MEASURING HOUSEHOLD RESILIENCE TO FOOD INSECURITY: APPLICATION TO PALESTINIAN HOUSEHOLDS

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Abstract

Most of the current literature on food security focuses on assessing household vulnerability in food-insecure regions. However, although the concept of vulnerability is dynamic and forward-looking, almost all statistical methodologies applied until now have been static and unable to predict future events. The main reasons for this are conceptual – for example, arising from the complexity (multidimensionality) of the concept of food security and the unpredictability of the many shocks that cause food insecurity – and empirical, such as the absence of longitudinal data over sufficiently long periods to identify the various sources of risk and thereby allow the analysis of trends and risks.

The concept of resilience has recently been introduced into food security literature. It aims to measure households' capability to absorb the negative effects of unpredictable shocks, as a legitimate component of vulnerability analysis. The definition of resilience to food insecurity has a direct effect on the methodology used to measure it, and the model described in this document, considers resilience to be a latent variable defined according to four building blocks: income and food access; assets; access to public services; and social safety nets. Two additional dimensions – stability and adaptive capacity – cut across these building blocks and account for households' capacity to respond and adapt to shocks; these too are latent variables. To measure the whole system, two approaches can be pursued. The first measures each dimension separately using different multivariate techniques (factor analysis, principal components analysis and optimal scaling) before estimating the resilience index; the classification and regression tree (CART) methodology has also been used for the understanding of the process. The second approach measures all the dimensions simultaneously through structural equation models, and is based on normality assumptions on observed variables. As most of the variables in resilience measurement are ordinal or categorical, the first approach was adopted in this document.

The role of the estimated resilience index in measuring vulnerability to food insecurity was then assessed through a regression model with food consumption in logarithmic scale as a dependent variable and the resilience index and other household characteristics as independent variables.

The document also discusses the policy implications of resilience, using the results of testing the methodology in the Palestinian context.

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Acronyms

A	assets
AC	adaptive capacity
APS	access to public services
CART	classification and regression tree (methodology)
DD	dietary diversity and food frequency score
EWS	early warning system(s)
FANTA	Food and Nutrition Technical Assistance
HFIAS	household food insecurity access scale
IFA	income and food access
IPCC	Intergovernmental Panel on Climate Change
MCMC	Markov Chain Monte Carlo
NGO	non-governmental organization
NIS	new shequel (the local currency: 4 NIS = approximately US$1)
OLS	ordinary least squares
PPPS	Palestinian Public Perception Survey
PRINCALS	principal components analysis by alternating least squares
R	resilience
S	stability
SD	standard deviation
SEM	structural equation model
SES	socio-economic-ecological system(s)
SSN	social safety nets
TTA	twin-track approach
USAID	United States Agency for International Development
VIF	variance inflation factor
WB	West Bank

Introduction

Most research in the field of food security in unstable environments has focused on developing and refining analysis methods to improve the understanding and prediction of crisis events and their magnitude. Such work has centred on developing methodologies that prepare for and manage the possible effects of food crises in specific susceptible areas. In particular, current food insecurity forecasting capacity focuses on establishing different early warning systems (EWS), based either on selected environmental indicators that are considered triggers of crises (drought, rain, floods, etc.) or on behavioural patterns that reflect individuals' vulnerability. These systems provide alerts on possible food insecurity risks arising from value changes in selected socio-economic indicators (Buchanan-Smith and Davies, 1995). However, vulnerability is defined in very different ways, depending on the discipline concerned. The most commonly used definition is that of the Intergovernmental Panel on Climate Change (IPCC, McCarthy *et al.*, 2001), which states that vulnerability is the degree to which a system is susceptible to and unable to cope with adverse effects (of specific hazards/risks). This interpretation limits the scope of analysis in unstable environments to the negative implications of crises, focusing only on susceptibility to harm, and not considering the mechanisms used by households to adapt to the new conditions generated by a crisis and, possibly, to improve their overall well-being.

In the last decade, collaboration between natural and social scientists concerned with the sustainability of jointly determined ecological and economic systems has led to the potentially fruitful concept of resilience, which is already well known in the ecological literature, but is new to socio-economic systems (Adger, 2000). Broadly speaking, resilience is a measure of a system's ability to withstand stresses and shocks, that is, its ability to persist in an uncertain world.

Recently, scholars, practitioners (Folke, Berkes and Colding, 1998; Folke *et al.*, 2002) and international organizations such as FAO (Hemrich and Alinovi, 2004), have proposed applying this concept to food security issues, to complement the EWS approach. While the EWS approach seeks to predict crisis, the resilience framework seeks to assess the current strength of a food system, and hence its ability to withstand shocks should they occur.

This paper assesses the possibility of adopting the resilience concept developed within the environmental context to the food security domain, and proposes a methodology for measuring household resilience to food insecurity as a solid basis for vulnerability analysis. Different authors define vulnerability in different ways, but all agree that it is a function of risks, hazards and one or more descriptors of resilience or its components. However, resilience has never been measured in such a context, and is a multidimensional concept, based on several pillars. This study aims to define a model that explains resilience, its pillars and its relations to food security. This first step in applying resilience to food security makes the measurement of resilience feasible. The study also discusses the data needs of a monitoring system, which will be adopted when suitable data sets become available.

Key issues addressed by the paper include: clarifying the meaning and scope of resilience as applied to the analysis and management of food systems; identifying the relationships between resilience and other concepts such as vulnerability; establishing how resilience in a food system should be measured; and identifying the relationships between resilience and food insecurity outcomes.

The analysis focuses on the household level because this is where most risk management and coping strategies are implemented, especially the informal strategies that are most readily available to the poor (cf. World Bank, 2001). It does not examine other important measurement issues pertaining to different levels of analysis, such as how to measure food system resilience at the regional, national or global levels. Another limitation is that the researchers lacked the necessary information to capture and quantify the volatility of vulnerability over time, which is very important to poor households, especially in view of the dynamic nature of resilience. Such information would require panel data-sets that are long enough to monitor the same households over time, allowing the direct observation of how households deal with shocks. Measuring household resilience to food insecurity requires data on household assets (physical, human and social capital) and on formal safety nets, the functioning of markets, and the economic policies that determine a household's opportunity set and the range of activities it can pursue to manage risk. Many household surveys do not provide such information. Last but not least, information on movement in and out of food security is available only after the facts have taken place. The challenge is to find indicators that monitor households' resilience in advance.

This research is presented in six chapters: chapter 1 describes the concept of resilience and its relationship to other food security concepts (e.g. vulnerability, sustainability); chapter 2 proposes a model for measuring the different dimensions of food security resilience, and presents methodological approaches for measuring household resilience; chapter 3 reports on how the proposed methodology was tested using data from the 11th Palestinian Public Perception Survey (PPPS 2007); chapter 4 validates the model through the classification and regression tree (CART) methodology and discusses the implications of resilience measurement for understanding food insecurity outcomes; chapter 5 provides a preliminary model for forecasting resilience; and chapter 6 summarizes the main findings and discusses policy implications for future research and the design of relevant surveys.

1. The concept of resilience and its relation to household food security

THE CONCEPT OF RESILIENCE

The concept of resilience was originally described in the ecological literature (Holling, 1973) and has recently been proposed as a way of exploring the relative persistence of different states in complex dynamic systems, including socio-economic ones (Levin *et al.,* 1998). The concept of resilience has two main variants (Holling, 1996). "Engineering" resilience (Gunderson *et al.,* 1997) is a system's ability to return to the steady state after a perturbation (Pimm, 1984; O'Neill *et al.*, 1986; Tilman and Downing, 1994). It focuses on efficiency, constancy and predictability, and is the concept that engineers look at to optimize their designs ("fail-safe" designs). "Ecological" resilience is the magnitude of disturbance that a system can absorb before it redefines its structure by changing the variables and processes that control behaviour (Walker *et al.*, 1969; Holling, 1973). This concept of resilience focuses on disruptions to the stable steady state, where instabilities can flip a system into another behaviour regime (i.e., into another stability domain).

Both variants deal with aspects of the stability of system equilibria, offering alternative measures of a system's capacity to retain its functions following disturbance. The two definitions emphasize different aspects of stability, however, and so "can become alternative paradigms whose devotees reflect traditions of a discipline or of an attitude more than of a reality of nature" (Gunderson *et al.*, 1997: 3).[1] The two definitions reflect two different world views: engineers aim to make things work, while ecologists acknowledge that things can break down and change their behaviour. The question now is how will economists define reliance? Traditionally, economists have tended to consider conditions close to a single stable state,[2] but the issue of ecological resilience is also beginning to emerge in economics, following the identification of multi-stable states caused by path dependency (Arthur, 1988), "chreodic" development (Clark and Juma, 1987) and production non-convexities such as increasing return to scale (David, 1985).

Levin *et al.* (1998) argue that resilience offers a helpful way of viewing the evolution of social systems, partly because it provides a means of analysing, measuring and implementing the sustainability of such systems. This is largely because resilience shifts attention away from long-run equilibria, towards a system's capacity to respond to short-run shocks and stresses constructively and creatively.

Within a system, key sources of resilience lie in the variety that exists within functional groups, such as biodiversity in critical ecosystem functions, flexible options in management, norms and rules in human organizations, and cultural and political diversity in social groups.[3] Resilience also comes from accumulated capital, which provides sources for renewal. Increasingly, resilience is seen as the capacity not only to absorb disturbances, but also to reorganize while undergoing changes, so as to retain the same functions, structures and feedbacks (Walker *et al.*, 2004; Folke, 2006). In ecological systems, this capacity includes mechanisms for regeneration, such as seeds and spatial recolonization, or soil properties. In social systems, it is the social capital of trust, networks, memory and relationships, or the cultural capital of ethics, values and systems of knowledge.

In addition, the kindred discipline of system ecology acknowledges that critical ecosystem organizational or "keystone" (Paine, 1974) processes create feedbacks that interact, reinforcing the persistence of a system's temporal and spatial patterns over specific scales. In social-ecological

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[1] For instance, engineering resilience focuses on maintaining the efficiency of functions, while ecological resilience focuses on their existence. This means that the former explores system behaviour in the neighbourhood of the steady state, while the latter explores the properties of other stable states, focusing on the boundaries between states. These attitudes reflect different traditions; engineering resilience was developed according to deductive mathematics theory; ecological resilience stems from inductive disciplines such as applied mathematics and applied resources ecology.

[2] For instance, in partial equilibrium analysis, multiple equilibria are excluded by constructing convex production and utility sets. or when multiple equilibria theoretically exist, their number is reduced by means of individuals' strategic expectations and predetermined normative and social institutions.

[3] Diversity does not support stability but it does support resilience and system functioning (Holling, 1973; 1986), while rigid control mechanisms that seek stability tend to erode resilience and facilitate system breakdown.

systems, many factors contribute to this – including institutions, property rights and the completeness and effectiveness of markets[4] – making the functions of critical organizational processes robust.

THE SYSTEMIC APPROACH: FOOD SYSTEMS AS COMPLEX SYSTEMS

A very general definition of a food system is that it is made up of all the interacting social and ecological components that affect the food security of a given group of people. A food system therefore involves all the phases from production to consumption of food, through distribution and processing. Such a definition is general and conceptually very broad because it entails many dimensions – economic, social, institutional, technological and cultural – and scales, being global, national or local depending on the purpose of the analysis. The multidimensionality of the food system concept derives from the fact that, whatever the scale of analysis, a food system always comprises at least two components: the resource base that ensures the food supply, and the socio-economic component that depends on this resource base.

Notwithstanding the multidimensionality of food systems, different disciplines have traditionally analysed them through sectoral approaches that reflect discipline-specific principles, categories and methods of analysis. This is especially true for the two components of food systems mentioned in the previous paragraph, which are usually analysed separately in the fields of ecology (for the resource base) and economics (for the socio-economic component). However, one of the more significant recent discoveries in the study of ecological and economic systems is that they are jointly determined, and the scale of economic activity matters.[5] In other words, the economy and its environment "co-evolve" (Norgaard, 1994) and cannot be analysed separately from each other. This applies specifically to food systems, which are jointly determined socio-economic-ecological systems (SES).

