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MEASURING CAPABILITY DEPRIVATION. MULTIDIMENSIONAL METRICS FOR FOOD SECURITY AND CHILDHOOD POVERTY

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List of Acronyms

AF	Alkire-Foster
CA	Capability Approach
CFA	Confirmatory Factor Analysis
CFS	Committee on World Food Security
DES	Dietary Energy Supply
ECD	Early Child Development
EFA	Exploratory Factor Analysis
FAO	Food and Agriculture Organization of the United Nations
FBS	Food Balance Sheets
FGT	Foster Greer Thorbecke
GDP	Gross Domestic Product
GHI	Global Hunger Index
HDI	Human Development Index
HFIAS	Household Food Insecurity Access Scale
HIV	Human Immunodeficiency Virus
HPI	Human Poverty Index
IFPRI	Institute for Food Policy Research
ILO	International Labor Organization
IPC	Integrated Food Security Phase Classification
MCA	Multiple Correspondence Analysis
MDGs	Millennium Development Goals
MIMIC	Multiple Indicators and Multiple Causes
PCA	Principal Component Analysis
POU	Prevalence of Undernourishment
PPP	Purchasing Power Parity
OECD	Organization for Economic Co-Operation and Development
SEM	Structural Equation Models
UN	United Nations
UNDP	United Nations Development Programme
UNICEF	United Nations International Children's Emergency Fund
WFS	World Food Summit
WHO	World Health Organization

Ai miei genitori

Introduction

> *"We will spare no effort to free our fellow men, women and children from the abject and dehumanizing conditions of extreme poverty, to which more than a billion of them are currently subjected. We are committed to making the right to development a reality for everyone and to freeing the entire human race from want" (*UN 2000*).*

In 2000, the United Nations committed to the Millennium Declaration (UN 2000), a global partnership to eradicate poverty and foster development. These broad objectives were incorporated in eight time-bound targets, with a deadline of 2015, which have become known as the Millennium Development Goals (MDGs). Through the Millennium Declaration, the international community committed to address the multiple deprivations faced by the world's worst-off and, at the same time, explicitly recognised the multidimensionality of the concept of development.

The first MDG focuses on poverty and hunger, with the aim:

> "*To halve, by the year 2015, the proportion of world's people whose income is less than one dollar a day and the proportion of people who suffer from hunge*r" (United Nations, 2001, p. 19).

In a world of plenty, members of the United Nations considered the persistency of extreme poverty and food insecurity as an unacceptable circumstance, and for this reason, their reduction was included as first goal in the strategy to promote global development in the new Millennium. Despite the broad agreement on the overall objective, however, the dispute on how to measure poverty and food insecurity is, as of yet, as pervasive and impassioned than ever[1]. Implicitly, such a stark disagreement emphasises the fundamental role that evaluative assessments play in policy-making, from design and formulation to monitoring and evaluation (Ravallion 1992, 1996; Alkire & Santos 2009). As recently declared by Prof. Cheung, director of the United Nations Statistics Division, in the context of the post-MDG debate:

[1] In the field of poverty, among the many contributions see: Alkire & Foster (2011a), Ravallion (2010, 2011); Wisor (2011); Reddy & Pogge (2010); Deaton (2010). For food security: Barrett (2010); Cafiero & Gennari (2011); Massett (2011); De Haen et al. (2011); CFS (2011).

> *"It is clear that without solid information we cannot measure where we are and what needs to be done, with respect to the MDGs or in other domains. If the world cannot get the right numbers, it cannot come with the right solutions." (Paul Cheung)*[2]

Ultimately, the core of the measurement debate revolves around the choice of an appropriate informational basis for assessments of well-being. The selection of the space of analysis is a fundamental stage in any evaluative exercise, as this choice will inevitably affect each of the steps required for the assessment itself, its outcomes, and the resulting policy analysis and prescriptions.

In this respect, the two key indicators that measure progress on the target set by the MDG1, the World Bank's $1 dollar a day headcount and FAO Prevalence of Undernourishment, implicitly adopt a resource-based view in the conceptualisation of poverty and food insecurity, which links achieved well-being levels to consumption or income, on the one hand, and to available calories (and their distribution) on the other. Although resources-based metrics represent the standard method to measure deprivations of human well-being in the realm of economics since the pioneer studies of Boots and Rowntree, scholars and international organizations alike have been increasingly questioning whether resources can satisfactorily capture the complexity of human well-being and of its deprivations[3].

Being grounded in Sen's Capability Approach (CA), the present research starts its investigation from the premise that resources such as income or calories are inadequate spaces for the capturing the "*constitutive plurality of welfare assessments*" (Sen 1993). This is not to say that resources, such as income, are not important at all: on the contrary, Sen clearly acknowledges their relevance to poverty, "*including starvations and famines*" (Sen 1999a, p. 72). However, the study of available commodities merely represents a useful starting point for well-being evaluations because the command over resources is not sufficient to ensure well-being outcomes to occur (Sen 1999a). This is due to a multiplicity of individual as well as social and environmental factors, which influence the conversion of available resources into

[2] Interview to "United Nations Department of Economic and Social Affairs News", Vol. 16(2), February 2012.

[3] A few examples are: Galbraith (1958); ILO (1976); Rawls (1971); Chambers (1983); Sen 1985, 1987, 1992, 1993, 1999a); ul Haq (1996, 2003); OECD (2001); UNDP 1990, 1994; 1997; 2010); Stiglitz *et al.* (2009).

actual well-being outcomes. Sen suggests that, when such "*parametric variation*" is explicitly acknowledged, the informational basis for the measurement of well-being should shift from the analysis of commodities to the direct assessment of *functionings or capabilities.* While the former are the "*actual being and doings*" of an individual, capabilities reflect her real opportunity freedom to achieve alternative combinations of functionings that she has reason to value (Sen 1985, p. 25). In the CA framework, human well-being is best seen *"as an index of the person's functionings*" (*ibidem*). Also, by focusing on people's achievements, the ultimate meaning of development also changes, shifting from resources accumulation to the expansion of people's real freedoms "to *lead the lives they value – and have reason to value"* (Sen 1999a, p. xii). It is immediately clear that, following the shift in focus from resources to achieved functionings, the assessments of well-being and of its deprivations must necessarily be multidimensional, as no single metrics can alone capture the complexity of those concepts. This feature suits well the analysis of poverty, which is now widely recognised by scholars, international organisations and, most importantly, by the poor themselves as multidimensional[4]:

> *"Poverty is hunger. Poverty is lack of shelter. Poverty is being sick and not being able to see a doctor. Poverty is not having access to school and not knowing how to read. Poverty is not having a job, is fear for the future, living one day at a time. Poverty is losing a child to illness brought about by unclean water. Poverty is powerlessness, lack of representation and freedom*" (Narayan et al. 2000a).

