and livelihoods against the many stressors (climate shocks, vagaries of weather, economic shocks, pests and diseases) that affect millions of households in low income, often fragile, environments (Cissé and Barrett, 2018). The World Bank talks of “building the resilience of the poor in the face of natural disasters” (Hallegatte et al., 2016), while the United States Agency for International Development (USAID) defines resilience as “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, 2016). In short, resilience

interventions typically seek to bolster the ability of people to prepare for shocks, mitigate the negative effects of those shocks, and rebound quickly from those shocks.

Given the policy prominence of this concept among governments and their development partners, the measurement of resilience, and of the effectiveness of actions aimed at securing it, have become important concerns. As Perrings (2006) notes, “a development strategy is not sustainable if it is not resilient: i.e. if it involves a significant risk that the economy can be flipped from a desirable state (path) into an undesirable state (path), and if that change is either irreversible or only slowly reversible” (Perrings, 2006). Taking that idea as a starting point, many donors have focused their resilience activities on seeking to enhance the robustness of livelihoods, physical assets and food systems to stressors and shocks (Barrett and Constan, 2014; Webb and Harinarayan, 1999; Tendall et al., 2015). This has led USAID, which recently established

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resilience as a major pillar of its global activities, to recommend pre- and post-project data collection on factors such as access to financial services, number of off-farm income-earning opportunities and number of communities trained in disaster preparedness (Vaughan, 2018).

While past efforts to measure resilience have tended to focus on how households deploy available resources in response to shocks, risk management often extends beyond protection against asset and production losses (Hallegatte et al., 2016; Fella et al., 2020; Alam and Mahal, 2014). Resilience often depends on less-easily measured dimensions of life, such as social capital, psycho-social risk and the quality of inter-personal networks (Röös et al., 2021; Czekaj et al., 2020). An individual's ability to withstand an unanticipated event and rebound from it also depends on education and experience, health, and nutrition. Some of these characteristics, such as education, are largely fixed in time, but others, particularly those associated with health and nutrition, are modifiable and can change rapidly. A deeper contextual understanding is needed of how such less-visible characteristics vary over time and/or by household type (Vaughan, 2018).

The concept of resilience is not new, dating back centuries to the earliest science in Europe. The first English usage is by Francis Bacon (1627), on the “resilience” of sound and light as revealed by rebounding through space in echoes or reflections in a mirror (n.d., 2021). Later uses concern whether products like timber and iron have more measurable elasticity than others (Garcia and Vale, 2017). The concept's early use in relation to global development issues was in ecology (Holling, 1973; Pimm, 1991), and for human development since the 1990s attention has focused on the physiological and psychological resilience of children facing trauma, from which many lessons were drawn to inform evolving international humanitarian and development priorities and practices (Keyes, 2004). Many disciplines have adopted this thinking around ‘elasticity’, and numerous definitions and corresponding metrics have since been proposed. (We do not attempt a comprehensive overview, as such reviews already exist (Ansah et al., 2019; Serfilippi and Ramnath, 2018)). The definition used in this paper is based on three properties of resilient socio-ecological systems defined by Grafton et al. (2019) (Grafton et al., 2019): resistance, recovery, and robustness. Several metrics have been proposed for these three different aspects of resilience (Béné and Doyen, 2018; Huizar et al., 2018; Chu et al., 2018). This paper applies an assessment method that focuses on the ‘recovery’ dimension, in the context of nutrition in low-income countries. By analyzing resilience in a way that requires recovery to be larger than would occur statistically due to mean reversion, this approach aims to be especially useful in settings where measurement error or random fluctuations might mask the degree to which recovery is due to social insurance, safety nets or other support that could be provided by policies and programs.

Conceptually, measuring resilience requires repeat observations. Using data at just one point in time, we can establish, for example, a household's absolute well-being and relative position vis-à-vis its neighbors. We might also ascertain from a cross-sectional survey whether a household possesses the skills, assets, or access to formal (e.g. credit) and informal (e.g. social network) institutions that allow it to withstand a shock. Unfortunately, such information provides limited insight into how households actually respond to or hold up to a shock.

With two rounds of balanced panel data, we can measure how a household's situation changes over time. For example, incomes might fall due to crop failure, diets might become less diverse due to higher vegetable prices in the marketplace, or a person's nutritional status might decline because of temporary caloric shortfalls or health insults. With two time points, we can also begin to form an understanding of how the situation of individuals or households changes relative to others in the population. For instance, some households might experience a larger relative loss of income than others, or children with certain characteristics may experience a larger reduction in their weight for height z-score than their counterparts. It is generally not possible, however, to ascertain “bounce back”, which is fundamental to the

concept of resilience, from only two observations on a household or individual. Our approach addresses this concern by using a sequence of three observations, which allows us to measure recovery following a decline. With three observations, we can measure whether, from an initial position (time point 1) a household experienced a loss (resulting in a less desirable outcome at time point 2) and whether the household then recovered (at time point 3) relative not only to its initial position. Our contribution is to test whether the magnitude of recovery in a population exceeds expectations, based on other observed fluctuations in that outcome for that population. Using this approach, we can define and measure with statistical precision how an observed movement compares with simple randomness (i.e. reversion to the mean) or whether it constitutes better than expected or worse than expected (less robust) recovery.