The consequences of this are important in terms of both the contents of the analysis (the subject under scrutiny) and the methodology adopted (how it is analysed), as they imply that food systems should be thought of as complex adaptive systems to be analysed using a non-reductionist, systemic approach. More precisely, recent research on jointly determined SES concludes that they are stochastic evolutionary systems (Perrings, 1998) characterized by the following features:

- *Path dependency:* History matters, and the current status of a system is largely determined by the sequence of states that system has gone through in the past.
- *Discontinuous changes:* Observed changes tend not to be continuous or gradual, but involve more or less sudden alterations around critical threshold values.
- *Multiple equilibria:* The functionally different states of a system involve different equilibria, that is, systems tend to evolve by switching equilibria.
- *Non-linearity:* System dynamics and stability tend to vary non-linearly according to the scale of the system.

An implication of this is that the stability of a jointly determined system depends less on the stability of its individual components than on its ability to maintain self-organization in the face of stress and shocks, that is, on its resilience. This means that the analysis of complex adaptive systems should focus less on the steady or near-equilibrium states and more on the conditions that ensure the maintenance of system functions in the face of stress and shock. This ultimately means moving from a static, deterministic analysis towards a dynamic, stochastic analysis. These conclusions have profound implications for the analysis of food systems and food security.

HOUSEHOLDS AS (SUB-)SYSTEMS OF A BROADER FOOD SYSTEM, AND HOUSEHOLD RESILIENCE

Households are components of food systems and can themselves be conceived as (sub-)systems. The household definition is consistent with Spedding's (1988: 18) definition of a system as "a group of

[4] From the operational point of view, it is important to establish the different actors' roles in supporting key processes over the relevant range of natural and economic conditions, and to identify the institutional conditions, regulatory framework and incentive structure required to assure the conservation of those conditions.

[5] Different scales of analysis imply different emphases on the specific dimensions that characterize a food system. For example, if the scale of analysis is the household or community (e.g., a village or a tribe), the implications of actors' actions on the system's natural resource base should be analytically more relevant than in a national-scale analysis.

interacting components, operating together for a common purpose, capable of reacting as a whole to external stimuli: it is affected directly by its own outputs and has a specified boundary based on the inclusion of all significant feedback." Moreover, as the decision-making unit, the household is where the most important decisions are made regarding how to manage uncertain events, both *ex ante* and *ex post*, including those affecting food security such as what income-generating activities to engage in, how to allocate food and non-food consumption among household members, and what strategies to implement to manage and cope with risks.

Households can therefore be viewed as the most suitable entry point for the analysis of food security. This does not mean disregarding the important relationships between the household and the broader food system it belongs to (e.g., the community, the market chain), which contribute to determining the household's food security performance, including its resilience to food insecurity. Systems comprise hierarchies, each level of which involves a different temporal and spatial scale, and a system's behaviour appears to be dominated by key structuring processes (see previous section) that are often beyond the reach of its single components (e.g., households) and so are assumed as given by those components at a specific scale and in a specific time frame (e.g., the short run). In other words, household strategies for managing and coping with risks prove to be more effective in a given neighbourhood (the household livelihood space) and over a finite time span.

The multidimensionality of the food security and poverty concepts and the complexity of the conduit mechanisms for food insecurity make the household a system that faces largely unpredictable exogenous shocks. This implies that a household should be considered as a complex adaptive system. The survival of a household as a system depends less on the stability of its individual components than on its ability to maintain self-organization in the face of stress and shock, in other words on its resilience. In a resilient household, change can create opportunity for development, novelty and innovation. As resilience declines, a progressively smaller external event can cause catastrophe. A household with low resilience may maintain its functions and generate resources and services – thereby seeming to be in good shape – but when subject to disturbances and stochastic events, it will exceed a critical threshold and change to a less desirable state.

Application of the concept of resilience to household food security therefore seems promising: it aims at measuring households' capability to absorb the negative effects of unpredictable shocks, rather than predicting the occurrence of a crisis (as most vulnerability literature does).

RESILIENCE ANALYSIS AND OPERATIONAL DIMENSIONS

Adopting a resilience-based approach to the management of food systems presupposes a framework for analysing resilience and enabling people to discover how the food system in which they live might be made more resilient to shocks, and more able to renew or reorganize itself should such shocks occur.[6] In turn, this requires an understanding of where resilience resides in the system, and when and how it can be lost or gained, which means identifying the points in a food system where interventions can increase the resilience to future changes of desired configurations.

Figure 1 illustrates a four-step framework for analysing resilience in food systems. It is a modification of the framework originally proposed by Walker *et al.* (2002), and has the following characteristics:

- *Close stakeholder involvement:* Without the participation of all involved actors it is impossible to achieve a collectively and socially desirable outcome, because the knowledge and mental models of stakeholders provide key information; without them any proposed solution would face legitimacy problems (Ostrom, 1999).
- *Feedback loops:* The process is iterative, and involves many rounds of discussion among stakeholders, policy-makers, local experts and scientists progressively refining the analysis of how a system will respond to and change in the face of external and internal driving forces.
- *Two main actions – resilience assessment and resilience management:* The first analyses current or future states of food system resilience, and the second implements actions aimed at restoring, conserving and enhancing food system resilience.

[6] Walker *et al.* (2002) refer to this as the "resilience analysis and management" approach.

Step 1: Resilience of what?
The first step is to develop a conceptual model of the food system to be analysed, based on stakeholder inputs. The model defines the boundaries of the issue to be solved and elicits information on important aspects of the food system. This step defines the system and uses the information collected to identify areas of uncertainty about the system's dynamics. The procedure varies according to the specific context, and the levels of knowledge, experience and expertise available.

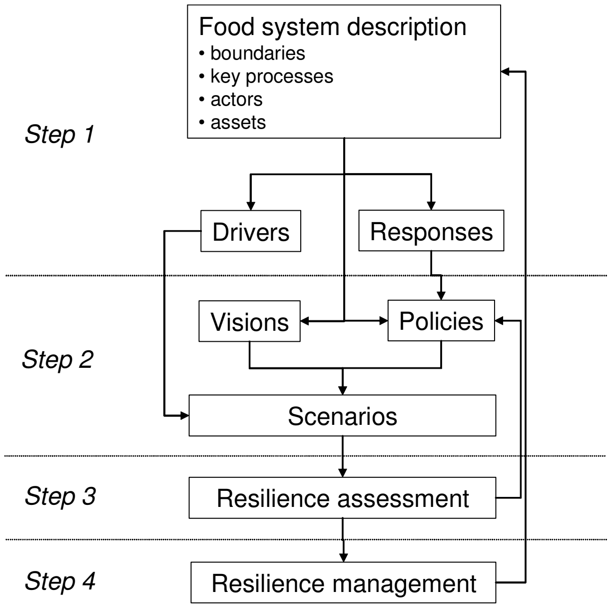


Figure 1: Framework for the analysis of resilience in food systems

Whatever the specific context of the analysis, however, the following information must be gathered: the system boundaries; the key processes involved; a census of actors/stakeholders; and the assets necessary to ensure food security and livelihood. Preliminary information on key drivers of past changes and the responses adopted to cope with such changes should also be gathered. The historical profile of the system should be summarized to increase understanding of how the present state was reached.

The output of step 1 is a conceptual model of what is known about issues in the system that stakeholders deem to be important, and what determines these issues. It provides an essential heuristic basis for step 2 and it defines what the resilience analysis is meant to analyse (Carpenter *et al.*, 2001).

Step 2: Resilience to what?
Step 2 develops some possible future scenarios, including the outcomes of uncontrollable and ambiguous external drivers. Development of the scenarios considers three kinds of future drivers of the system: external shocks and disturbances (physical, social and economic); people's visions, hopes and fears regarding the future; and policies that might be imposed.[7]

Stakeholders may initially develop a large number of potential scenarios, and then condense these into a manageable few that capture the most important uncertainties spanning the range of conditions the system might face, as well as people's visions for their future. A minimum of three scenarios should be developed: a business-as-usual one; a more conservative one; and a more development- or growth-oriented one.

[7] Policies arise in many forms and at many levels. Some policies influence the general adaptive capacity of a system; others control the system's dynamics regarding particular state variables.

Step 3: Resilience assessment

Step 3 explores the interactions among the information gathered in the previous two steps through a combination of modelling and non-modelling methods. The aim is to identify possible driving variables and processes in the system that govern the dynamics of the issues stakeholders deem to be important (food system goods and services), focusing on threshold effects and other non-linearities.

This is an iterative process that starts with discussions among stakeholders, policy-makers, other local experts and scientists to examine how the system will respond and change in the face of the scenarios developed. The aim is to identify possible groups of interacting variables where non-linearities are likely.

Two sets of information are needed to assess resilience:

- the crucial (slow) variables that collectively determine the dynamic behaviour of the system and that therefore govern the supply of its goods and services;
- the processes that drive the dynamics of this set of crucial variables, particularly those that determine the thresholds along these variables.

Step 4: Resilience management

The final step involves a stakeholder evaluation of the whole process and its implications for policy and management actions.[8] Changes in policy and management will only arise when all the different stakeholders share an understanding of the processes and their implications for the system.

There is no guarantee that such a shared understanding can be achieved; intractable ecological or social issues can get in the way. Experience suggests that social issues might be the more difficult to resolve, but the chances of success are always increased when the full range of stakeholders is engaged

[8] Policies aim to provide a set of rules (incentives and disincentives) that enhance a system's ability to reorganize and move within a configuration of acceptable states.

2. From concept to measurement

VULNERABILITY VERSUS RESILIENCE

According to Dercon (2001: 16–19), "households and individuals have assets, such as labour, human capital, physical capital, social capital, commons and public goods at their disposal to make a living. Assets are used to generate income in various forms, including earnings and returns to assets, sale of assets, transfers and remittances. Households actively build up assets, not just physical capital but also social or human capital, as an alternative to spending. Incomes provide access to dimensions of well-being: consumption, nutrition, health, etc., mediated by information, markets, public services and non-market institutions. Generating incomes from assets is also constrained by information, the functioning of markets and access to them, the functioning of non-market institutions, public service provision and public policy. … Risks are faced at various steps in this framework." Assets, their transformation into income and the transformation of income into dimensions of well-being are all subject to risk (Table 1).

According to this framework, well-being and its dimensions such as food security or poverty are *ex-post* measures of a household's decision-making about its assets and incomes when faced with a variety of risks. Vulnerability to food insecurity describes the outcome of this process *ex ante*, that is, considering the potential outcomes rather then the actual outcome. Food insecurity is measured at a specific point in time, as a "snapshot"; vulnerability is essentially forward-looking, based on information about a particular point in time. Vulnerability is the propensity to fall below the (consumption) threshold, and its assessment therefore deals not only with those who are currently poor but also those who are likely to become poor in the future (Chaudhuri, Jalan and Suryahadi, 2002).Vulnerability to food insecurity is determined by:

- the risks faced by households and individuals in making a living;
- the options available to households (individuals, communities) for making a living (including assets, activities, market and non-market institutions, and public service provision);
- the ability to handle this risk.

This framework is not very different from that proposed in the global change literature (Ahmad *et al.,* 2001), which defines vulnerability as a function of:[9]

- exposure to risks, that is, the magnitude and frequency of stress experienced by the entity;
- sensitivity, which describes the impacts of stress that may result in reduced well-being owing to the crossing of a threshold (below which the entity experiences lower well-being);
- adaptive capacity, which represents the extent to which an entity can modify the impact of a stress, to reduce its vulnerability.

TABLE 1
Framework for analysis

[9] The first and third items in these two lists are the same. The second item in the second list (sensitivity) can be regarded as the outcome of the second item in the first list (options available to the household).