By the same token, the multidimensionality stemming from the adoption of the CA also suits well assessments of food security, which, according to the 1996 World Food Summit (WFS) definition:

> *"A situation in which all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life"* (WFS 1996),

is a multifaceted concept characterised by the four pillars of food availability, access, utilisation and stability (WFS 1996; Barrett 2010; CFS 2011).

[4] For instance see: UNDP (1997); World Bank (2000); Narayan et al. (2000a, 2000b); UN (2000); Kakwani & Silber (2007); Comim et al. (2008).

Despite the strong theoretical advancement that the conceptualisation of food insecurity and poverty provided by the adoption of the CA, some theoretical, methodological and empirical questions inevitably arise. These are particularly marked in the measurement of both phenomena, especially in the light that Sen has never provided specific guidelines on how to operationalize the approach for evaluative purposes[5]. As such, one of the recurrent themes of the present work is *how to deal with the complexity* that the adoption of the CA as relevant conceptual skeleton for well-being evaluations implies.

By acknowledging both the advantages and difficulties embedded in any operationalisation of the approach, the starting point of the present research is to ask whether the adoption of the CA as overarching theoretical framework for the analysis and measurement of food insecurity and poverty is able to contribute to a better understanding of both phenomena, and hence to offer better inputs for policy. In other words, we ask if are there theoretical, methodological and empirical advantages in adopting the CA as theoretical framework for the analysis of these two deprivations of human well-being.

In order to answer to this question, the Thesis is structured in three main Parts: while Part A provides the conceptual and methodological framework for rest of the dissertation, Parts B and C respectively focus on the analysis of food security and childhood poverty. In particular, Part A is structured in two main chapters, which, respectively, address the three basic steps that are required in any evaluation of deprivations: the choice of the space of the analysis on the one hand, and of the identification and aggregation steps on the other. Chapter 1 critically reviews advantages and drawbacks of the adoption of resources-based *viz.* capability-based informational bases in the assessment of human well-being. Then, Chapter 2 reviews the literature on the measurement of multidimensional phenomena. Its original contribution lies in systematically reviewing the large body of empirical literature that has been developed in the last two decades in order to capture the multidimensionality of well-being and its deprivations. The aims of this chapter is to provide a survey of the most recent advancements in the measurement of multidimensional phenomena

[5] The undoubted difficulties in providing metrics that could capture the complexity of well-being on the one hand, and being usable on the other (Sen 1987) led some scholars to reject the CA *tout court* in favour of resources-based metrics (Sudgen 1993; Ysander 1993; Srinivasan 1994; Roemer 1996).

and to provide an accessible, yet rigorous, entry point for all the scholars or practitioners interested in the topic.

Part B of the dissertation focuses on the measurement of food security. Chapter 3 provides the conceptual framework for the following chapters: in doing so, it first explores in depth the concept of food security, then it proposes an original analytical framework grounded in the CA to food security analysis and, finally, it proposes an operational definition of food security that will serve as basis for measurement. In turn, Chapter 4 reviews the way in which food security is measured at the country level, which is the unit of analysis of the assessments contained in Chapters 5 and 6. These two address the measurement of multidimensional phenomena from two distinct perspectives: on the one hand, Chapter 5 presents a suite of indicators to monitor food security at the country level, while Chapter 6 a multidimensional measure based on the latent variable methodology. The reason underlying the use of these two distinct aggregation strategies is that they appear as complementary in providing an overall picture of countries' food security, rather than in opposition as often argued in the literature on multidimensional measurement [6] (OECD-JRC 2008). In particular, Chapter 5 presents an original methodology to select indicators in multidimensional assessments and in turn applies it to the choice of a suite of indicators of food security, while Chapter 6 builds on the theoretical and methodological insights presented in the previous chapters to measure food security through a Structural Equation Model (SEM) (Jöresdog 1973; Jöresdog & Goldberger 1975). In this framework, a countries' "capability to be food secure" is seen as a latent variable that is manifested in a vector of measurement economic, social, and institutional factors.

Finally, Part C of the dissertation is concerned with the measurement of multidimensional childhood poverty and the modelling of its medium-term effects by using data from Young Lives, an innovative longitudinal study on childhood poverty in Ethiopia, India (Andhra Pradesh), Peru and Vietnam. By grounding the analysis in

[6] On the ever-ending dispute over the use of composite measures *viz.* suites of indicators, Sharpe (2004, quoted in OECD-JRC 2008, p. 14) noted: *"The aggregators believe there are two major reasons that there is value in combining indicators in some manner to produce a bottom line. They believe that such a summary statistic can indeed capture reality and is meaningful, and that stressing the bottom line is extremely useful in garnering media interest and hence the attention of policy makers. The second school, the non-aggregators, believe one should stop once an appropriate set of indicators has been created and not go the further step of producing a composite index. Their key objection to aggregation is what they see as the arbitrary nature of the weighting process by which the variables are combined".*

the CA, the Chapter attempts for the first time to bridge the gap between the literatures on the measurement of children's multidimensional poverty and the one on Early Child Development (ECD), which scrutinises the effects of deprivations experienced *in utero* and in the first three years on later achievements. The Chapter empirically addresses the critical question of whether the experience of multiple deprivations is dynamically associated to worse cognitive attainments at different development stages (i.e. the preschool and primary school years). In doing so, it takes a step beyond the measurement of multidimensional poverty by scrutinising its potential effects on children's cognitive development in various domains (i.e. vocabulary, logic, Maths, reading) at age 5 and 8. Also, it asks whether the interaction across multiple dimensions of deprivations is dynamically complementary in leading to worst cognitive attainments.

The analysis included in this work shows that the adoption of the CA for assessments of poverty and food insecurity has many implications on theoretical, methodological and empirical levels. On a theoretical basis, the conceptualisation of both phenomena as deprivations of critical capabilities sheds new light on their meaning and on the role they assume in the field of international development. From a capability perspective, poverty is conceptualised as the substantive unfreedom of escaping hunger, avoidable diseases, premature mortality, homelessness, ignorance, or, more generally, of being able to lead the kind of life one has reasons to value (Sen 1980; Foster & Sen 1997; Sen 1999a, 2009; Drèze & Sen 1989). Analogously, food insecurity, a critical constituent of poverty (UNDP 2012, Burchi & De Muro 2012a), relates to the substantive unfreedom to reach one of the most basic needs of human beings: the adequate and stable nourishment for an active and healthy life. In the light of the CA, poverty and food insecurity are the worst forms of coercion conceivable. As such, if the ultimate end of development relates to the removal of the substantive unfreedoms that constrain the flourishing of human beings, the reduction of poverty and food insecurity is definitely a key priority in the development agenda, as also pointed out by the MDG framework.