To gauge the usefulness of testing whether recovery exceeds expectations, we apply this new method using longitudinal panel household- and individual-level data on diets and health in diverse contexts across South Asia and East Africa. We focus on a set of indicators that are (i) widely used by researchers and practitioners, (ii) reliably quantified and measured, and (iii) likely to respond to external shocks within the timeframes under examination. The indicators include measurements of dietary diversity and anthropometry among non-pregnant women of reproductive age and children below five years of age, in Nepal, Bangladesh and Uganda. We first identify relevant ranges of resilience in these populations. We then measure how observed patterns of resilience vary across geographic locations depending on infrastructure and household characteristics, such as access to credit or adoption of certain agricultural practices.

2. Data and methods

The method used here requires at least three successive observations, and is implemented here using panel survey data of a type commonly collected in a variety of settings. For Nepal, the data source is the Policy and Science for Health, Agriculture and Nutrition (PoSHAN) survey, a household-level regionally and nationally representative survey (Klemm et al., 2018; Shrestha et al., 2018; KC et al., 2020). A total of four annual rounds were collected between 2013 and 2016 across all three major agroecologies of the country. The present study uses PoSHAN data from the Terai region only (tropical lowlands) since data collection in the other regions (mountains and hills) did not occur in 2015 due to that year's massive Nepal earthquake. Our other South Asian data source is the Bangladesh Aquaculture-Horticulture for Nutrition Research (BAHNR) (Aker et al., 2020) household survey, with three bi-annual rounds conducted in 2016–17 across three divisions of south-western Bangladesh (Dhaka, Khulna and Barisal). For Uganda data came from three rounds of a biennial household survey conducted between 2012 and 2016 in 6 districts (4 from northern Uganda and 2 from south-western Uganda) as part of the Uganda Community Connector panel study (Bashaasha et al., 2020).

The outcomes of interest are diet quality and anthropometry of women between 13 and 47 years of age and children between 2 and 5 years old. Diet quality was assessed using daily and weekly dietary diversity scores (DDS), which reflect the variety of food groups consumed measured by a numeric count of food groups consumed by a person during the past 24 h and the past 7 days, respectively. For Nepal and Uganda, food items were categorized into eight food groups as defined by FAO (FAO, 2013): (1) starchy staples; (2) dark green leafy vegetables; (3) vitamin-A rich fruits and vegetables; (4) other fruits and vegetables; (5) meat and meat products including meat, fish, poultry; (6) eggs; (7) dairy; and (8) legumes, nuts and seeds. For Bangladesh, foods were classified into six groups: (1) starchy staples; (2) fruits and vegetables; (3) meat and meat products including meat, fish, poultry; (4) eggs; (5) dairy; and (6) legumes, nuts and seeds. The anthropometric outcome for women was Body Mass Index (BMI), calculated as weight in kilograms divided by the square of height in meters. The anthropometric outcome

for children was weight-for-height z-score (WHZ) expressed as the number of standard deviations below or above the median of a reference population, adjusted for child age and sex using the WHO defined protocols. The surveys also provide individual-, household-, and community-level information that we used in our analysis. Summary statistics are shown in Tables S1–S3.

This paper uses an empirical metric of resilience developed by Zaharia et al. (2021) (Zaharia et al., 2021). By this metric, a group of households or individuals is considered resilient with respect to a particular outcome if, after having experienced a decline in that outcome (for example, dietary diversity), their recovery is larger than would be expected to occur due to mean reversion. This definition implies that observing recovery after decline is not sufficient to conclude that a population is resilient. Testing whether recovery from decline is larger than random originates in financial analysis of asymmetric mean reversion of asset prices or other time-series data. Our approach adapts this concept to panel data with at least three observations, by comparing recovery among those who experienced initial declines to others in their same community (Fig. S1). The resulting metric tests whether the community as a whole is resilient, in the specific sense that its members have greater recovery after declines than could be explained by random fluctuations or measurement error. Testing for resilience in this way uses a measurement framework that can reveal other kinds of dynamics as well, such as momentum (when declines are followed by declines and/or improvements are followed by improvements) and random walks (when declines and/or improvements are not associated with subsequent changes) (Fig. S2).

To measure how resilience varies across geographic locations and households with different characteristics, we extend the method from Zaharia et al. (2021) (Zaharia et al., 2021) by adding an interaction term that allows resilience to vary with particular characteristics. Using dietary diversity scores (DDS) as the outcome of interest, our regression specification is:

$$\begin{aligned} \Delta DDS_{i,t} = & \alpha_1 + \alpha_2 \text{Declined}_{i,t-1} + \beta_1 \Delta DDS_{i,t-1} + \beta_2 \Delta DDS_{i,t-1} * \text{Declined}_{i,t-1} \\ & + \beta_3 \Delta DDS_{i,t-1} * \text{Declined}_{i,t-1} * \text{Characteristic}_{j,t-2} \\ & + \beta_4 \text{Characteristic}_{j,t-2} \\ & + \beta_5 \Delta DDS_{i,t-1} * \text{Characteristic}_{j,t-2} \\ & + \beta_6 \text{Declined}_{i,t-1} * \text{Characteristic}_{j,t-2} + \mathbf{z}' \boldsymbol{\gamma} + \Delta \varepsilon_{i,t}, \end{aligned} \quad (1)$$

where $\Delta DDS_{i,t}$ denotes change in individual i 's DDS from $t-1$ to t , $\text{Declined}_{i,t-1}$ is a binary variable that indicates if the previous change in DDS from $t-2$ to $t-1$ was negative, $\text{Characteristic}_{j,t-2}$ is an attribute of the individual's household or geographic unit j at the initial time, $t-2$, and \mathbf{z} is a vector of individual and household-level control variables, also measured at that earlier time $t-2$, such as age, gender, education and socio-economic status.