Assets	*Incomes*	*Well-being - 'Capabilities'*
• Human capital, labour • Physical/financial capital • Commons and Public goods • Social Capital	• Returns to activities and assets • Returns from asset disposal • Savings, credit and investment • Transfers and remittances	ability to obtain *(inter alia)* • Consumption • Nutrition • Health • Education
Examples of Risk (a)	*Examples of Risk (b)*	*Examples of Risk (c)*
• loss of skills due to health or unemployment • land tenure insecurity, uncertain titles to other assets • asset damage due to climate, war or disaster • access to commons and unclear commitments regarding public goods • violations of commitment and trust • loss in value of financial assets or pension funds linked to inflation, stock market or exchange rate collapses.	• output risk due to climatic shocks, disease, conflict • output price risk • covariance in incomes and asset prices • risk in asset returns from savings and investment (including inflation) • uncertain access to inputs or cash flow support during production • imperfect enforcement of contracts, such as payment for goods or services rendered • uncertainty about enforcement of informal arrangements, including informal protection – for example, transfers and remittances may not materialise • uncertainty regarding rationing in public support, for example, risk of exclusion from safety net • imperfect information and knowledge about opportunities • risks in policy environment – credibility and commitment to continue policies	• price risk in food markets • food availability and rationing risk • uncertain quality of public provision in health and education • uncertainty about rationing scheme employed in health or education • imperfect knowledge about health and nutrition 'production' (uncertainty about right answer)

Source: Dercon, 2001: 17.

In the food security literature (FIVIMS/FAO, 2002), vulnerability to food insecurity is seen as a function of the nature of risks and the individual's or household's responses to such risks.[10] In this paper, however, vulnerability is a function of a household's risk exposure and its resilience to such risks (cf. FAO, 2004); an output-based analysis framework is adopted, which is in the same vein as the asset–income–outcome causal chain suggested by Dercon (2001).[11] Therefore, household resilience to food insecurity, defined as a household's ability to maintain a certain level of well-being (food security) in the face of risks, depends on the options available to that household to make a living and on its ability to handle risks. It refers therefore to *ex-ante* actions aimed at reducing or mitigating risks, and *ex-post* actions to cope with those risks. It also covers both short-term actions (e.g., coping) and actions that have a longer-term impacts (e.g., adaptation to structural changes to ensure household functioning). Empirical application focuses on how to measure resilience to food insecurity as a contribution to vulnerability assessment.[12]

THE MODEL

Figure 2 summarizes the rationale for attempting to measure resilience to food insecurity. Consistent with the framework in Table 1, it is assumed that the resilience of a given household at a given point in time, T_0, depends primarily on the options available to that household to make a living, such as its access to assets, income-generating activities, public services and social safety nets. These options represent a precondition for the household response mechanisms (its ability to handle risk) to a given risk.

[10] The nature of risks is the counterpart to the first item in each of the previous two lists, while responses to risks correspond to the second and third items.

[11] This is quite different from a risk-based approach, such as the World Bank's social risk management framework, which focuses on minimizing risk exposure, but virtually disregards those risks that stem from insufficient ownership or access to assets (cf. FAO, 2006b).

[12] This paper therefore does not focus on the broader issue of how to measure vulnerability (cf. Dercon, 2001; Chaudhuri, 2004; Ligon and Schechter, 2004; FAO, 2006b), but on a subset of such a framework.

Assume that between T_0 and T_1, some shocks occur, which may be endogenous, if related to the household's control of its options, or exogenous, if beyond the household's control. Whether the shocks are endogenous or exogenous, the household reacts to them by using available response mechanisms and its absorption and adaptive capacities. The reaction to some shocks (e.g., systemic shocks) occurs through policy support by decision-makers other than the household (e.g., government or international institutions), and might themselves be the causes of external shocks.

A third dimension of resilience is stability, which is the degree to which a household's options vary over time. Households showing high adaptability and high stability will likely have high resilience to food insecurity, while those showing low adaptability and low stability will have low resilience. Intermediate cases will likely determine medium-level household resilience.[13]

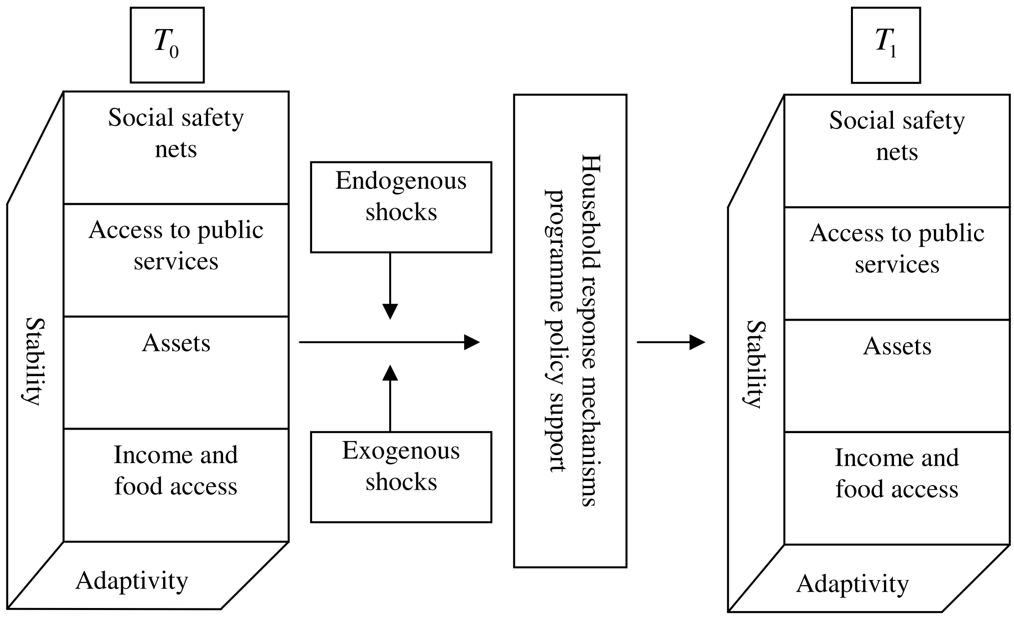


Figure 2: Resilience conceptual framework

Every component at time T_0 is estimated separately, to generate a composite index of household resilience. The different components of the resilience observed at time T_1 then reflect how all these factors produce change in a household's resilience. In algebraic terms, the resilience index for household *i* can be expressed as follows:

$$R_i = f\left(IFA_i, A_i, APS_i, SSN_i, S_i, AC_i\right) \qquad (1)$$

where: R = resilience; S = stability; SSN = social safety nets; APS = access to public services; A = assets; IFA = income and food access; and AC = adaptive capacity.

Resilience is not observable *per se,* and is considered a latent variable depending on the terms on the righthand side of the equation. To estimate *R,* it is therefore necessary to estimate separately *IFA, S, SSN, APS, A, AC*, which are themselves latent variables because they cannot be directly observed in a given survey, but it is possible to estimate them through multivariate techniques.[14]

[13] Recalling discussion of the different meanings of resilience in the previous chapter, it can be argued that high stability with low adaptability create a status closer to the definition of engineering resilience, while ecological resilience is closer to a status characterized by high adaptability and low stability.

[14] For example, *IFA* does not include just household income (which is observable), but also a series of estimated variables related to food consumption and expenditure and to the household's perception of food access and dietary diversity, which are context- and data-specific.

METHODOLOGICAL APPROACHES

The model described in the previous section can be estimated through an extension of multivariate regression models. Equation 1 is a hierarchical model in which some variables are dependent on one side and independent of the other. Unobservable (i.e., latent) variables have also to be dealt with. Figure 3 shows the path diagram of the model concerned.

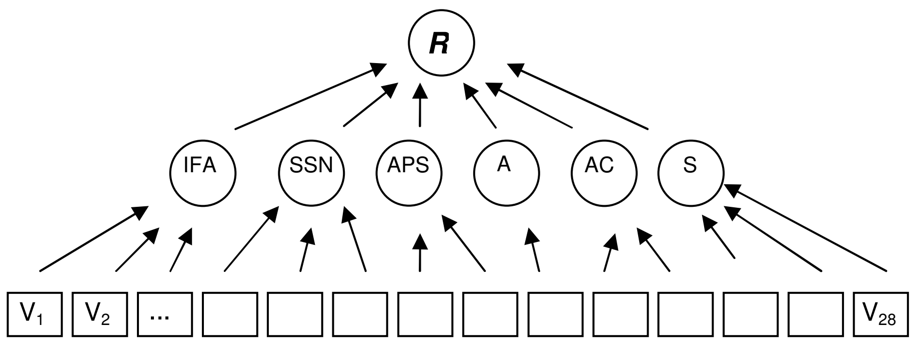


Figure 3: Path diagram of the household resilience model

In the causal models literature (Spirtes, Glymour and Scheines, 2000), circles represent latent variables and boxes represent observed variables. Most of the hierarchical or multi-level models studied in the literature deal with measured variables, so the regression properties are extended. One of the innovative contributions of this research is the estimation of latent variable models in complex survey data.

Considering the complexity of the model concerned, two alternative estimation strategies could be adopted for the estimation of household resilience: structural equation modelling and multi-stage modelling.

Structural equation models (SEMs) are the most appropriate tools for dealing with the kind of model illustrated in Figure 3. Structural equation modelling combines factor analysis with regression. It is assumed that the set of measured variables is an imperfect measure of the underlying latent variable of interest. Structural equation modelling uses a factor analysis-type model to measure the latent variables via observed variables, while simultaneously using a regression-type model to identify relationships among the latent variables (Bollen, 1989). Generally, the estimation methods developed for SEMs are limited to the normally distributed observed variables, but in most cases (including this one), many variables are nominal or ordinal. The literature has proposed some attempts to broaden the SEMs to include nominal/ordinal variables, but there are difficulties regarding computational aspects (Muthén, 1984). It is also possible to use generalized latent variable models (Bartholomew and Knott, 1999; Skrondal and Rabe-Hesketh, 2004) to model different response types. A major concern in using SEMs for measuring resilience is that the algorithms of SEM procedures are usually totally data-driven, but this paper seeks to include some prior knowledge on deterministic relations among measured variables. Bayesian procedures could be used for their flexibility, but the number of variables to be used in this case make parameter identification problems likely to emerge, requiring careful consideration to incorporate proper prior information. In the last decade, the use of Markov Chain Monte Carlo (MCMC) simulation methods (Arminger and Muthén, 1998; Lopes and West, 2003; Rowe, 2003; Mezzetti and Billari, 2005) has simplified the computational concern.

The other approach explored is a multi-stage strategy for estimating the latent variables separately, based on the relevant observed variables. This involves the use of various sets of observed variables (represented as squares in Figure 3) to estimate the underlying latent variables (circles in Figure 3). In other words, the circles represent the common pattern in the measured variables. The methods used for generating these latent variables depend on the scales of the observed variables. Traditional multivariate methods are based on continuous variables, but most of the variables in household-level surveys are qualitative (nominal, ordinal or interval), so it is necessary to use different techniques for non-continuous types of variables. The main multivariate techniques relevant for this analysis are

SEMs or Lisrel methods,[15] factorial analysis, principal components analysis, correspondence analysis, multidimensional scaling, and optimal scaling, all of which are usually combined with deterministic decision matrices that are based on prior knowledge of variables.[16]

In the household surveys considered, most of the variables are categorical or ordinal, and measured at different scales, which makes the situation even more complex and requires a mechanism to identify the optimal scaling. The variables require the use of optimal scaling methods, and scaling categorical variables is an important issue. Usually, these variables are coded with natural numbers (1, 2, ..., *n*), but they may be coded as *a*, *b*, *c*, etc. In many cases, the distance between 1 and 2 may not be equal to the distance between 2 and 3, so categorical variables cannot be treated as quantitative variables. In this paper, the principal components analysis by alternating least squares (PRINCALS) algorithm (De Leeuw and Van Rijckevorsel, 1980) is used to estimate optimal scaling and principal components simultaneously. The estimation minimizes the following objective function (loss function):

$$\sigma(X,Y) = m^{-1}\sum_j SSQ(X - G_j Y_j) \tag{2}$$

where: SSQ = the sum of squares; m = the number of variables; X = the matrix of object scores; G_j = the indicator matrix for variable j; and Y_j (scaling) = the matrix of category quantifications for j.