In the CA, capabilities are interconnected and mutually reinforcing. This characteristics is immediately evident in the analysis of the relationship between poverty and food insecurity: on the one hand, poverty, understood not only as lack of income, but also as of basic health and care facilities, education, access to water and sanitation, or voice in face of governments, is a critical determinant of food insecurity[7] (Drèze & Sen 1989; Burchi & De Muro 2012a; UNDP 2012). By the same token, food insecurity causes capability poverty in various ways (i.e. by undermining health, education, employment *etc*.), and this link can last for generations (UNDP 2012). The empirical analysis of Chapters 6 and 7 shows such interconnectedness very well. Chapter 6 simultaneously estimates the latent "capability to be food secure" and models its main covariates for a sample of low and middle-income countries. Coherently with the CA framework, the empirical results show that countries' food security is strongly and significantly associated to their levels in three critical capabilities: health, female education and income poverty. By the same token, Chapter 7 estimates the dynamic association between children's multidimensional poverty in the early years and later cognitive achievements in Ethiopia, India (Andhra Pradesh), Peru and Vietnam. The estimates not only show that early childhood poverty matters in children's later cognitive development, but also that other capabilities related to the children themselves, their care-givers and households reinforce the effect of early deprivation and amplify it over children's life-course. This evidence underlines that a truly multidimensional approach to the analysis of childhood poverty and its dynamic repercussions is needed.

Indeed, as discussed earlier, the adoption of the informational space of functionings and capabilities implies that the evaluative exercise needs to be multidimensional. The results of our empirical analyses show that a multidimensional approach to measurement is able to seize more effectively the complex nature of food insecurity and childhood poverty than single indicators. In the case of the former, the empirical evidence of Chapter 6 shows that the estimated multidimensional measure is able to capture cross-country variation in food security outcomes more effectively than unidimensional metrics, such as the one proposed in the realm of MDG1. The analysis of Chapter 7 points to similar conclusions. Controlling for a large number of child, caregiver and household characteristics, as well as children's lagged cognitive tests scores, the adoption of a multidimensional approach to the measurement of early childhood poverty in the health and nutrition dimensions enriches the standard model

[7] As it will be discussed thoroughly in Chapter 3.

of child development[8] by increasing the predictive power of the model itself. In this way, the analysis also contributes to the ECD literature by incorporating for the first time the multidimensionality of the health dimension (Glewwe & Miguel 2008; Strauss & Thomas 2008) in a model of children's cognitive development in a developing country setting. As in the case of food security, the multidimensionality of poverty was dealt through the use of a suite of indicators and of a multidimensional measure of early poverty. Both aggregation strategies were tested in the econometric model and, in terms of model fit, the "suite of indicators" approach is able to explain more variation in medium-term cognitive outcomes than the alternative specification in which the multidimensional index is included. Also, in such a regression setup, the suite of indicators approach appears to be more valuable as it provides detailed information on which dimensions of early deprivations are persistently associated to medium-term cognitive achievements, and in which contexts and different stages of childhood such association exists.

This last point leads us to another characteristics of the CA that renders it advantageous in assessments of well-being: its context-specificity. The empirical analyses contained in this Thesis show that country-specific institutional, social and environmental characteristics are fundamental factors in the determination of well-being outcomes. Sen refers to these elements as 'instrumental freedoms' (Sen 1999), and they represent the "enabling environment" that allows for the determination of the capabilities. One example is the great heterogeneity that the empirical estimates show in the link between early deprivation and later cognitive achievements across the four study countries. For instance, while in Peru the model explains between one third and half of the cognitive achievements at age 8, in Vietnam the model seems to work much worse. This may be explained by the way in which the educational systems in the two countries are organised: in particular, the high inequalities of the Peruvian educational system seems to amplify early childhood poverty, instead of mitigating it through the provision of quality education.

The results of the structural part of the model for estimating food security also showed that a variety of country-specific factors are strongly and significantly associated to

[8] In the ECD literature that focuses on developing countries, health is commonly measured through height-for-age scores, which measure chronic malnutrition, probably due to scarce data availability on other dimensions of health.

food security levels. In turn, these also influence the conversion of available resources (i.e. caloric levels and food entitlements) into actual food security outcomes, for which great heterogeneity exists across countries characterised by equal levels of resources (Chapter 6). While this empirical result suggests to embrace the CA's focus on actual well-being outcomes, the Thesis also shows that the emphasis on achievements has also relevant methodological implications to select indicators. This criterion proved to be particularly useful to discriminate among the hundreds of food security indicators available in the literature. Over the last two decades, scholars and international organizations alike have proposed very long suites of indicators with the aim of capturing the multidimensionality of food security. However, these lists, by assembling tens, in not hundreds, of indicators triggered confusion on the magnitude, trends and nature of the phenomenon (CFS 2011). In order to address this problem, the fifth chapter of the Thesis builds on the clear conceptual distinction between "means" and "ends" of development of the CA and provides a methodology to select indicators for measuring multidimensional phenomena. As of yet, this methodology is at the basis of the suite of indicators for food security launched by the Food and Agricultural Organization of the United Nations (FAO) in October 2012 (FAO 2012). Finally, the discrimination between inputs and outcomes was also useful in order to select the measurement indicators for the empirical analyses of Chapters 6 and 7, and to address one of the key drawbacks of available multidimensional indicators: their failure to distinguish between "means" and "ends" of human development (OECD-JRC 2008; Burchi & De Muro 2011b). Also, by grounding the evaluative exercise in the sound theoretical background of the approach, the metrics proposed in this Thesis attempted to avoid the typical problem of "measuring without theory" (Koopmans 1947).

From this short excursus, it seems that the CA is able to provide theoretical, methodological and empirical advantages for the measurement of poverty and food insecurity, which in turn provide a better understanding of these phenomena for better policy-making. Indeed, the ultimate goal is not "to measure, but to *reduce* poverty" (Alkire & Santos 2009).