The coefficient of main interest is on the interaction term $\Delta DDS_{i,t-1} * \text{Declined}_{i,t-1} * \text{Characteristic}_{j,t-2}$. To measure resilience, we look at the slope difference between those observations with an initial decline and those with an initial increase, $\beta_2 + \beta_3 \text{Characteristic}_{j,t-2}$, which varies by $\text{Characteristic}_{j,t-2}$. Since a negative slope difference indicates resilience, a negative β_3 increases the magnitude of this slope difference and indicates that this kind of resilience is associated with $\text{Characteristic}_{j,t-2}$.

3. Results

3.1. Recovery and resilience in the surveyed population

Figs. 1 and 2 present the average level of each nutritional outcome over the three or four rounds of each survey. We find that mean dietary diversity over the previous 24 h fluctuated somewhat from year to year in the three countries (Fig. 1, Panel A), and that in Nepal dietary diversity over the previous 7 days declined from round 1 to 2, then rose from round 2 to 3, and then declined from round 3 to 4 (Fig. 1, Panel B).

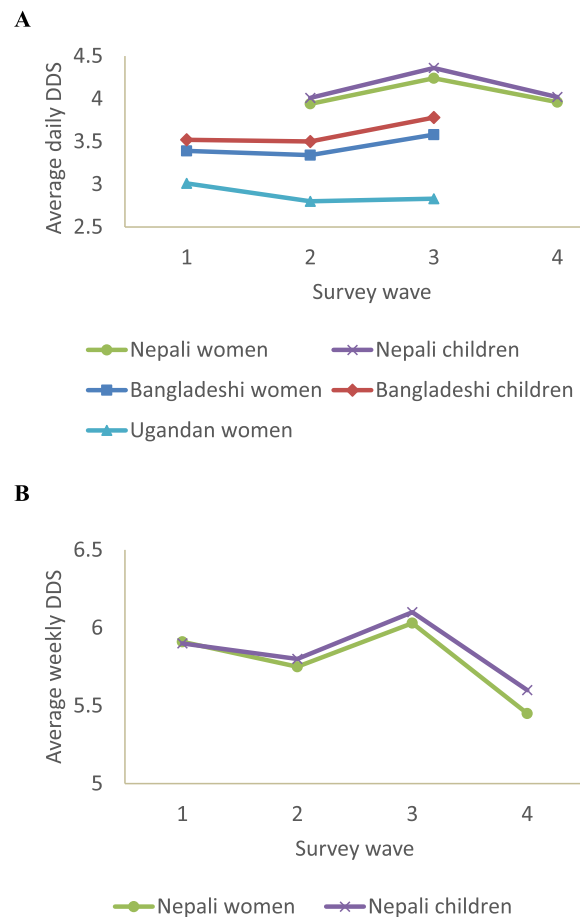


Fig. 1. Average dietary diversity scores over time

The figures show average daily (A) and weekly (B) dietary diversity scores (DDS) of women and children from Nepal, Bangladesh and Uganda. DDS are computed from 24 h and 7-day diet recall data using the FAO classification of foods into food groups. The data sources are the PoSHAN survey conducted yearly in Nepal (2013–2016), the BAHNR semi-annual survey in Bangladesh (2016–2017), and the biennial Uganda Community Connector panel study (2012–2016).

For anthropometry, we find that mean BMI of women rose across all survey rounds (Fig. 2, Panel A) but mean child WHZ declined in Bangladesh while staying constant or rising in Nepal (Fig. 2, Panel B). Most research focuses on this type of average outcome, but our focus is the trajectory of individuals around these trends, and particularly whether those whose outcomes worsened from one period to the next subsequently recovered more than would be expected from mean reversion.

To test for resilience in the trajectories of those who experience a decline in dietary diversity, BMI or WHZ, we compute bias-corrected estimates of change after decline in each outcome, in each survey, and compare those to the corresponding bias-corrected estimates of change after improvement. The resulting estimates are listed in Table 1, showing the magnitude and significance of expected changes after decline (column 1) and after improvement (column 2). The point estimates are shown graphically on Fig. 3, with ρ^- (changes after decline) along the vertical axis, and ρ^+ (changes after improvement) on the horizontal axis. Along each axis, negative values imply reversion, while positive values imply continuation in the same direction. Each point appears in a region of the chart that is labeled with its interpretation. Pure mean reversion would imply that coefficients appear along the diagonal line in the upper-left quadrant. Observations that meet our criteria for resilience appear to the right of that line, because declines revert more than improvements. To the left of the diagonal line of mean