There are two main reasons for adopting the second (multi-stage) estimation strategy: 1) the available variables are not normally all distributed, so may require the use of different multivariate techniques; and 2) measuring the different components separately makes the model more flexible, allowing the inclusion of prior information and thus reducing the parameter identification problem.

After estimation of the different components and resilience, CART methodology is adopted to test the validity of the adopted model and identify the contributions of the original variables to the resilience index.

[15] This should not be confused with the holistic SEMs proposed in the first approach. A single latent variable may be estimated through simpler cases of the general structural equations for the latent variable model: $\eta = B\eta + \Gamma\xi + \zeta$, where: η = a vector of latent endogenous variables; and ξ = a vector of exogenous variables.

[16] This paper does not explain these methods, which are described in all multivariate analysis manuals. The following chapters provide the information necessary for an understanding of the procedures.

3. Measuring Palestinian food security resilience

THE DATA SET

The Palestinian Public Perception Survey (PPPS) is an interagency effort aimed at building understanding of the socio-economic conditions in the West Bank and Gaza Strip. The University of Geneva implemented the 11th PPPS in 2007, with the collaboration of several agencies, including FAO for the food security component. Responsibility for the data collection rests with the Palestinian Central Bureau of Statistics. PPPS provides a very rich dataset, including key indicators relevant for defining and analysing household food security status and its dynamics.

The data are repeated cross-sections, but it is not possible to use the surveys carried out before 2007 owing to some changes in the food security section of the questionnaire, which make the last survey incompatible with the previous ones. In 2007, the sample size was 2 087 households and the sampling design was a two-stage stratified cluster. The sampling weights (the reciprocal of selection probability) were adjusted to compensate for non-response and to satisfy the population size estimates, particularly in the analysis disaggregated by region, sex and age group.

The questionnaire has the following sections for each household in the survey:

- demographic, occupational and educational status;
- security/mobility;
- labour market;
- economic situation (including the food security module);
- assistance/assistance priorities;
- infrastructure;
- coping strategies;
- health;
- children;
- women;
- politics and peace/managing security;
- religion.

Preliminary data screening took place during the preparatory phase of the analysis, to select the variables related to each component in Equation 1.

THE ESTIMATION PROCEDURE

The empirical strategy follows a three-step procedure: 1) identification and measurement[17] of the variables selected for each resilience block; 2) estimation of the latent variable representing each block, and of the resilience index, using multivariate methods (factor analysis, principal components analysis, optimal scaling, etc.); and 3) application of CART methodology to estimate precise splitting rules based on a regression tree, to improve understanding of the whole process.[18]

The selection of relevant variables for estimating the latent indicator for each block is particularly complex. The multidimensionality of the concept gives rise to concerns about having variables that are relevant for more than one block, when a variable cannot be included more than once in the model. The conceptual framework described in the previous chapter simplifies this issue.

The following subsections describe the separate estimation process for each component of the resilience framework.

---

[17] Not all the observed variables are taken directly from the raw data. Some are measured using complex procedures (e.g., the household food insecurity access scale [HFIAS] and the dietary diversity and food frequency score [DD]).

[18] The use of CART also made it possible to validate the decision process and identify the original variables (indicators) that play major roles in the different blocks defining resilience.

Income and food access (*IFA*)

This indicator is directly related to a household's access to food. Economic access to food is considered the main food insecurity concern in Palestine (Mane, Alinovi and Sacco, 2007; Abuelhaj, in press). The traditional indicator for measuring food access capacity is income, but this study includes two additional indicators: the dietary diversity and food frequency score (DD) as a nutritional indicator; and the household food insecurity access scale (HFIAS) as an indicator of the household's perception of food security. Estimation of the *IFA* indicator involves use of the following variables:

- *Average per person daily income* (NIS/person/day): This is an aggregated value of the different sources of income measured by PPPS.
- *DD:* This is computed using specific methodologies for food security assessments applied to the weekly consumption of 20 food items. It can also be used as a proxy indicator for food access (Hoddinott and Yohannes, 2002).
- *HFIAS:* This indicator of a household's perception of food insecurity is measured through a set of nine questions developed by the Food and Nutrition Technical Assistance (FANTA) project[19] (Coates, Swindale and Bilinsky, 2006).

Missing values in these variables are imputed using regression techniques.

All these indicators aim to measure food access, so the high correlation among them should produce a latent variable that fits the common pattern in the data. Because of this, to estimate the *IFA* latent indicator, a factor analysis is run using the principal factor method and the scoring method suggested by Bartlett (1937):

$$\hat{f}_B = \Gamma^{-1}\Lambda'\Psi^{-1}x\,, \tag{3}$$

Where: $\Gamma = \Lambda'\Psi^{-1}\Lambda$; Λ = the unrotated loading matrix; Ψ = the diagonal matrix of uniquenesses; and x = the vector of observed variables. The estimates produced by this method are unbiased, but may be less accurate than those produced by the regression method suggested by Thomson (1951).[20] The regression-scored factors have the smallest mean square error, but may be biased. The first factor produced is quite meaningful and can be considered the underlying latent variable for food access. Table 2 shows the eigenvalue for each factor, and Table 3 shows the factor loadings for the original variables. The three indicators play almost the same role in estimating the *IFA* indicator, because their correlation coefficients are similar. As expected, HFIAS has a negative correlation because its score increases as food security decreases.

TABLE 2
Eigenvalues

Factor	Eigenvalue
Factor 1	1.54613
Factor 2	0.75363
Factor 3	0.70024

TABLE 3
Factor loadings and correlations

Variable	Factor 1	IFA
Income	0.4466	0.6779
DD	0.4786	0.7308
HFIAS	-0.4860	-0.7431

Access to public services (*APS*)

Public service provision is beyond households' control, but is a key factor for enhancing a household's resilience, such as by improving the effectiveness of that household's access to assets. As a result, better access to public services affects a household's capacity to manage risks and respond to crisis. The following public services are considered in the analysis:

[19] The FANTA project supports integrated food security and nutrition programming to improve the health and well-being of women and children. It is managed by the Academy for Educational Development and funded by the United States Agency for International Development (USAID).

[20] The formula for Thompson's regression method is: $\hat{f}_T = \Lambda'\Sigma^{-1}x$, where Σ = the correlation matrix of x.

- *Health:* Measurement of health involves two indicators: physical access to health (need not received, need received after time limit, and need received within time limit); and the health care quality score (based on the quality of services provided in different health areas).
- *Quality of education system* (ordinal scale from 1 to 6).
- *Perception of security* (ordinal scale from 1 to 4): For this, a proxy index based on the general perception of security is constructed.
- *Mobility and transport limitations* (ordinal scale from 1 to 3): Different sources are used to generate an indicator from the restrictions to mobility questions in the questionnaire.
- *Water, electricity and telecommunications networks:* An indicator is developed for the number of services available.

A characteristic of the variables related to *APS* is that households in the same neighbourhood are expected to be highly correlated in terms of having the same availability of services. Missing values in these variables are therefore treated using the governorate-level mean.

In this case, use of the traditional multivariate methods (factor or principal component analysis) is impossible because the observed variables are not continuous. It was therefore decided to use the optimal scaling technique. The first factor (the *APS* indicator) obtained through PRINCALS is very satisfactory. Table 4 shows that all the original variables (transformed using optimal scaling) are, as expected, positively correlated with the estimated *APS*.

TABLE 4
Correlation of APS with transformed variables

Transformed variable	***APS***
Physical access to health	0.6040
Health care quality	0.5984
Education system quality	0.4329
Perception of security	0.5317
Mobility constraints	0.5451
Water, electricity and telecommunications	0.2838

Social safety nets (*SSN*)

Social safety nets are a crucial aspect of mitigating crises in Palestine. More and more households are becoming dependent on assistance from international agencies, charities and non-governmental organizations (NGOs). Help received from friends and relatives is also substantial. Safety nets can therefore be considered to represent the system's capacity to mitigate shocks, and a general indicator for them has to be included in the estimation of resilience. The variables used to generate the *SSN* indicator are:

- *amount of cash and in-kind assistance* (NIS/person/day);
- *quality of assistance* (ordinal scale from 1 to 4);
- *job assistance* (binary yes/no response);
- *monetary values of first and second types of assistance* (NIS/person/day);
- *evaluation of the main type of assistance* (ordinal scale from 1 to 4)
- *frequency of assistance* (times assistance received in the last six months);
- *overall opinion of targeting* (assistance targeted to the needy; to some not needy; or without distinction).

Missing values are treated using the governorate-level means and the level of income. It was decided to show the measurement scale of the variables as this is a crucial aspect of choosing the method for estimating the latent variable. The list above shows that types of variables were mixed, so for *SSN*, use of the PRINCALS algorithm is required. The first factor obtained is acceptable for estimating the latent variable *SSN*. Table 5 illustrates the correlation between estimated *SSN* and the transformed variables. All the variables are positively correlated with *SSN* and play important roles in the estimation. Nevertheless, the degree of satisfaction with the assistance received is the core of the generated variable.

Moreover, the correlation matrix for the various resilience blocks shows that *SSN* is negatively related to the others. This is because social cohesion increases as poverty increases. This aspect will be explained in more detail in the following section discussing the results.

TABLE 5
Correlation of *SSN* with transformed variables

Transformed variable	*SSN*
Amount of cash and in-kind assistance	0.1669
Quality of assistance	0.7347
Job assistance	0.3794
First and second types of assistance	0.7223
Evaluation of main assistance	0.7304
Frequency of assistance	0.6775
Opinion of targeting	0.4462

Assets (*A*)

Assets are part of a household's capital, and their availability is an important coping mechanism during periods of hardship. They therefore have to be considered as a key factor in estimating resilience. Information on assets was not available from the PPPS dataset; it was decided not to use proxies, so as not to contaminate the estimates.

Adaptive capacity (*AC*)

The adaptive capacity indicates a household's capacity to cope with and adapt to a certain shock, enabling that household to keep performing its key functions. In other words, *AC* represents households' capacity to absorb shocks. For example, having more coping strategies means having more probability of mitigating food insecurity after, say, losing a job. The characteristic of adaptability is the buffer effect on household key functions. *AC* is measured by the following indicators:

- *Diversity of income sources* (count from 0 to 6): This indicates the number of income sources from different sectors (public, private, etc.); during a crisis, the more sources of income, the less the risk of losing the essential basis of the household's livelihood (i.e., income).
- *Coping strategy index* (count from 0 to 18): This represents the number of available coping strategies that have not yet been used. It does not consider whether or not a specific coping strategy has been adopted by the household (*ex post*), but instead how many coping mechanisms are available to the household (*ex ante*).
- *Capacity to keep up in the future* (ordinal scale from 1 to 5): This is based on a household's perception of its own capacity to keep up in the future, considering the current socio-economic shocks in Palestine. It is a forward-looking variable, which allows households' expectations to be taken into account.

The variables are not continuous, even in this case, so PRINCALS methodology is needed. Table 6 shows the correlation of the estimated *AC* with the transformed variables. The correlation coefficients correspond to the loadings of component 1; the coping strategy index and the capacity to keep up in the future are twice as important as the diversity of income sources.