Part A – Conceptual Framework

Chapter 1

Measuring Deprivations of Human Well-Being: Choice of the Space of Analysis

1.1. Introduction

Even if the enhancement of human well-being and the eradication of its deprivations lies at the centre of the development agenda[9], very little agreement has been reached among policy-makers, practitioners, and academics on what human well-being means. This question is certainly not new neither in the history of philosophical thought, as it can be traced back to Aristotle, the Buddha or to some Sanskrit writings of 8th Century b. C., or in economic theory from Adam Smith onwards. Differences in conceptualisations of well-being partly reflect the richness and complexity[10] of the idea; at the same time, they also echo ethical differences on what constitutes a good society and a good life, and, ultimately, on which the fundamental ends of development are (Ruggeri Laderchi *et al.* 2003; Sen 1999a). In this respect, the critical issue at stake is how to deal with the complexity of human well-being, while, at the same time, to provide usable information for policy-making (Sen 1987; Chiappero Martinetti 2008).

Over time, different approaches have been proposed in the economic literature, ranging from highly simplified frameworks to others that aim at explicitly recognising such complexity through substantial and multidimensional views of well-being (Chiappero-Martinetti 2008). The same issues apply to the conceptualisation of two

[9] As noted by Gough *et al.* (2007, pp. 3-4): *"Well-being is far from an irrelevant concept in the study of international development (...). As its broadest and most utopian, the objective of international development could be described as the creation of conditions where all the people in the world are able to achieve well-being. Thus, the purpose of development policies and the raison d'être of governments and the agencies that generate and implement the specific policies and programmes, is to work to establish those preconditions in different societies".*

[10] Chiappero Martinetti (2008, pp. 270-271) refers to complexity as "*(...) to describe multifaceted, multidimensional concepts consisting of many interrelated elements and patterns for which, generally speaking, the whole cannot be fully understood by separately analyzing its components. From this point of view, what determines complexity is not only the existence of many parts and how they are related or connected to one another but also the necessity of considering them jointly".*

key deprivations of human well-being, poverty and food insecurity. The latter concepts can be either boiled down to mere lack of income or calories (Deaton 1997; Smith et al. 2006), or, if their intrinsic complexity is fully acknowledged, as highly multi-faceted phenomena (UNDP 1997; World Bank 2000; Narayan et al. 2000a, 2000b; UN 2000; Kakwani & Silber 2007; Comim et al. 2008; WFS 1996; Barrett 2010; CFS 2011). Ultimately, the core of this question lies in the choice of the relevant space for the assessment of human well-being and of its deprivations (Sen 1999a). The selection of the informational basis is a fundamental and prior step for any evaluative exercise, as the outcomes of such assessment and the resulting policy prescriptions will critically depend on the way well-being, poverty, or food insecurity are conceptualized. As the choice of the informational basis for conceptualising well-being, poverty and food insecurity is not value-free, there is no unique or "objective" way to define those phenomena, and each different conceptualisation necessarily entails arbitrariness and differences in the results of the assessment (Ruggeri Laderchi *et al.* 2003). For instance, in the case of poverty measurement, the choice of the space of the analysis, ranging from the unidimensional one of consumption to the multi-faceted ones of capabilities and functionings, entails a series of subsequent choices on the use of indicators for measurement, which in turn can lead to the identification of different individuals and groups as poor and urge distinct policy responses for the reduction of poverty reduction (Ruggeri Laderchi *et al.* 2003).

It is hence of fundamental importance to understand the meaning and implications of these choices in the context of well-being assessments. This is the main objective of this Chapter, which represents the theoretical core of the present dissertation. In particular, the two main approaches to the conceptualisation of well-being and the lack of it, the resources-based and the CA (Wisor 2011), will be presented, together with what their adoption entails when it translates into different evaluations of poverty and food insecurity.

This Chapter proceeds in the following way: Sections 1.2 and 1.3 respectively present the resources-based and the capability approaches. In turn, Section 1.4 discusses the main challenges involved in the operationalisations of the CA, while Section 1.5 discusses the theoretical and methodological implications of the adoption of the CA as theoretical framework for the analysis of poverty and food insecurity. Finally, Section 1.5 concludes.

1.2. The Resource-Based Approach

Before presenting this theoretical framework, a more extensive discussion of the term "resourcist" is in order, as it will be recurrent in the thesis. In the context of poverty measurement, the literature usually refers to "monetary" approaches, which focus on the unidimensional metrics of income, consumption or wealth as a proxy for human well-being. Nonetheless, as our focus also encompasses the conceptualisation of food insecurity, we use the terms "resource-based" or "resourcist" approaches to denote those frameworks that conceptualise food security outcomes as the result of the availability of food or calories (i.e. Smith et al. 2008; Ecker and Qaim, 2011). As it will be thoroughly discussed below, the two approaches are theoretically equivalent, as they both assume that the availability of a given resource (i.e. income, consumption, or food) is a sufficient condition to ensure a given well-being outcome to occur (i.e. the absence of poverty or of food insecurity), and as they share the same methodological apparatus.

Notwithstanding the many communalities of the measurement of food security and poverty based on evaluation of resources, this Chapter will only focus on the monetary approach for the measurement of poverty for two main reasons: first, in order to enhance the simplicity of the exposition; secondly, and most importantly, because the different methodologies to measure food security will be reviewed in depth in Chapter 4[11] . Beyond technicalities, this section aims at critically unveiling the assumptions that are embedded in all the approaches that consider resources as a satisfactory measure of human well-being. As such, the considerations exposed below are equally applicable in the case of the assessments of food insecurity based on calories.

1.2.1. Monetary poverty: the undefined yet measurable thing[12]

As mentioned earlier, over the years economists have provided a range of insights about the criteria and domains that are most critical for the measurement of well-being and of its deprivations, and on the relation between well-being and measures of

[11] In particular, Sections 3.1 and 3.2 include a technical discussion of the resources-based approach in the domain of food security evaluations.