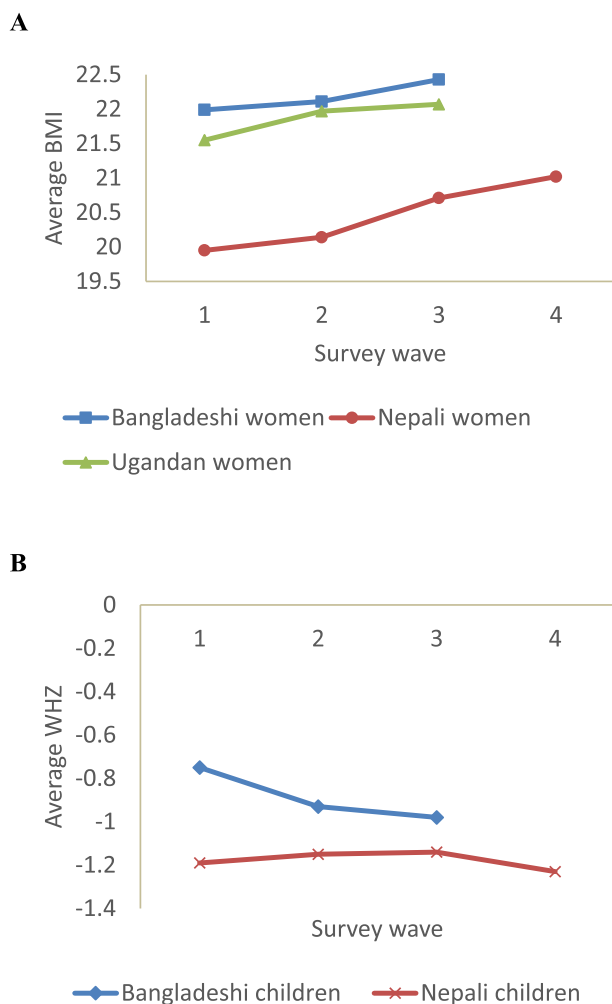


Fig. 2. Average anthropometric outcomes over time
 The figures show average women’s BMI (A) and children’s WHZ (B) using data on women and children from Nepal, Bangladesh and Uganda. “BMI” is the Body Mass Index (kg/m²), “WHZ” is the weight-for-height z score, a measure of relative weight expressed as the number of standard deviations below or above the median of the WHO reference population, adjusted for child age and sex. The data sources are the PoSHAN survey conducted yearly in Nepal (2013–2016), the BAHNR semi-annual survey in Bangladesh (2016–2017), and the biennial Uganda Community Connector panel study (2012–2016).

reversion, there is the possibility of recovery without resilience, and estimates may also be found in the lower half of the diagram where declines have momentum but improvements revert (the lower-left quadrant) or both declines and improvements have momentum (the lower-right quadrant).

The outcome for which we observe resilience is dietary diversity over the previous week in Nepal, where declines in dietary diversity were estimated to have reverted in the subsequent year by an average of 54 percent of the initial decline for children and 36 percent for women. For that same outcome and population, any increases in dietary diversity were followed by further increases that averaged 39 percent of the initial increase for children and 31 percent of the initial increase for women. The other variables have a variety of patterns, for example along the horizontal line of zero statistically significant change after declines, we find that daily dietary diversity in Nepal, measured by 24-h recall, tends to improve after improvements. That upward momentum averages 23 percent of the original improvement for children, and 13 percent of the original gains for women.

For Bangladeshi women and children, we find a slight increase in average daily dietary diversity over the period studied (Fig. 1, Panel A).

Table 1
 Estimation results.

Outcome	Reverting tendency of declines (ρ^-)	Reverting tendency of improvements (ρ^+)
Nepal		
Women’s weekly DDS	-0.360*** (0.094)	0.314*** (0.054)
Women’s daily DDS	-0.026 (0.143)	0.128* (0.067)
Women’s BMI	0.397*** (0.122)	0.572*** (0.098)
Children’s weekly DDS	-0.540*** (0.111)	0.389*** (0.078)
Children’s daily DDS	-0.032 (0.181)	0.234*** (0.088)
Children’s WHZ	0.190 (0.198)	0.464*** (0.165)
Bangladesh		
Women’s daily DDS	0.383*** (0.109)	-0.272*** (0.060)
Women’s BMI	0.864*** (0.094)	0.621*** (0.086)
Children’s daily DDS	0.133 (0.147)	-0.229*** (0.081)
Children’s WHZ	0.232* (0.135)	0.520*** (0.136)
Uganda		
Women’s daily DDS	0.481*** (0.117)	-0.163** (0.082)
Women’s BMI	0.217 (0.165)	0.012 (0.188)

Notes: The table reports bias-corrected estimates of the reverting tendencies of declines ρ^- and improvements ρ^+ for women’s and children’s outcomes using data from Nepal, Bangladesh, and Uganda. “DDS” are dietary diversity scores computed from daily and weekly diet recall data using the FAO classification of foods into food groups. “BMI” is the Body Mass Index (kg/m²), “WHZ” is the weight-for-height z score, a measure of relative weight expressed as the number of standard deviations below or above the median of the WHO reference population, adjusted for child age and sex. The estimation strategy and detailed results are presented in Zaharia et al. (2021) (Zaharia et al., 2021). The data sources are the PoSHAN survey conducted yearly in Nepal (2013–2016), the BAHNR semi-annual survey in Bangladesh (2016–2017), and the biennial Uganda Community Connector panel study (2012–2016). Bootstrap standard errors are shown in parantheses. ***p < 0.01, **p < 0.05, *p < 0.1.