TABLE 6
Correlation of *AC* with transformed variables

Transformed variable	*AC*
Diversity of income sources	0.3659
Coping strategy index	0.7551
Capacity to keep up in the future	0.7800

Stability (*S*)
Stability is a widely used concept in food security literature, although it is usually used to describe the stability of food supply. This paper considers stability to be a cross-sectoral dimension of resilience. For example, an index of income stability may be its variability (increase, decrease or the same) over the last six months. The following variables are used to measure stability:

- *Professional skills* (count): The number of household members with at least a diploma[21] is used as a proxy.
- *Educational level* (continuous): This is measured by the average number of years of schooling of household members.
- *Employment ratio* (from 0 to 1): This is the ratio of the number of employed household members to the household size.
- *Number of household members to have lost jobs* (count): This is the number to have lost their employment in the last six months.
- *Income stability* (increased; the same; decreased): This is measured by income variation over the last six months.
- *Assistance dependency* (ratio from 0 to 1): This is the ratio of the monetary value of assistance to total income.
- *Assistance stability* (increased; the same; decreased): This is the variation in the quality of assistance over the last six months.
- *Health stability* (count from 1 to 8): This is measured by the number of institutions providing medical care.
- *Education system stability* (increased; the same; decreased): This is the variation in the quality of education over the last six months.

The variables have mixed measurement scales, so the PRINCALS algorithm is used to generate the *S* index. The correlations in Table 7 show that professional skills, educational level and employment ratio play the major roles in estimating *S*. Obviously, the correlations with the variables number of household members to lose their jobs and assistance dependency are negative. Stability decreases as dependency on assistance increases, and as more household members lose their jobs. More surprising is the negative correlation with stability of the education system. This is because households with higher educational levels perceive a greater worsening of the education system than those with lower educational levels.

TABLE 7
Correlation of *S* with transformed variables

Transformed variable	*S*
Professional skills	0.7234
Educational level	0.7930
Employment ratio	0.6786
Household members to lose jobs	-0.0609
Income stability	0.2112
Assistance dependency	-0.3723
Assistance stability	0.3116
Health stability	0.1198
Education system stability	-0.1315

[21] A weighting system is used to give major relevance to household members with a Masters or Ph.D. degree.

Estimation of resilience (*R*)

The variables estimated in the previous subsections become covariates in estimation of the resilience index. Considering that all the estimated components are normally distributed with mean zero and variance 1, it is easy to apply traditional factor or principal components analysis.[22] A factor analysis is run using the iterated principal factor method, which re-estimates communalities iteratively.[23]

The results obtained are very satisfactory. Table 8 shows that factor 1 alone explains more then 75 percent of the variance, with factors 2 and 3 accounting for 16 and 8 percent, respectively. Table 9 presents some interesting results in terms of interpretation, especially of the first two factors. The first factor seems to represent fairly well the household's level of well-being. Of the resilience building blocks, only *SSN* is not positively related to the first factor, because it is negatively correlated to the other variables. This is obvious given that social cohesion usually increases as households become poorer. Social safety nets are a positive feature of resilience, however, so they are captured in the second factor, where *SSN* becomes positive. Even adaptive capacity (*AC*) assumes a positive value in the second factor. It can be imagined that when a household becomes poorer it acquires adaptive capacities that it did not have when it was richer (e.g., household members consider doing lower-level jobs than they would have done before). This second factor probably captures mechanisms – mainly non-economic and informal – that are triggered when a household is under stress (i.e., when it is poorer and in need, income and stability become negatively correlated). The third factor is rather more difficult to interpret. It seems to have something in common with the concept of utilization in food security because it is positively related to public services and level of income.

TABLE 8

Eigenvalues and variance explained

	Eigenvalue	% variance
Factor 1	1.51766	0.7529
Factor 2	0.32620	0.1618
Factor 3	0.15795	0.0784
Factor 4	0.01399	0.0069
Factor 5	-0.00018	-0.0001

TABLE 9

Factor loadings

Variable	Factor 1	Factor 2	Factor 3
IFA	0.8077	-0.0089	0.1396
AC	0.6039	0.3130	-0.1380
S	0.5753	-0.1407	-0.2049
APS	0.2808	0.1146	0.2759
SSN	-0.3011	0.4419	-0.0363

The factor analysis shows that resilience cannot be a one-dimensional concept. As explained, the positiveness of *SSN* is not captured by the first factor but by the second. Even if the first factor explains more then 75 percent of the variance, the other two factors have to be included in the measurement of resilience. It is possible to have a weighted sum of three scored factors because they are orthogonal to each other, so the risk of multicollinearity is avoided. To estimate resilience, the three factors must therefore first be generated using the Thompson's regression method and then each must be multiplied with its own proportion of variance explained:

$$\text{Resilience} = 0.755^{*}\text{Factor 1} + 0.165^{*}\text{Factor 2} + 0.08^{*}\text{Factor 3} \quad (4)$$

Factor analysis produces a resilience index that is normally distributed with mean zero and variance depending on the variance and covariance of the scored factors. This is a common feature of factor and principal component analysis, and is a limitation when resilience indices are to be compared among different countries or, more generally, different samples. Nevertheless, the role of the resilience index becomes crucial for policy-makers seeking to analyse sub-samples of the original population, such as regions or social groups.

[22] It is assumed that all variability in an item should be used in the principal component analysis, while only the variability in an item that is common to other items is used in factor analysis. In most cases, these two methods yield very similar results, but principal component analysis is often preferred as a method for data reduction, and principal factors analysis for cases when the goal of the analysis is to detect the structure in the data.

[23] Communality is the proportion of the variance of a particular item that is due to common factors (i.e., that is shared among several items).

DISCUSSION OF RESULTS

This section presents some of the estimates of the resilience index and its components in the five subregions of Palestine. Figure 4 shows the Epanechnikov's kernel density estimates of the resilience distribution. The initial presentation of the results is based on a non-parametric method, because such methods are normally more informative.

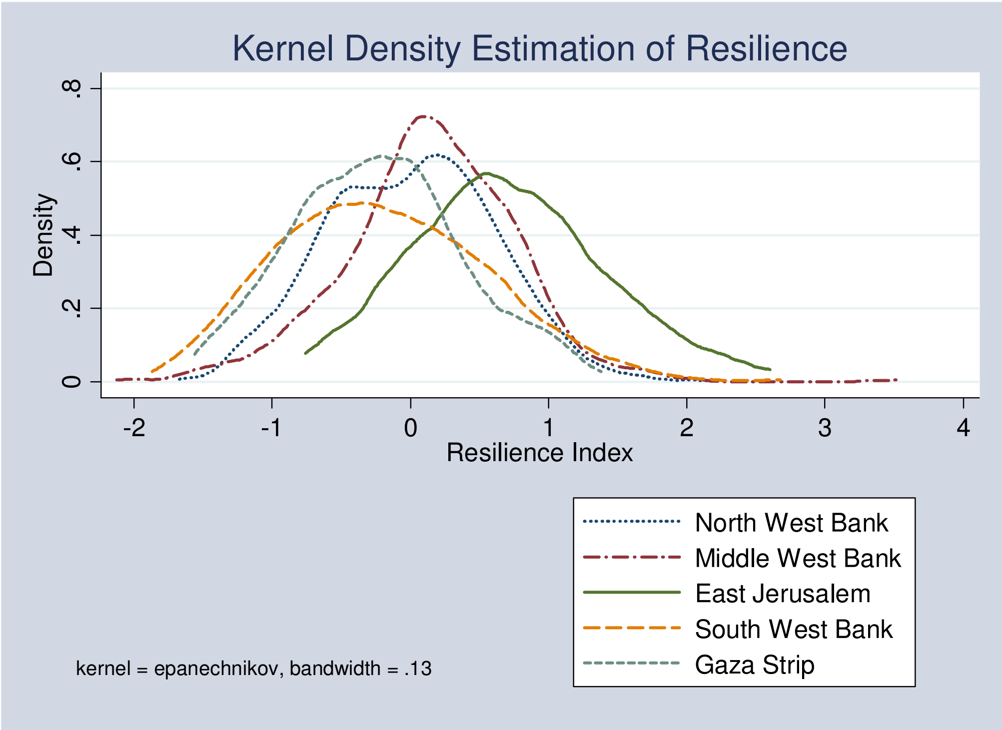


Figure 4: Distribution of resilience in the five Palestinian subregions

Figure 4 shows a clear difference in resilience distribution between East Jerusalem[24] and the other subregions. However, South West Bank (WB) and Gaza Strip seem to have more or less the same resilience level, so the parametric approach is used to improve understanding of the differences among subregions and to obtain the relevant significance level. Table 10 shows the means and standard deviations (SDs) for resilience and its standardized components. The matrix in Table 11 shows the t-statistics for pair-wise comparison among the means of the different subregions.

TABLE 10
Means and standard deviations for resilience and its components

	Frequency	Resilience		*IFA*		*APS*		*SSN*		*AC*		*S*	
Region	**N**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
North WB	648	.0045	.5987	-.021	1.264	-.242	.966	.017	1.017	.106	1.022	.054	.961
Mid-WB	614	.1436	.6165	.434	1.389	.058	.936	-.190	.830	.077	.984	-.036	.981
Jerusalem	93	.7055	.6931	1.880	1.509	.951	1.021	-1.014	.395	.119	1.066	.452	1.226
South WB	408	-.1922	.7539	-.370	1.625	.080	1.089	-.143	.992	-.372	.934	-.053	1.079
Gaza Strip	324	-.2415	.6089	-.854	1.377	.000	.862	.797	.874	.075	.941	-.104	.898
Total	**2 087**	**0**	**.6760**	**0**	**1.525**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**

[24] Villages outside the wall of Jerusalem are included in Mid-West Bank.

TABLE 11

Differences among the means across subregions' t-statistic tests

	North WB	Mid-WB	Jerusalem	South WB	Gaza Strip
North WB	0				
Mid-WB	-4.0660	0			
Jerusalem	-10.3430	-8.0543	0		
South WB	4.6930	7.7906	10.5135	0	
Gaza Strip	6.0040	9.1352	12.8082	0.9563*	0

* Not significant.

The differences among subregional resilience levels are all significant except for that between Gaza Strip and South West Bank. The level of resilience in Gaza Strip would have been much lower if social safety nets had been excluded from the analysis. Figure 5 shows the differences among subregions, not only of resilience but also of its different components.

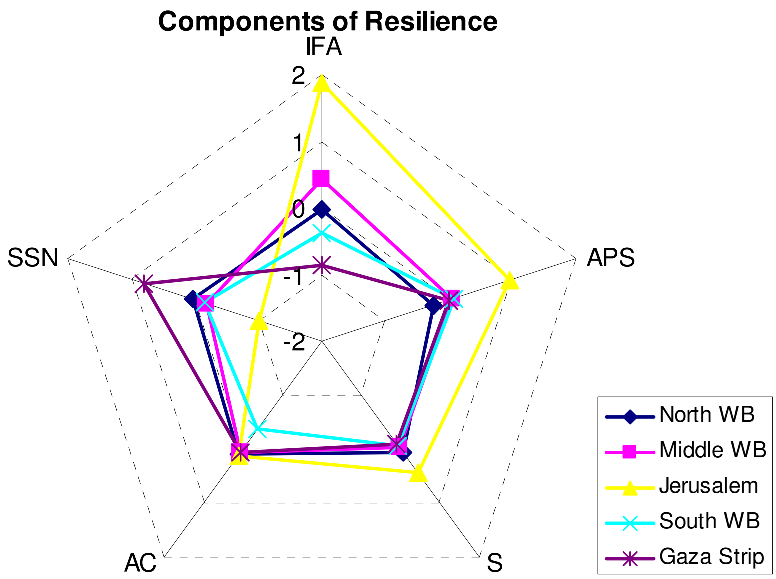


Figure 5: Radar graph for resilience components

Jerusalem has the highest level of resilience, which depends mainly on income capacity, access to services and stability. Adaptive capacity seems to remain relatively similar to that of other subregions, however. At the opposite extreme, Gaza Strip shows very limited access to food and income, and a high level of dependency on safety nets (from both family ties and external assistance) and on services provided by the Palestinian Authority. South West Bank, with a low level of resilience that is equally distributed among the five pillars, shows a substantially lower level of adaptive capacities. North and Mid-West Bank seem to have relatively balanced distributions across the five pillars and more stable structures of their resilience levels.