[12] Ruggeri Laderchi (2000).

economic resources (Boarini *et al.* 2006). Sen (1984) traced this investigation back at the roots of the political economy, where the classics - Smith, Ricardo, Marx, and J.S. Mill - interpreted 'welfare' as the result of individual command over bundles of goods and services. Although the following marginalist[13] thinkers, such as Pigou and Hicks, incorporated such a resources-based view, in the first, neoclassical formulation the relation between welfare and resources ceased to be direct as in the classics but mediated through the use of a utility function (Hicks 1939). This element is clearly evident in the following extract by Pigou:

> *"(...) it is fair to suppose that most commodities, especially those of wide consumption that are required, as articles of food and clothing are, for direct personal use, will be wanted as a means to satisfaction, and will, consequently be desired with intensities proportional to the satisfactions they are expected to yield" (Pigou 1920, quoted in Sen 1984, p. 290).*

In later formulations, marginalist theory abandoned the ambition to make interpersonal comparisons of utility, and the utility function is merely used to map individual preferences over bundles of resources (Mas-Colell et al. 1995; Sen 1999a). Despite this theoretical shift, from Hicks onwards the neoclassical approach is the 'gold standard' to economic analyses of well-being and its deprivations (Ravallion 1992, 1994, 1996; Lipton & Ravallion 1995; Deaton 1997). It is nonetheless interesting to notice that, under the general tag of monetary poverty – the "*undefined, yet measurable thing*" (Ruggeri Laderchi 2007, p. 37) – a broad spectrum of different theoretical constructs exists. The peculiarity of the 'monetary approach' to poverty measurement as an analytical category is that very different theoretical constructs might underlie similar measurement practices. Nonetheless, a mix of revealed preference theory, nutrition sciences and money-metrics acts as minimum common denominator of the empirical works rooted in this theoretical framework (Kanbur & Shaffer 2007). Revealed preference theory postulates that, given a budget constraint, the observation of consumers' choices over bundles of goods and services reflects the

[13] In the rest of the discussion, the terms "marginalist" and "neoclassical" will be used indifferently.

maximization of their preferences (Mas-Colell et al. 1995). Under a set of stringent assumptions (complete markets, no public goods and absence of economies of scale), revealed preference theory assumes that individual preferences, *a priori* unknowledgeable, can be inferred by the observed demand of maximising consumers. The resulting welfare function is the link between consumption to market prices, incomes, household size and demography, and any other relevant variables that can influence tastes[14] (Samuelson 1938; Ravallion 1992). The second building block of the approach is nutritional science, which is used to distinguish between "basic" and "non basic" preferences, where the former define the poverty line, i.e. the minimum threshold for dichotomising the poor from the non-poor[15]. Finally, a measure of welfare is derived by total consumption enjoyed, which in turn can be proxied mainly by either income or expenditure data[16], or in absence of those, wealth (i.e. Filmer & Pritchett 2001). Total consumption reflects the marginal utility through which the maximizing agent evaluates different bundles of commodities. This evaluation is done, when they are available, at market prices. For this reason, the monetary approach is intrinsically uni-dimensional, as it either tracks only one dimension of deprivation or it measures multiple dimensions of deprivations by reducing them to same metrics, the one of income or consumption ("*money metric*").

1.2.2. Why is the monetary approach appealing for the measurement of well-being?

The principal appeal of the monetary approach lies in its compatibility with the principle of preference maximization that underpins the whole edifice of microeconomics (Hicks 1939; Mas-Colell *et al.* 1995) and of the most recent formulations of macroeconomics (e.g. Wickens 2008). In this view, poverty is defined as a shortfall in consumption below a minimum threshold, which in turn reflects a

[14] On the other hand, Ravallion (1992, p. 16) also recognised that "*the basic problem to be aware of is that a given set of revealed preferences over goods may be consistent with infinitely many reasonable ways of making inter-personal welfare comparisons; it is a big step to assume that a particular utility function which supports observed behaviour as an optimum is also the one which should be used in measuring well-being. For example, I would be surprised if the extra satisfaction that parents derive from a new baby is fully evident in their consumption behaviour*".

[15] For further discussion on the identification of the poor, see Chapter 2.

[16] In this regards, Deaton (1997) suggests that expenditure data are more reliable to measure consumption.

non-fulfilment of basic preferences (Kanbur & Shaffer 2007). The aggregation of individual or households under the poverty lines, and comparisons of welfare levels across persons and households, is made possible by the adoption of the unifying money metrics. As Kanbur & Schaffer (2007) effectively pointed out:

> *"In the consumption poverty approach, ''utility'' is the chosen dimension of well-being. It is equated with preference fulfilment and rendered observable by restricting preferences to consumer preferences revealed by choice (recorded in consumption modules in household surveys). These are subsequently transformed into consumption expenditure, or money. This process facilitates ''subject invariance'' in that any two ''competent'' persons should be able to rank individuals in the same way once this money metric criterion has been adopted. Money becomes a representation of well-being or poverty, which subsequently facilitates the aggregation of those below the poverty line as well as consistent interpersonal comparisons of well-being. The key point is that the well-being metric itself, utility, is transformed into an intersubjectively observable datum, revealed preferences, to which an ''empirical'' scale, money, is applied" (p. 5).*
>
> *The reduction of the complexity of well-being into a single, unifying, metrics – the one of money – is the key element of success of the monetary approach. On the one hand, such a unidimensional conceptualisation "reflects the apparent homogeneity of current mainstream practices, and the underlying tension between theoretical complexity and diversity" (Ruggeri Laderchi 2007, p. 37). On the other, money metrics has been widely adopted for the apparent "simplicity of adopting standards measurement practices on the other" (ibidem).*

Boasting the title of being objective, external, and individualistic, the monetary approach has been appealing the economic profession since the pioneer contributions of Boots and Rowntree[17] at the beginning of the XX century (Ruggeri Laderchi et al. 2003). By rooting its constituent elements on intersubjectively observable data (Kanbur & Shaffer 2007), the monetary framework aims at being objective in the sense it provides (apparently) value-free snapshots of reality (Ruggeri Laderchi et al. 2003). Boots and Rowntree's contributions attempted to create a scientific and orderly method for identifying the poor (Ruggeri Laderchi 2000), and this overall purposes has been pursued through the explicit inclusion of nutrition science and revealed preference theory, which respectively set a minimum level of caloric content and to make preferences observable. In this way,

> *"(...) the derivation of the poverty line, the interpersonal comparisons of well-being and the revelation of preferences are all conducted in intersubjectively observable fashion" (Kanbur & Shaffer 2007, p. 186).*

Secondly, the method is considered to be "external" because professionals, and not the poor themselves, are in charge of poverty evaluations; finally, it is inherently individualistic, since poverty is defined with respect to individual circumstances and behaviour and not as the ultimate outcome of social processes[18]. Although both Boots and Rowntree's saw poverty as a social evil to eradicate, deprivation was still conceived as a problem related to individuals as opposed of being a socially determined phenomenon (Ruggeri Laderchi 2000).