Looking at the patterns of change for each individual in the sample, however, we find no evidence of resilience in the sense that women who experienced declines in daily DDS experienced additional declines in the following period, by an average of 38 percent of the initial decline. Improvements in daily DDS were estimated to reverse half a year later, on average by 27 percent of the initial improvement for women and 23 percent of the initial improvement for children (Fig. 3 and Table 1). We do not find evidence of resilience in Ugandan women’s daily dietary diversity either. The estimates indicate that declines in their daily DDS were followed by further declines two years later, on average by 48 percent of the initial decline. Improvements in their daily DDS were reversed two years later, on average by 17 percent of the initial improvement (Fig. 3 and Table 1).

In all three countries, average women’s Body Mass Index (BMI), calculated as weight in kilograms divided by the square of height in meters, follows an upward trend. In contrast, children’s weight-for-height z-scores (WHZ), expressed as the number of standard deviations below or above the median of a reference population, decreased over time in Bangladesh and Nepal (Fig. 2). Bias-corrected estimates of the reverting tendencies of declines and improvements indicate similar direction of change in anthropometric outcomes for both women and children in Bangladesh as well as Nepali women, and upward momentum of Nepali children’s WHZ. In the Ugandan panel, maternal BMI is indistinguishable from a random walk (Fig. 3 and Table 1). For Nepali