The analysis also increases understanding of the current situation in different areas of West Bank and Gaza Strip, particularly Gaza Strip's dependence on external aid. The availability of and access to food depend substantially on the capacity of social safety nets mechanisms, both traditional household-based ones and those provided by the international community. Physical access to markets also has a major influence on the overall capacity of Gaza Strip households to bounce back after acute crises.

The study of resilience according to its different components is crucial, especially for policy decisions. A more detailed analysis will therefore be conducted in the following chapters to explore the policy implications.

4. Testing resilience measurement

MODEL VALIDATION WITH CART

A cross-validation process is used to assess whether the procedures adopted for estimating the resilience index are meaningful. The cross-validation process tests the original hypothesis that sets of different variables and indicators belonging to different dimensions of food insecurity, the social sector and public services are correlated (i.e., contribute) to the overall resilience index. CART methodology (see Steinberg and Colla, 1995; and, Breiman *et al.*, 1984) is used to estimate the resilience decision tree and related splitting rules. The greatest advantage of CART is its cross-validation procedure, which allows the measurement of any errors in the model estimation.[25]

The target variable for the model implemented with CART is the resilience index. Because this is a continuous variable, CART performs a regression tree. (When the target variable is categorical, CART performs a classification tree.) As predictors, the model includes all the original variables used in the empirical approach. The weights deriving from the sample design are also considered. Figure 6 illustrates the upper part of the regression tree generated by CART.[26] The optimal tree has 281 terminal nodes, and a relative cost (error) equal to 0.123. The approximated R-squared can be calculated using the formula: 1 – the resubstitution error (i.e., 1 – 0.019 = 0.981). This is very important in confirming that the variables used in the multi-stage approach explain most of the resilience variability when a different estimation method is used (i.e., a non-parametric instead of a parametric one). The CART procedure includes use of the Gini splitting criterion and ten-fold cross-validation for testing.[27]

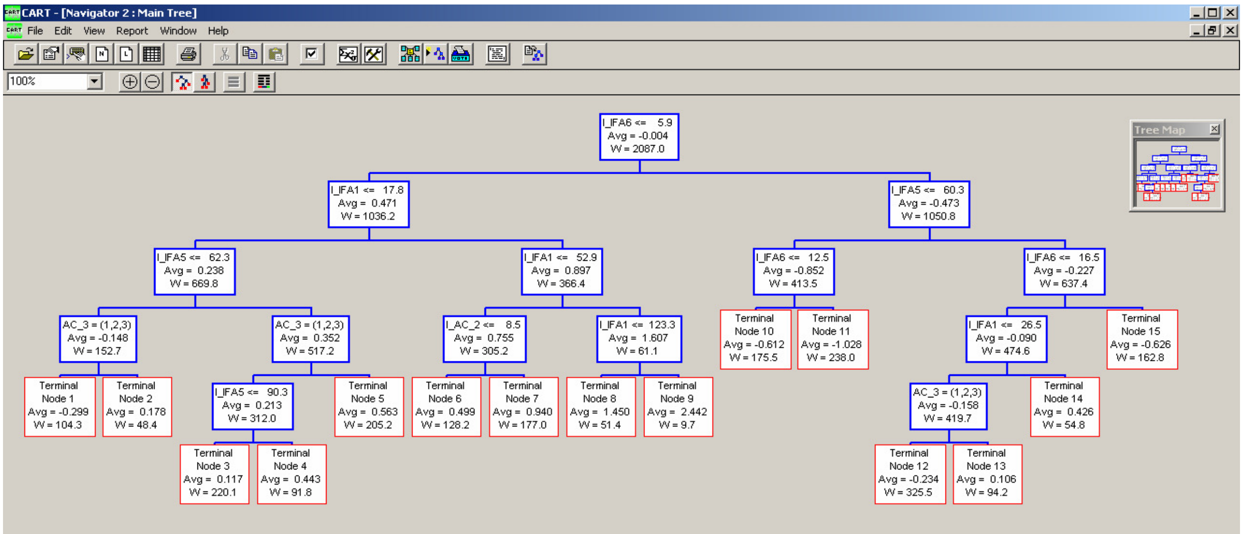


Figure 6: The upper part of the regression tree

The ranking of the variables according to their importance is shown in Table 12, and explains the role of each variable in defining resilience. This ranking takes into consideration main splitters, competitors and surrogates.[28]

[25] Other advantages of using CART are: it is a robust non-parametric tool; it has the capacity to handle complex data structures; it does not require probability density function assumptions; it overtakes heteroskedasticity and multicollinearity; its testing procedures are more accurate; it has the capacity to deal with missing values; and decision rules can be transferred to new observations.

[26] Figure 6 shows the splitting rules, the mean of resilience and the weighted number of observations at each node (terminal nodes are in red).

[27] The cross-validation test takes place over ten sub-samples from the learning sample.

[28] When a variable is considered a competitor, CART finds the best split that reduces node heterogeneity; when the variable is considered a surrogate, it is constrained in mimicking the primary split.

TABLE 12
Variable importance

Code	Description	Importance	Code	Description	Importance
IFA1	Income	100	*SSN4*	Monetary values of first and second types	2.069
IFA3	HFIAS	91.543	*APS3*	Education system	1.854
IFA2	DD	86.325	*SSN2*	Quality of assistance	1.458
AC2	Coping strategies	72.959	*S6*	Assistance dependency	1.450
AC3	Capacity to keep up in the future	65.945	*S9*	Education system stability	1.241
S3E	Employment ratio	53.730	*APS4*	Perception of security	1.210
S2	Educational level	15.162	*S7*	Assistance stability	1.168
SSN5	Evaluation of main assistance	5.315	*APS1*	Physical access to health	1.161
S1W	Professional skills	4.502	*SSN6*	Frequency of assistance	0.917
APS2	Health service quality	3.770	*APS5*	Mobility constraints	0.689
AC1	Diversity of income sources	3.590	*S5*	Income stability	0.623
SSN1	Cash and in-kind assistance	3.304	*SSN7*	Opinion on targeting	0.609
S8	Health stability	2.670	*S4*	No. of household members to lose jobs	0.194
APS7	Water, electricity and telecommunications	2.078	*SSN3*	Employment assistance	0.070

In summary, the main advantage of CART is its capacity to capture variables that are relevant for specific sub-groups of the population, which an ordinary least squares (OLS) estimator does not consider relevant for the whole population.

Moreover, as the approximated R-squared is very high, the decision rules established by the regression tree can be transferred to future applications on the same population to make predictions. The ranking by importance of variables makes it possible to return to the earlier steps of the analysis to build up more parsimonious models and select the most important variables for making predictions. In the next section, a regression model for forecasting resilience is built up.

THE ROLE OF RESILIENCE IN MEASURING VULNERABILITY

In most studies of poverty, vulnerability indicators consider the probability distribution of household consumption as their objective (cf. Dercon, 2001). They consider consumption as a stochastic variable, try to estimate the deterministic part of it through regression models, and then calculate the probability of falling below a certain threshold, usually the poverty line or a proxy for food security. Other theoretical studies consider vulnerability as a function of people's exposure to risks and their resilience to these (FAO, 2004). This section assesses the role of the estimated resilience index in measuring vulnerability. As vulnerability to food insecurity is the issue, the study focuses on food consumption. The following regression model can be built, with food consumption in the logarithmic scale as a dependent variable, and resilience and other household characteristics as independent:

$$LogToTFC = \alpha + \beta_1 R + \beta_2 HSize + \beta_3 MWB + \beta_4 J1 + \beta_5 SWB + \beta_6 GS + \beta_6 Gender + \varepsilon \quad (5)$$

The aim of this is to construct a parsimonious model, from which all the variables previously used to estimate resilience are excluded. Subregions are included in the model through dummies. To avoid collinearity, one of the subregions is left out: North West Bank because it has a medium level of consumption. The household characteristics included in the model are household size (number of household members) and a dummy variable regarding the gender of the household head. The OLS estimates are shown in Table 13.

TABLE 13
Regression model of food consumption

OLS estimates: log total food consumption	Coefficients
Resilience	0.381

	(0.000)**
Household size	-0.084
	(0.000)**
Mid-West Bank (dummy)	0.128
	(0.001)**
East Jerusalem (dummy)	0.465
	(0.000)**
South West Bank (dummy)	0.053
	(0.199)
Gaza Strip (dummy)	-0.327
	(0.000)**
Gender household head (dummy; female = 1)	0.112
	(0.037)*
Constant	2.281
	(0.000)**
Observations	2087
R-squared	0.528

Robust p values in parentheses: * = significant at 5 percent; ** = significant at 1 percent.

Resilience is the most important regressor and the variance explained by the model ($R^2 = 0.528$) is quite satisfactory. The OLS estimator produces consistent estimates and the disturbances are homoskedastic. The Breusch-Pagan test is used to detect heteroskedasticity, and produces an X^2 equal to 0.50 (p-value = 0.48), so the hypothesis of homoskedasticity is accepted. The variance inflation factor (VIF)[29] is used to detect collinearity when individual VIF is greater than 10 or mean VIF is greater than 6. As reported in Table 14, the test shows that there is no multicollinearity in the model.

TABLE 14
Variance inflation factors

Variable	VIF
Mid-West Bank	1.39
South West Bank	1.33
Gaza Strip	1.30
Resilience	1.16
East Jerusalem	1.15
Household size	1.13
Gender household head	1.05
Mean VIF	1.22

The regression model in Table 13 shows the relevance of resilience as a key indicator in food security and vulnerability analysis. A unit increase of the level of resilience implies an increase of 0.381 in the logarithmic scale of total food consumption. The opposite is observed for household size, where a unit increase implies a decrease of 0.084. The coefficient of gender of household head confirms the argument that female-headed households are more food secure. In fact, female-headed households have a food consumption level that is 0.112 logarithmic scale units higher then that of male-headed households. Interpretation of subregional coefficients is more complex. Positive values mean the level of consumption is higher than in the omitted subregion (North West Bank), and negative values mean a lower level of consumption. In fact, East Jerusalem and Mid-West Bank, where conditions are better, have positive values, while Gaza Strip, where conditions are very poor, has a negative value. South West Bank also has a positive coefficient, but it is not statistically significant.

[29] $VIF = (1 - R_k^2)^{-1}$, where R_k^2 = the partial R^2 of the variable k on all other variables in the model.

5. Forecasting resilience

The output of CART shown in Table 12 is very important in identifying the most important variables for defining resilience. The multivariate models applied so far have a major limitation: they always produce normalized indicators with mean zero, so it is difficult to compare the level of resilience over time. To make such comparison feasible, this section presents an OLS regression model, constructed using resilience as a dependent variable and the variables with a CART importance index of more than 15:

$$R = \alpha + \beta_1 IFA1 + \beta_2 IFA2 + \beta_3 IFA3 + \beta_4 AC2 + \beta_5 AC3 + \beta_6 S3 + \beta_7 S2 + \varepsilon \quad (6)$$

The error term represents the negligible information of the variables used to estimate resilience but excluded from the regression model in Equation 6. Changes to the variables on the lefthand side imply changes to the level of resilience. This allows comparison of the resilience level over time.

TABLE 15
Regression model of resilience

OLS estimates: resilience	Coefficients
Income	0.011
	(0.000)*
DD	0.011
	(0.000)*
HFIAS	-0.031
	(0.000)*
Coping strategies	0.029
	(0.000)*
Capacity to keep up in the future (expectation)	0.104
	(0.000)*
Employment ratio	0.382
	(0.000)*
Educational level	0.025
	(0.000)*
Constant	-1.466
	(0.000)*
Observations	2087
R-squared	0.967

* = p-value significant at 1 percent.

Only seven of the 28 original variables are used in the forecasting model, and these variables explain almost 97 percent of the variance (R-squared equal to 0.967). The Breusch-Pagan test produces an X^2 equal to 3.07 (p-value = 0.08), so the null hypothesis (constant variance) is accepted. The variance inflation factors produced are shown in Table 16, where individual VIFs are all very low, so the hypothesis of collinearity is rejected.