Despite the fact that the approach has been methodologically refined over time (Lipton & Ravallion 1995; Deaton 1997; Grosh & Glewwe 2000), these three elements are still at the heart of the practice of assessing monetary poverty (Ruggeri Laderchi *et al.*

[17] For an in-depth discussion of the contributions of Boots and Rowntree to the current monetary approach to poverty measurement see Ruggeri Laderchi (2000).

[18] This is an element that distinguishes the view of poverty maintened by neoclassical economists viz. the one of the classical school of political economy of Smith, Ricardo, J. S. Mill and Marx. The latter is characterised by the concepts of "social subsistence", which refers to the bundle of goods and services that is necessary in order to actively participate in the life of the society, and by the way in which income distribution is determined, which results from the relative positions and bargaining power across distinct social classes. In particular, the element of subsistence as socially determined has many points of contact with some recent works on the concept of social exclusion in the European Union (Lenoir 1974; European Council 2000).

2003; Stewart *et al.* 2007), both at the national (Deaton 1997) and global level (World Bank 1990).

1.2.3. Are resources-based measures able to capture the complexity of well-being and of its deprivations?

While technically elegant and coherent with the marginalist theory, the critical question relates to the relevance of the monetary approach in the conceptualisation of human well-being. Answering this question means to make explicit and in turn assess the underlying assumptions and value judgments that are embedded in the methodology.

Many of these assumptions are substantiated in the role that prices play in the theoretical apparatus of the monetary approach: on the one hand, by levelling out different components of well-being deprivations to the same metric, they allow for interpersonal comparisons of utility levels achieved. On the other, market prices act as the "anonymous" weights in the aggregation of multiple items of goods and services into the unidimensional money-metrics (Sen 1976). Prices are fundamental in the definition of the poverty measure, as they replace the actual and unknown individual preferences by an indirect demand function defined by the income or consumption of the person and the vector of prices (Atkinson & Bourguignon 1982).

The implicit assumption, however, is that markets – and consequently prices – exist for all goods, which is particularly "heroic" in a variety of circumstances (Ruggeri Laderchi 2003). First, clearing markets are the exception, rather than the norm, in most developing economies[19]. As such, the prevalence of imperfect markets or government interventions result in prices that do not reflect scarcity value, as envisaged by the marginalist theory itself[20]. Moreover, according to the theory market prices are essentially the reflection of efficiency in the exchange, and do not reflect any distributional concern, for which the marginal utility of a good satisfying a basic

[19] No less than in many cases for advanced ones!

[20] It is not surprising that the structural adjustment programmes of the 1980s and 1990s aimed precisely at 'getting the prices right', by pushing for an agenda of heavy liberalizations and privatisations, with the overall goal of making prices reflect market values.

need below the deprivation level could actually rise instead than falling with income levels (Thorbecke 2008).

The absence or difficulties in pricing goods for which markets are imperfect or absent, or that are not exchanged through the market system, such as public goods and services, unpaid household labour, own-production of food, or non-monetary dimensions of well-being, often entails the strong value judgement of excluding those dimensions from the analysis, by assigning them a zero-weight in the aggregation into the welfare measure. Further, the fact that in this frameworks weights are assigned through market prices silences public discussion on which dimensions of well-being should be part of a life free from poverty, as well as on which relative values and weights should be attached to different constituencies of poverty (Sen 1999a, 2004). Finally, by reducing all the components of the poverty measure to the same price-metrics, there is also an implicit assumption of perfect substitutability among the different elements of well-being accounted by the measure (Lugo & Maasoumi 2008). The idea of substitutability has been heavily criticised by some authors (Tsui 2002, Bourguignon & Chakravarty 2003), according to which each attribute in the poverty measure should be considered essential, in the sense that a person who is deprived in that attribute should be considered poor irrespectively of her attainment in all the other dimensions[21].

Ultimately, however, the role of market prices in the approach is inextricably linked to an even more substantial question, which relates to whether comparisons of real incomes, or, in other words, of "*the commodity basis of utility*" (Sen 1999a, p. 69), can be justified as an adequate space for conceptualizing and evaluating the complexity of human well-being and of its deprivations. The key assumption of the method is that, through the use of appropriately devised tools, uniform monetary metrics can take into account all the relevant heterogeneity across individuals and their conditions and allow for robust interpersonal comparisons of welfare levels. In this way, formal economic theory has attempted to reduce the plurality of focus stemming from the evaluation of a person's state and interest through into the single

[21] This approach is coherent with the union method to poverty identification in a multidimensional setting, which will be thoroughly discussed in the next Chapter.

utility metrics[22] (Sen 1985). Inevitably, this approach results insensitive to both the complexity of human well-being and the "*empirical fact of pervasive human diversity*" (Sen 1992, p. 3). With respect to the former, during the second half of the XX century, scholars (Galbraith 1958; Rawls 1971; Chambers 1983; Sen 1985, 1987, 1993, 1999a; ul Haq 1996, 2003; Stiglitz *et al.* 2009) and international organisations (ILO 1976; UNDP 1990, 1994; United Nations 2000; OECD 2001) alike started to challenge the conventional wisdom of linking achieved welfare to consumption or resources-related indicators and incorated others, often non-monetary, dimensions in their evaluations. On the other hand, individual diversity manifests itself in a series of personal characteristics that render individual needs diverse and that *de facto* hampers the possibility of homogeneity in the individual conversions of resources into well-being outcomes (Sen 1999a). These factors will be discussed in depth in the next section, since they are integral part of Sen's critique to resource-based spaces for the evaluation of human well-being[23].

1.3. The Capability Approach

These strong value judgments embedded in the monetary approach and its critiques point to the limitations of utility as an adequate proxy for the complexity of well-being and point to the need for an alternative approach for its conceptualization and measurement (Sen 1980, 1981, 1984, 1985, 1992, 1993, 1999a; Nussbaum 1988, 2000, 2003; Robeyns 2003). One of these alternatives is the CA, which is a theoretical framework for evaluating well-being, social arrangements, inequality, and justice[24]. In his pioneer contributions, Nobel Graduate Amartya Sen disputed the idea that the command over resources could provide an adequate space to evaluate human well-being and argued

[22] *"It is fair to say that formal economics has not been very interested in the plurality of focus in judging a person's state and interests. In fact, often enough the very richness of the subject matter has been seen as an embarrassment. There is a powerful tradition in economic analysis that tries to eschew the distinctions and make do with one simple measure of a person's interest and its fulfilment. That measure is often called 'utility"* (Sen 1985, p. 1).