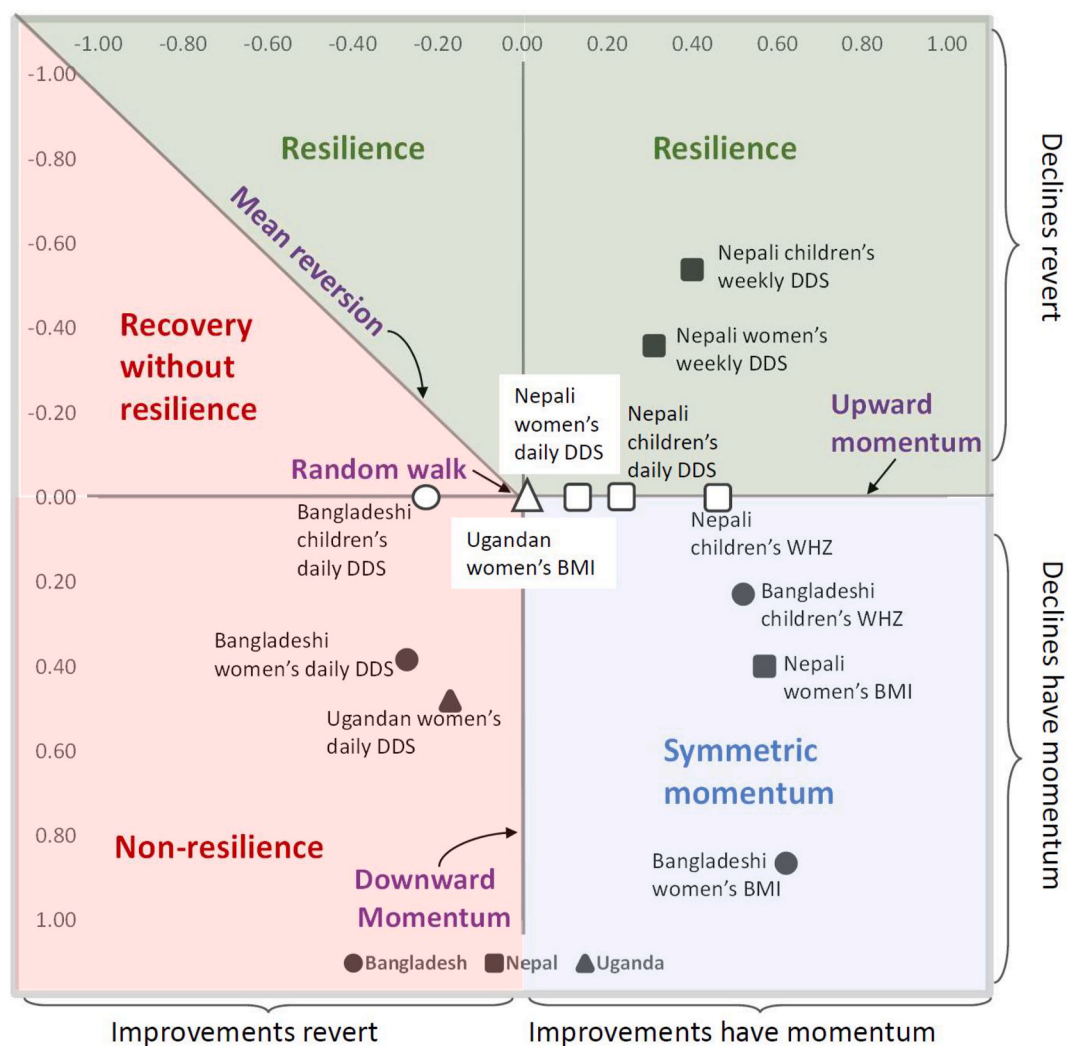


Fig. 3. Overview of resilience estimation results

The figure plots bias-corrected estimates of the reverting tendencies of improvements ρ^+ (horizontal axis) and declines ρ^- (vertical axis) for women’s and children’s outcomes using data from Nepal, Bangladesh, and Uganda and the classification shown in Fig. S2. “DDS” are dietary diversity scores computed from daily and weekly diet recall data using the FAO classification of foods into food groups. “BMI” is the Body Mass Index (kg/m²), “WHZ” is the weight-for-height z score, a measure of relative weight expressed as the number of standard deviations below or above the median of the WHO reference population, adjusted for child age and sex. Hollow markers are used for estimates that were not different from zero at a statistically significant level. The estimates are reported in Table 1, and the estimation strategy and detailed results are presented in Zaharia et al. (2021) (Zaharia et al., 2021). The data sources are the PoSHAN survey conducted yearly in Nepal (2013–2016), the BAHNR semi-annual survey in Bangladesh (2016–2017), and the biennial Uganda Community Connector panel study (2012–2016).

women’s BMI, the estimates indicate that initial declines were followed by further declines in the subsequent year, on average by 40 percent of the initial decline. Those with initial improvements in their anthropometric measurements showed further improvements in the following year, on average by 57 percent of the initial change. Similarly, for children’s WHZ, improvements were sustained by 46 percent of the initial improvement. In Bangladesh, initial declines in women’s BMI and children’s WHZ were followed by further declines half a year later, on average by 86 percent of the initial decline for women and 23 percent of the initial decline for children. Initial increases in women’s BMI and children’s WHZ were followed by further improvements six months later, on average by 62 percent of the initial improvement for women and 52 percent for children. In Uganda, we find no statistically significant change two years after either improvements or declines (Fig. 3 and Table 1).

3.2. Heterogeneity of resilience by geography and household characteristics

In Nepal, where maternal and child weekly dietary diversity were both found to be resilient, we analyze how that nutritional resilience varies across geographic locations with different extent and quality of infrastructure as well as groups of households with diverse characteristics. We split households into geographic locations based on the lowest administrative units called Village Development Committees (VDCs). The sample includes households from 7 VDCs located in different districts of the Terai region. We test for differences in resilience of maternal and child diet diversity across VDCs with different infrastructure, described by characteristics such as the number of schools, clinics, hospitals, NGO centers, banks, paved roads, food shops, irrigation canals and government offices. To assess how resilience varies by household characteristics we account for heterogeneity in terms of household wealth, ownership, sources of income, indebtedness, agricultural practices, and household membership of community groups. SI Appendix Tables S4 and S5 provide a complete list of the VDC and household

characteristics included in the analysis.

Figs. 4–6 illustrate results obtained from estimating Model 1 with those household and VDC characteristics for which we obtained statistically significant estimates on the coefficient of interest at the 10% level or higher. All regressions include a set of individual and household-level control variables: child’s age and gender, mother’s education, and socio-economic score of the household in the regressions that use the sample of children; woman’s age and education, and socio-economic score of the household in the women dietary diversity regressions. We tested whether adding or removing each control variable affected the significance of our results. The corresponding regression tables are available upon request. Negative coefficients imply that being part of a household or geographic location with a larger value for that specific characteristic is associated with a more resilient dietary diversity.

Overall, we find that resilience is heterogeneous both across different types of households and across geographic locations. In terms of VDC-level characteristics, women and children living in areas with more developed infrastructure and services (e.g. those with more shops, pharmacies, female teachers, and male post office workers) exhibit greater resilience in their weekly dietary diversity (Fig. 4, Tables S6 and S7) after controlling for women’s and children’s age, children’s gender,