TABLE 16
Variance inflation factors

Variable	VIF
HFIAS	1.40
Employment ratio	1.33
Income	1.29

Coping strategies	1.23
Future expectation	1.22
Educational level	1.20
DD	1.17
Mean VIF	1.26

This model also increases understanding of the impact that righthand side variables have on the household's resilience, and is an important instrument for decision-making. Elasticities or semi-elasticities can be studied to identify the most appropriate policy interventions.

Using the regression model in Equation 6, Figure 7 shows predictions of the level of resilience as a function of the number of coping strategies available and the number of different income sources. All the other variables of the models are held equal to their mean. The level of resilience varies from -0.25 for a household with no available income source and coping strategies, to 0.81 for a household with six income sources and 18 coping strategies available. According to the OLS estimates, a one-unit increase in coping strategies implies an increase of 0.029 in the level of resilience.

Figure 8 considers the per capita daily income in NIS, instead of the number of coping strategies available. An increase of ten units in income means an increase of 0.11 in the level of resilience. The level of resilience varies from -0.25 in households with no income, to 1.47 in households with income of 100 NIS/capita/day from six sources.

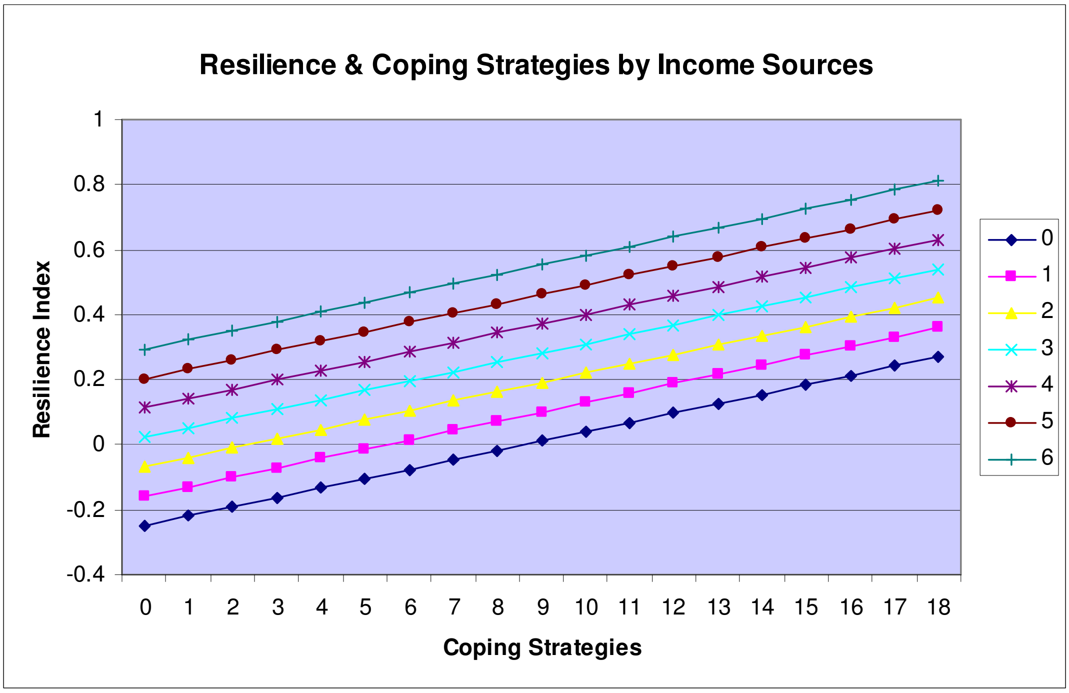


Figure 7: Predictions of resilience level related to coping strategies

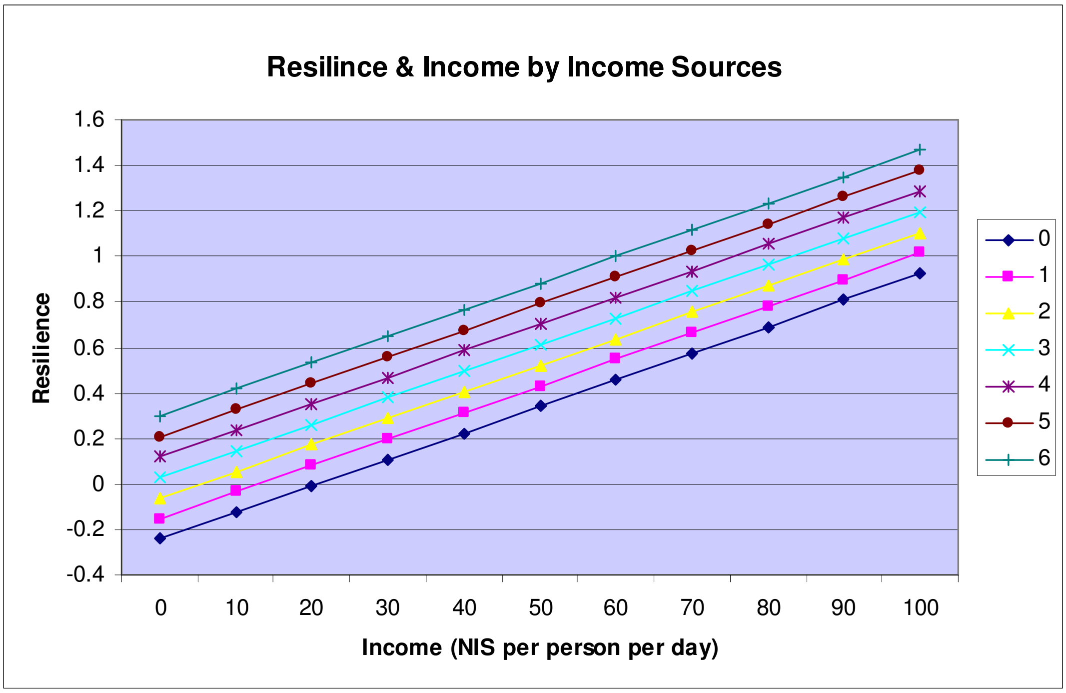


Figure 8: Predictions of the level of resilience related to income

It is clear that both variables affect the level of resilience positively. As the regression model is linear, the slope of the lines (the coefficients) represents the impact of each variable on resilience. To compare the coefficients of two different variables, they must have the same measurement scale, and studying Figure 8 without considering the scale may be misleading.

6. Conclusions and policy implications

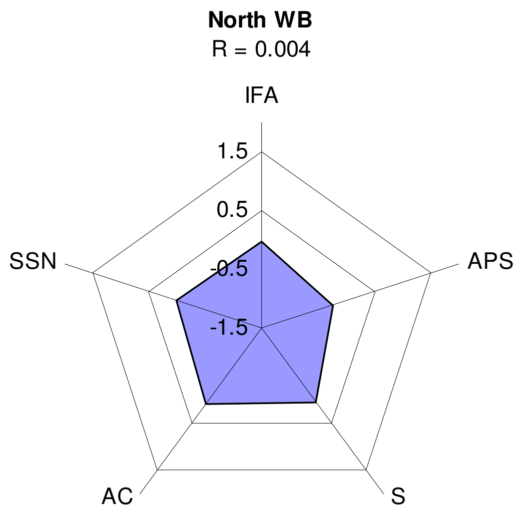
KEY FINDINGS

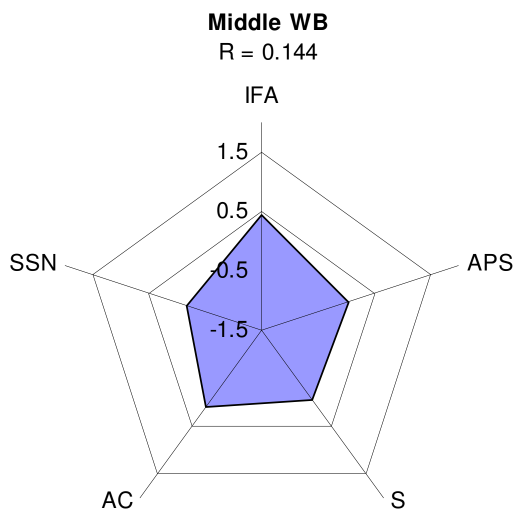
Vulnerability to food insecurity depends on a household's risk exposure and resilience to such risks. Most risks are unpredictable, which makes it difficult to measure vulnerability. This study therefore focuses on household resilience to food insecurity, which is defined as a household's ability to maintain a certain level of well-being (food security) in the face of risks, depending on that household's available options to make a living and its ability to handle risks. The study tests a conceptual framework that was developed for this purpose.

Analysis of the 11th PPPS seems to confirm the validity of the conceptual framework adopted. The results are meaningful and the resilience indices in the five subregions show significant differences, as do the five components of the resilience model. Of particular note is that the overall structure of resilience is very different in each of the five subregions. The analysis shows that while in the richest and more stable area (East Jerusalem), most resilience depends on income and food access capacity, in Gaza Strip most depends on social safety nets (Figure 9).

However, this analysis has limitations owing to the static nature of the available database. Such analyses should be carried out with panel data, as soon as panel databases become available in the future. It would also be interesting to extend the analysis to other case studies to assess the robustness of the proposed analytical framework and any emerging patterns of resilience.

Although the methodology adopted gives significant results, it is necessary to test the alternative methodology proposed in this research – the structural equation models with Bayesian networks – before making a final decision on which is the most appropriate. Further work is also necessary on how to use the resilience index to identify the key determinants needed for designing adequate food insecurity responses and policies, and for strengthening households' economic resilience in crisis situations.





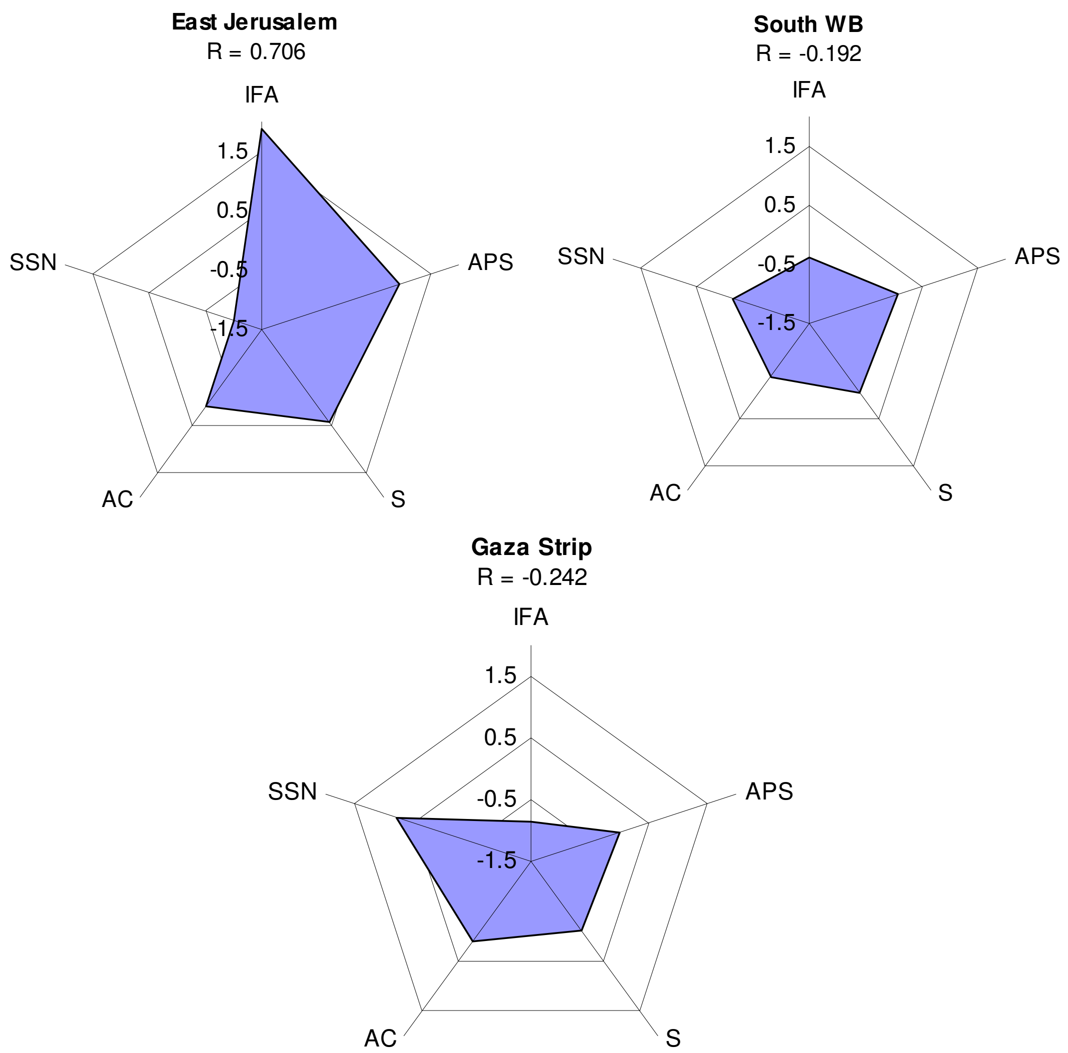


Figure 9: Radars of the components in the five subregions

A NEW APPROACH TO POLICY

The complexity of food systems and the acknowledgement that they must be qualified as stochastic evolutionary systems (as described in the first section of Chapter 1) has profound implications on policy design. These are related to the resilience problem, which implies the existence of threshold effects, irreversibility and uncertainty.