[23] Sen (1977) has also criticised the same assumption of utility-maximising economic agents on different grounds: first, only "rational fools" can deliberately apply the same criteria to distinct subjects such as determining market chocies or defining their own well-being, and secondly, because other factors such as "symphaty or commitment" may determine market choices.,

[24] For theoretical reviews, see Robeyns (2005); Comim (2008), while for a critique of the approach refer to Pogge (2002, 2010).

that the appropriate informational basis for evaluative assessments should be the one of functionings and capabilities. *Functionings* are being and doing activities that people value or have reason to value. They include achievements in different dimensions of life, ranging from basic ones such as being nourished, being in good health or avoiding premature mortality, to more complex ones, such as the ability of taking part to the own community or achieving self-respect. The notion of *capability to function* is closely linked to the one of functionings, as capabilities are the various combinations of functionings that a person can achieve. The concept of capability can be assimilated to the one of 'budget sets' in commodity spaces (Sen 1985). Capabilities reflect the various functionings available to the person and her real *opportunity freedom* to achieve those vectors of well-being outcomes that she has reason to value (Sen 1992, 1999a). The distinction between functionings and capabilities is between "*achievements on the one hand, and freedoms or valuable options from which one can choose on the other*" (Robeyns, 2005b, pp. 95) In this way, "*achieved well-being itself depends on the capability to function*" (Sen 1992, p. 42, *italics original*), and, consequently, on one's freedom to select among valuable functionings. Hence, opportunity freedom plays a key role in the theoretical foundations of the capability approach, as it is instrumental in order to discriminate among possible valuable livings (Sen 1999a; Comim 2008). Yet, the approach also emphasises the intrinsic value of freedom, which is reflected in the concept of *agency*. The latter is a person's ability to act on behalf of valuable objectives (Alkire and Deneulin 2009). Consequently, an agent is "*someone who acts and brings about change*" (Sen 1999a, p. 19), and acts on behalf "*of goals and values other than the pursuit of one's own well-being*" (Sen 1992, p. 56). In terms of overall approach to the study and practice of development, people are not seen any more as passive recipients of development programs, but as active agents in "*shaping their own destinies*" and the life of their communities (Sen 1999a, p. 53). From a CA perspective, human development is hence identified with the removal of those 'un-freedoms' that constrain people exercise of reasoned agency. In other terms,

> *"Development can be seen ... as a process of expanding the real freedoms that people enjoy ... the expansion of the 'capabilities' of*

persons to lead the kind of lives they value – and have reason to value" (Sen 1999a, xii).

1.3.1. Enlarging the Informational Basis from Resources to Capabilities and Functionings: Advantage…

In the CA framework human well-being "*is best seen as an index of the person's functionings*" (Sen 1985, p. 25). As a result, through its emphasis on the "*constitutive plurality of a welfare assessments*" (Sen 1993), the CA explicitly recognises the complexity of human well-being by conceptualising them in the multifaceted space of capabilities and functionings. As noted by Chiappero-Martinetti (2008), this acknowledgment goes well beyond the use of multidimensional evaluations for the assessment of well-being, as it involves further layers of analysis: first, the "*multivariate evaluative perspective"* brings into focus two distinct informational spaces, the ones of functionings and capabilities, which bring about the distinction between what people *do* from what they *can* do. Secondly, both the informational bases of capabilities and functionings are commonly understood as multidimensional and consequently assessed through a variety of qualitative and quantitative indicators. The multidimensionality of the approach also implies an enlargement of the informational basis for the evaluation of well-being to dimensions that have been traditionally neglected by resources-based approaches, such as freedom and empowerment, voice and dignity, participation in the own community, subjective well-being[25] *etc.*

Thirdly, the CA adopts a truly pluralistic perspective regarding the heterogeneity in the instrumental relationship between resources and functionings and capabilities, which stems from a variety of individual, social and environmental factors[26]. In Sen's

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[25] Participatory poverty assessments such as in Narayan et al. (2000a, b) uncovered the relevance of traditionally excluded dimensions such as lack of voice, humiliation, dependence in poor's people definitions of their poverty. Additionally, analyses of consumption patterns among the poorest (i.e. Banerjee & Duflo 2007) found that a considerable share of the poor's budget is devoted to festivals and religious celebrations. Although apparently "irrational", such behavior can be explained by the fundamental need of being part of the own community and maintaining cultural identity.

26 In particular, these sources of diversity among human beings relate to (Foster & Sen 1997; Sen 1999a, p. 70-71): (i) Personal heterogeneities (e.g. age, sex, level of education, health and disability status, etc.); (ii) Environmental diversities (e.g. differences in climatic circumstance, presence of infectious diseases,

words, "*...the impact of income on capabilities is contingent and conditional"* (Sen 1999a, p. 88): as individuals are inevitably diverse, well-being evaluations based exclusively on resources can be extremely misleading, because they conceal the heterogeneity for which the same bundle of resources is converted into different well-being outcomes for distinct individuals [27]. In this respect, Sen clarified that the relationship between resources and human well-being is only "instrumental", which implies that the informational basis to capture human well-being must shift from resources to indicators "*which might directly capture the level at which a given functioning is (or could be) achieved*" (Ruggeri Laderchi 2008, p. 207). By failing to recognise the "*inherent variety"* of human beings, resources-based approaches to welfare confound the "means" with the "ends" of development, i.e. the expansion of substantive freedoms (Sen 1999a).

Additionally, the intrinsically multifaceted perspective brought about by the CA allows to admit the hypothesis of 'couplings of disadvantages', which render capability poverty more intense than what would otherwise appear in the income or resource spaces (Sen 1999a). For instance, sickness may reduce the individual's ability to find a job, and at the same time, her capability to convert calories acquired into good nutrition. This recognition is crucial in the design of policies that target al.l those people with 'conversion difficulties' in addition to their lowness of income or calories. Additionally, as recently pointed out by Thorbecke (2008), there may be strong dynamic complementarities stemming from multiple deprivations in determining weaker well-being outcomes over the lifecourse, which, in turn, render people more likely to be trapped in persistent poverty. In the previous example, the joint coupling of bad health status and

pollution, etc.); (iii) Variations in the social climate (e.g. presence of welfare state, absence of crime and violence, nature of the social capital...); (iv) Differences in relational perspectives (e.g. relative position towards the other members of society); (v) Intrafamily distribution (e.g. prioritisation, discrimination of some members etc (Haddad & Kanbur 1990, Sen 1999a).