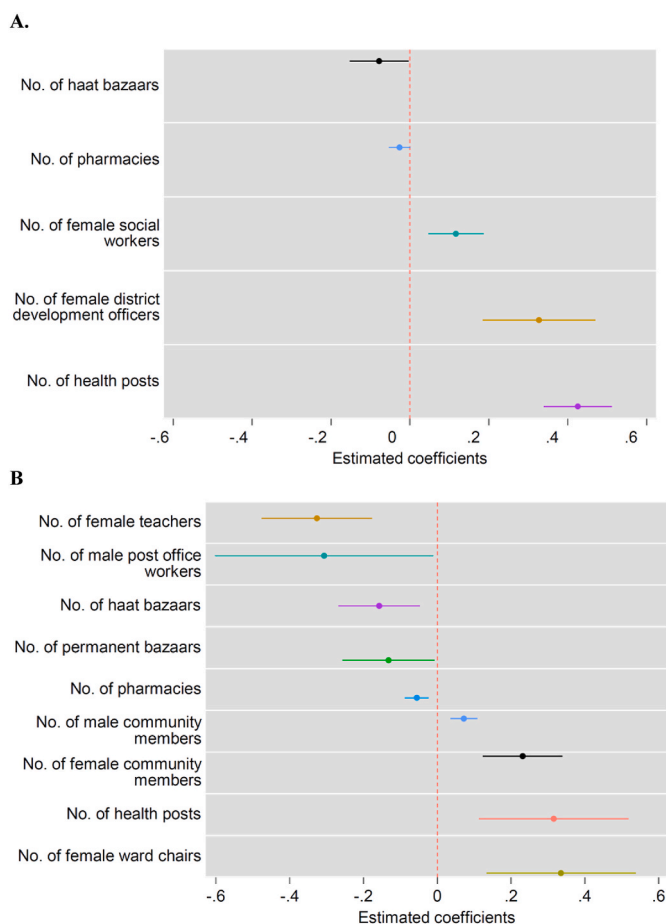


Fig. 4. Resilience of Nepali women’s and children’s DDS varies across geography

The figures plot coefficient estimates with 95% confidence intervals for the coefficient β_3 from model (1) which measures by how much diet diversity of women (A) or children (B) is more resilient in districts (VDCs) with a larger value for a particular VDC characteristic. All regressions in (A) control for the woman’s age and education, and the socio-economic status of her household. Regressions in (B) control for the child’s age and gender, the mother’s education, and the socio-economic status of the household. The data source is the PoSHAN survey conducted in Nepal. Detailed regression results are reported in Tables S6 and S7.

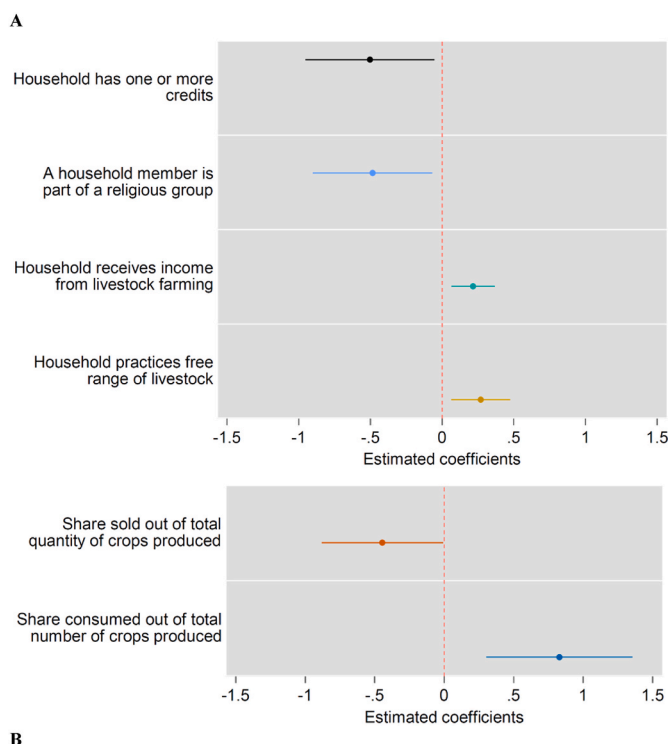


Fig. 5. Resilience of Nepali women’s DDS varies by household characteristics

The figures plot coefficient estimates with 95% confidence intervals for the coefficient β_3 from model (1) which measures by how much women’s diet diversity is more resilient in households with a larger value for that particular household characteristic (B) or, if the characteristic is a binary variable, in households in which the variable equals 1 (A). All regressions control for the woman’s age and education, and the socio-economic status of her household. The data source is the PoSHAN survey conducted in Nepal. Detailed regression results are reported in Table S8.

women’s education, and the socio-economic status of their household. For some services, a distinction arises depending on whether these are market-based (number of bazaars and pharmacies) or state-provided (number of social workers, health posts, district development officers), with more resilience associated with the former than the latter. In terms of household characteristics (Figs. 5 and 6, Tables S8 and S9), we find that households with access to credit and those selling a relatively larger share of their crops show more resilience of both women’s and children’s dietary diversity after controlling for age, child’s gender, women’s education, and socio-economic status of the household. Resilience also varies by participation in social groups; in particular, participation in a women’s group is positively related to children’s dietary diversity resilience. However, being part of a household that reported a larger circle of families to which they can turn for help (social capital) is associated with lower nutritional resilience in children. In terms of agricultural practices, we find lower resilience among children from households that adopted inter-cropping (versus monocropping of cereals) and among women from households practicing free range of livestock (rather than penning).

4. Discussion

Assessing the sustainability of policy and program-based interventions is increasingly important to stakeholders at the regional and global level such as development agencies, practitioners and governments. Resilience is about change over time, and the duration over which resilience can be measured depends on the length of time over which data were collected. This study demonstrates how conventional