The lack of knowledge about system dynamics and unobserved key structuring process variables, the existence of non-convexities and cross-scale interactions (Brock, Mäler and Perrings, 1999), and the difficulties in measuring the state of the system, administering the control mechanisms and uncovering the true distribution of exogenous shocks all tend to favour more conservative target values for the state variables, that is, a precautionary approach (Ludwig, 1993).

Adopting a precautionary approach means that policy should be oriented to (Perrings, 2000):

- safeguarding the range of options open to future generations by protecting thresholds of resilience in desirable states of nature;
- containing the fundamental uncertainty associated with human activities either by restricting the level of activity to preserve a degree of system predictability or by ensuring that the risks associated with innovative activities/experiments that test the resilience of the system are bounded.[30]

[30] It is worth noting that policies that safeguard future options by protecting thresholds of resilience are at least analogous to the imposition of sustainability constraints.

The fundamental question now is how to design policies to maintain system resilience and avoid flips of the system into undesirable domains. In general, policies that maintain resilience are those that adaptively monitor key variables of the jointly determined system; provide and sustain ecological, economic and cultural diversity; provide and sustain appropriate natural and social capital; and seek integrative understanding. Operationally, this means focusing on keystone structuring processes that cross scales, on sources of renewal and reformation and on multiple sources of capital and skills, keeping in mind that no single mechanism can guarantee, *per se*, the maintenance of resilience.

In conclusion, the adoption of resilience as a criterion for policy design shifts the focus of policies from controlling change in systems assumed to be stable, to managing the capacity of social-ecological systems to cope with, adapt to and shape change. Managing for resilience enhances the likelihood of sustaining development in changing environments where the future is unpredictable and surprises are likely (Levin *et al.*, 1998; Holling, 2001).

RESILIENCE-BASED POLICIES AND THE TWIN-TRACK APPROACH

FAO has recently proposed a conceptual framework – the twin-track approach (TTA) – to address food security and poverty issues and promote agricultural and rural development. Under TTA, pursuing these objectives requires two sets of interventions (Broca, 2002; FAO, 2003):

- interventions aimed at supporting and enhancing the livelihoods of the poorest and most vulnerable groups through sustainable agricultural and rural development (the first track);
- targeted interventions and programmes to enhance immediate and direct access to food and nutrition by the most needy (the second track).

Løvendal and Knowles (FAO, 2005) analysed TTA in terms of key options available for managing risks related to the different dimensions of food security. As shown in Table 17, TTA policies can be grouped according to the different dimensions of food security and to the actions that can be undertaken to address food security risks. The first track addresses mainly the structural, longer-term factors causing vulnerability. and covers most of the options for reducing vulnerability *ex ante* (risk mitigation and prevention). The second track mainly addresses present food insecurity and the short-term factors determining it, and entails *ex-post* policies (risk coping).

TABLE 17
Options for managing food security risks

	Availability	Access	Utilization
Track 1 Improving long-term food security			
Prevention	Stable macro-environment Trade promotion Development of market and storage infrastructure Improvement of input and output markets Natural resource management Increased productivity and production capacity Reduced production variability	Increased productivity of income-generating activities Empowerment of women and other marginalized groups	Promotion of preventive health practices Food safety regulations and institutions Immunization Water and sanitation infrastructure
Mitigation	Improved agricultural extension services Facilitation of diversification Buffering of stocks	Livelihoods diversification Insurance and savings	Provision of health services
Track 2 Addressing immediate food requirements			
Coping	Market facilitation (transport, information) Food aid Food imports	Social safety nets, including cash transfers, food subsidies and work programmes Migration Smoothing of consumption Asset sales	Disease control Immunization Water and sanitation

Availability	Access	Utilization
	Formal/informal credit	
	School feeding	

Source: FAO, 2005.

It is interesting to assess how policies aimed at enhancing the resilience of a food system match TTA policies. As expected, resilience-based policies do not match perfectly with the set of policies envisioned by TTA, which are rooted in standard economic theory and designed to address efficiency and distributive issues. They are therefore not purposely devised to enhance system resilience; they can enhance system efficiency and/or improve income distribution, but in doing so they may make the system more bristle (i.e., less resilient).

Examples of such policies are the provision of agricultural output and input subsidies that give farmers incentives to concentrate on producing a few subsidized products and adopting less sustainable agricultural techniques, which could eventually increase farmers' vulnerability to economic and environmental shocks, thereby decreasing system resilience. The is true of many trade liberalization schemes, which in most least-developed country situations induce a shift of smallholder agriculture production from staple to cash/export crops. This is not bad, *per se*, but lack of access to the institutional infrastructure required to ensure poor farmers against the increased risks implied by globalization (which generally arise owing to widespread poverty, cf. Romano, 2006), qualifies the post-liberalization situation as less resilient than the pre-liberalization situation.

On the other hand, some policies not explicitly listed in TTA are fundamental instruments for building resilience. Examples include the diversification of food system functions, the conservation of biodiversity in critical ecosystem functions, the adoption of flexible options for management, the promotion of cultural and political diversity in social groups, and the creation of a system of social incentives to maintain or restore social capital (e.g., learning, trust building and stakeholder participation).

Although there is no perfect consistency between the two sets of policies, some of the TTA policies have a greater resilience-enhancing effect than others. Contrasting resilience-enhancing policies with the TTA classification, it can be concluded that most policies classified under the first track (sustainable agriculture and rural development) can in principle contribute to enhancing food system resilience. More specifically, these policies include all *ex-ante* instruments of risk management (e.g., livelihood diversification, insurance and savings, extension services) and some *ex-ante* instruments of risk prevention (e.g., developing market storage infrastructure, empowering women and other marginalized groups, promoting preventive health practices).

In contrast, second-track interventions (addressing immediate food requirements) are generally not resilience-enhancing (e.g., food aid, food imports, asset sales), although some can help to restore food system resilience (e.g., school feeding, credit). In conclusion, the field of eligibility for resilience-based interventions seems to be restricted to non-emergency, business-as-usual contexts or to after-crisis rehabilitation interventions. In severe crisis contexts, the priority is not to implement resilience-enhancing policies, but to intervene to save lives (i.e., humanitarian aid). In other words, the time frame matters.

POLICY IMPLICATIONS OF ADOPTING THE RESILIENCE CONCEPT IN WEST BANK AND GAZA STRIP

The findings and conclusions of this analysis provide the necessary elements for identifying key building blocks for adequate policy responses. To operationalize these policy measures effectively, a coordination mechanism will be necessary, to ensure functional contributions from different national and international actors. To alleviate poverty and sustain food security, a twin-track strategy is recommended: strengthening social safety nets to ensure access to food, while attacking the root causes of food insecurity with initiatives to enhance the productive capacity of the Palestinian economy, particularly agriculture and industry, by stimulating food production, increasing employment and reducing poverty.

Regarding the first track, this includes the following interventions:

- Protection of livelihoods and mitigation of poverty can take place through sustainable employment generation schemes, promotion of productive and income-generating activities, micro-enterprises and microfinance, for example. Of particular importance for strengthening resilience is support to small agricultural producers, and measures to ensure own production. Support to industries and the private sector requires close policy dialogue and the commitment of different stakeholders to long-term processes. Support to local food production ensures stable food access and can be used as a coping mechanism to contain the escalation of humanitarian needs and help protect entitlements to land and water resources. In particular, strengthening food production mechanisms should focus on:
  - strengthening and promoting Palestinian production capacity in agriculture sectors with commercial perspectives, such as poultry, vegetables and olive oil;
  - improving technology to increase agricultural productivity within the natural limits of land and water resources, focusing on expanding income opportunities from agriculture by increasing the production and marketing of high-value crops that are also suitable for local consumption (WFP and FAO, 2007).
  - supporting local food production as a source of food for local people (e.g., from the farmer to the poor, complementary high-value food commodities for school feeding).
- Food markets and trade need support to: 1) address traders' vulnerabilities in the areas of credit and the supply chain; and 2) regulate food prices and affordability to protect the purchasing power of the poor. As there is little experience of supporting traders and markets, interventions should be carefully studied in close collaboration with the private sector (WFP and FAO, 2007).

The following interventions will address the second track:

- The provision of temporary employment (income support) to the unemployed, and cash assistance to enhance households' capacity to cope with shocks and stresses tends to have a positive spin-off effect on local economies, especially if aimed at creating productive assets. Job creation schemes can address different non-mutually exclusive requirements:
  - development and maintenance of infrastructure including roads, water schemes, water sanitation and other civil infrastructure, thus preventing degradation and maintaining minimum acceptable standards at towns and camps;
  - investment in the productive asset base, particularly land and water conservation and management, to prevent degradation of the physical environment (WFP and FAO, 2007).
- Social welfare/protection schemes for the socially marginal and poorest of the poor prevent these groups from falling into destitution and offer younger generations opportunities for education and jobs. Schemes of this type are normally implemented by government organizations (e.g., the Ministry of Social Affairs) and non-governmental actors (religious and secular charities and NGOs). These schemes aim at:
  - direct income transfers (cash assistance, food aid);
  - vocational training;
  - promotion of income-generating activities.

  Assistance should be based on the household's current stability of access to the minimum required consumption and its capacity to adapt to new shocks. The diverse range of eligibility and targeting criteria utilized by key actors need to be reviewed with a view to ensuring social equity (WFP and FAO, 2007) and reaching the poorest of the poor.
- Food aid interventions should include:
  - protection of the food consumption/nutrition levels of very poor households;
  - response to acute food shortages (e.g., in situations of blockades and armed conflict) through contingency planning (WFP and FAO, 2007);
  - creation of productive assets (food for work) and protection of the livelihoods assets base;
  - support for education where alternative measure are not available, such as school feeding and vocational/literacy training (food for training).
- Ideally the integration of policy instruments should involve integrating both supply- and demand-side instruments of food security, as well as the anti-hunger measures foreseen in poverty reduction strategies. Integration of these different policy measures would allow the design of a

coherent and integrated food security strategy. Such an approach requires revision of current institutional mechanisms. The Ministry of Agriculture is in charge of domestic agricultural production, nutrition is located in the Ministry of Health, and employment schemes and food for work are managed by the Ministry of Labour or the Ministry of Public Works. To coordinate the food security activities of all these agencies, an adequate institutional mechanism should be established under the prime minister's or president's office, to provide a common platform, possibly with decision-making mechanisms.

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