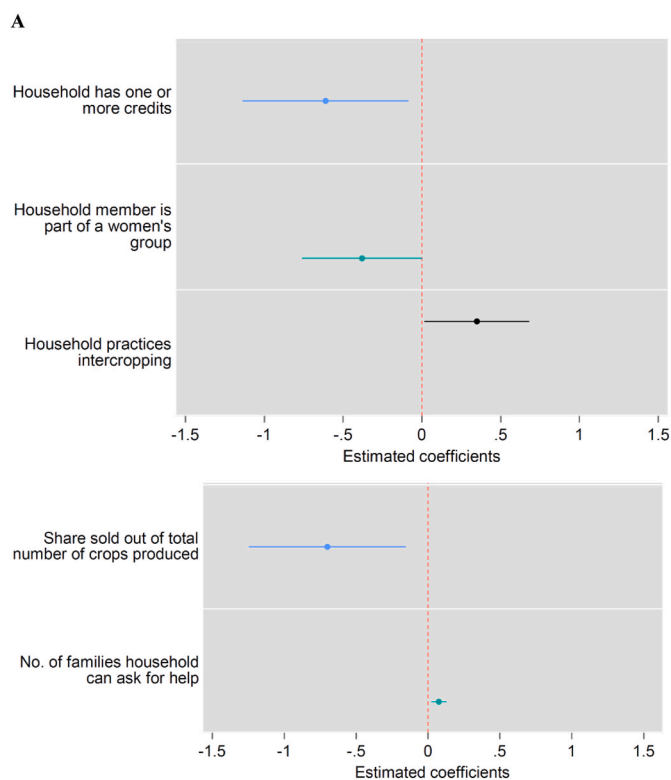


Fig. 6. Resilience of Nepali children's DDS varies by household characteristics

The figures plot coefficient estimates with 95% confidence intervals for the coefficient β_3 from model (1) which measures by how much children's diet diversity is more resilient in households with a larger value for that particular household characteristic (B) or, if the characteristic is a binary variable, in households in which the variable equals 1 (A). All regressions control for the child's age and gender, the mother's education, and the socio-economic status of the household. The data source is the PoSHAN survey conducted in Nepal. Detailed regression results are reported in [Table S9](#).

approaches with just one or two points in time (e.g. pre- and post-intervention) provide insufficient information to draw conclusions regarding resilience into a third period, but that having three or more observations for each individual allows analysts to distinguish resilience from other patterns in the data, including measurement error in variables such as anthropometric outcomes and dietary quality indicators such as DDS ([Ulijaszek and Kerr, 1999](#); [Thorne-Lyman et al., 2014](#)). Having at least three observations for each outcome allows analysts to test whether recoveries exceed expectations, based on comparison with others in the survey.

The approach used in this study concerns resilience of dietary diversity and nutrition as outcomes that are affected by a very wide range of unobserved shocks, and are also subject to random measurement errors. Future studies could focus on resilience with respect to particular events such as illness or agroclimatic changes, and whether specific interventions or household and community characteristics confer resilience to those shocks. Future studies could also be extended in time, moving from just three or four periods of observation to higher-frequency data or longer time periods. The empirical benefits of using more observations over time in the study of resilience have been widely noted ([Knippenberg et al., 2019](#)), not only for diet and anthropometry but also other indicators of human well-being at all levels of aggregation for individuals, households, countries and the world as a whole.

In our data on diets and nutrition from Nepal, Bangladesh, and Uganda, we found that recovery was often not significantly more likely than would be expected by chance, given random fluctuations and

trends in these environments. Outcomes in each country were measured at different intervals (annual in Nepal, biennial in Bangladesh, and bi-annual in Uganda), for different time periods (dietary diversity over the previous week versus the previous day), and for different surveyed populations (nationally representative in Nepal, chosen for interventions due to their vulnerability in Bangladesh and Uganda). The results span a variety of situations that may be encountered in low-income settings, and yield potentially important findings. For example, we found that while diet diversity improved over time in Bangladesh, there was no significant pattern of resilience in the sense that those whose dietary diversity initially worsened did not have a larger-than-expected subsequent improvement. Since the data were collected at six month intervals, at least some of the fluctuations we observed are seasonal, and Bangladesh is also particularly vulnerable to extreme weather events, so the lack of resilience despite overall improvements is concerning. In contrast for Nepal we found the opposite situation, with a slight decline on average but statistically significant resilience for women's and children's weekly dietary diversity. In Uganda we found that women's daily dietary diversity was not resilient according to our measure. The results obtained for anthropometric outcomes are similar across countries, with momentum found for both women's BMIs and children's WHZ scores. Unlike diets, which can often adjust rapidly, biological outcomes appear to be more persistent over time.

For Nepali women and children, we also measured how resilience of their weekly diet diversity varied across households and by geographic location. We found greater resilience among women and children from households that sold a larger share of their crops and/or had access to credit, which could be related to entrepreneurship and resourcefulness. Nutritional resilience was lower for children from households that had a larger circle of families they could ask for help. This may be a case of reverse causality, in which those households that were more vulnerable relied more heavily on social networks. The differences in nutritional resilience by geographic location were related to the density of local infrastructure, consistent with other evidence for Nepal and Uganda ([Shively, 2017](#)). Women and children from VDCs with more market-based services (number of bazaars and pharmacies) were more resilient, while those from VDCs with more state offered services (social workers, health posts, district development officers) exhibited less resilience. This could again reflect reverse causality, especially if markets arise in areas with more community resilience and the government offers more services in areas perceived to be at risk.

Although the evidence presented here is insufficient to draw conclusions in terms of causality, it successfully describes the heterogeneity that exists in sampled populations and the potential of certain behaviors, characteristics, or local infrastructure to increase resilience. Social protection systems that transfer income and may buffer diets during periods of stress, investments in rural infrastructure to increase access to markets, and ensuring access to healthcare services mean that income constraints do not force households to choose between health-seeking or food. The role of diet quality matters in its own right as a goal of long-term development. However, protecting diets during times of stress is also a priority for humanitarian action in response to shocks. Directly measuring how individuals 'manage' their diets during times of hardship therefore offers potential for policymakers and programmers to better understand this important human dimension of resilience that goes beyond assets and income.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.gfs.2021.100573>.

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