[27] Thorbecke (2008) provided another way to look at this issue when holding that: *"Even if it were possible to specify the minimum thresholds of each and every basic need and put a price tag on them and aggregate across minimum thresholds to derive the monetary poverty line, there is no guarantee that individuals with incomes at – or even above – the poverty line would actually allocate their incomes so as to purchase the minimum basic needs bundle. For instance, there are examples of household heads who receive an income above the poverty line and allocate it to satisfy wants for alcohol and tobacco at the expense of satisfying the minimum caloric requirements of their children. In the money-metric approach, such households would be classified as non-poor whereas in reality at least some of their members are deprived of some basic needs and therefore should be considered poor"* (Thorbecke 2008, pp. 4-5).

inadequate access to enough calories is likely to lead not only to nutritional deprivation today (*cross-sectional coupling of disadvantages*), but also to decreased educational and cognitive abilities in the future caused by the long lasting impacts of inadequate nutrition on schooling (Behrman 1996, Hoddinnott *et al.* 2008). This hypothesis will be explored more in depth in Chapter 7.

Finally, beyond multidimensionality, the complexity of the approach also stems from its focus on the linkages and differences between capabilities and functionings, the technicalities related to the measurement of one concept *viz*. the other, and how individual, social, and environmental conversion factors influence achievements and capabilities [28] (Chiappero-Martinetti 2008). This is a relevant, although often overlooked, characterising feature of the approach:

> *"(...) the capability approach is much more than a mere multidimensional framework for assessing poverty and well- being; it offers a broader, richer, and intrinsically complex theoretical scheme for describing the multifaceted nature of poverty, understanding its causes and effects, and investigating interrelated layers of analysis that have traditionally been neglected or not adequately debated. However, while this intrinsic complexity is often (though not always) considered a strength at the conceptual level, it is also generally perceived as a potential drawback due to the indisputable challenges it entails at the methodological level" (Chiappero-Martinetti 2008, p. 285).*

Consequently, the next section will focus on a discussion of those challenges.

1.3.2. … or additional burden for well-being evaluations?

[28] The role of the environment *latu sensu* in the determination of capabilities and functionings will be discussed more in depth in Chapter 3, in relation to the process in which food security is achieved, and in the empirical analyses of Chapters 6 and 7.

One of the methodological strengths of the approach is to explicitly recognize the richness of the concept of well-being without trying to conceal it as an "embarrassment to hide" (Sen 1993) and to translate it in multiple and increasingly complex frameworks for the evaluation of well-being outcomes, i.e. living standards, functionings and capabilities. On the other hand, however, the adoption of the CA also entails non-trivial methodological and technical issues when its key concepts are translated in empirical evaluations (Sen 1987; Chiappero-Martinetti 2000, 2008; Comim 2008; Chiappero-Martinetti & Roche 2009; Ruggeri Laderchi 2008). Unsurprisingly, some scholars have attributed to those undoubted difficulties as an overall weakness of the approach, which jeopardizes the actual chance of making effective use of this theoretical framework in empirical applications (Sudgen 1993; Ysander 1993; Srinivasan 1994; Roemer 1996). As noted by Comim (2008):

> *"In few words, they have suggested that the 'multidimensional-context-dependent-counterfactual-normative' nature of the capability approach might prevent it from having practical and operational significance" (p. 160).*

However, as Comim goes on:

> *"One should not despair of the capability approach (...) in face of the for the 'measurement challenge'" (ibidem).*

The "measurement challenge" (Comim 2008) of the CA stems not only from the increased complexity due to the expansion of the informational basis in order to include the multidimensionality of well-being, but also from its context-dependent and theoretical underspecified nature, and for its refusal to provide "one-fits-all" formulas for evaluating distinct well-being states (Robeyns 2003; Chiappero-Martinetti 2000, 2006, 2008; Saith 2001; Chiappero-Martinetti & Roche 2009; Comim 2008; Ruggeri Laderchi 2008). Coherently with the bottom-up and under-specified nature of the approach, Sen never provided any precise guidelines on how the CA should be operationally translated for policy analysis and evaluation, in the belief that the choice of the appropriate method needs to vary in relation to the specific contingencies of the assessment. According to Sen (1999a, 2004a, 2004b), the choice of the space of analysis, dimensions, indicators and weights should be the result of a participatory and democratic deliberation and not as a technocratic outcome. In particular, the procedural aspect of the evaluation is fundamental in Sen's CA, as it can affect the overall political or academic legitimacy of the assessment itself (Robeyns 2003).

The pluralistic stance of the CA is not only manifested into its multidimensional nature, but also in the variety of methodological tools that are used to evaluate well-being in the expanding literature related to empirical operationalisations of the approach (Chiappero-Martinetti 2008). This vast and growing literature shows that, beyond the significant challenges that any operationalisation of the approach entails, the CA can indeed adopted for the well-being analysis and policy formulation. The next sections will examine the step required for the operationalisations of the approach in depth.

1.4. Operationalising the CA for Evaluating Human Well-Being

This section deals with the discussion of the steps required for the empirical applications of the CA. These can be summarised in four critical passages: (i) identification of the space of the analysis; (ii) choice of dimensions; (iii) selection of the indicators; (iv) choice of an appropriate aggregation (or weighting) method (Robeyns 2003; Comim 2008; Chiappero-Martinetti & Roche 2009). Beyond these general elements, Chiappero-Martinetti & Roche (2009) identified two additional requirements that researchers interested in empirical applications of the approach must be confronted with, which relate, on the one hand, to the plurality of units of analysis, ranging from individuals, households of population sub-groups, and of individual conversion factors that influence the conversion of resources into well-being outcomes. On the other, operationalisations [29] also have to deal with heterogeneity due to different socio-economic, institutional, political and environmental contexts, which also cannot but affect the abovementioned process of conversion.

With respect to the former step, the critical question relates to the choice of the space in which the analysis will be conducted. Sen (1999a) outlined that there are real advantages from relying on the wider informational basis provided by capabilities, as

[29] For a review of the meaning of this term for different authors, see Chiappero Martinetti & Roche (2009).

they account for individual freedom in choosing the kind of life she wants to lead. On the other hand, however, measuring capabilities inevitably increases the informative burden required for the evaluation, as not only choices, but also the set of opportunity available to the individual should be included. Indeed, even though freedom is one of the distinguishing features of the approach, trying to measure the set of valuable opportunities that have not been preferred by the individual is, inevitably, a very daunting task (Kuklys 2005; Comim 2008). Despite the greatness of the challenge, some attempts in this direction have been nonetheless made in the literature (Anand et al. 2005, 2006; Anand & Van Hees 2006).

On a strictly theoretical basis, nonetheless, the choice of focusing on functionings or capabilities should not be driven by empirical concerns, as *in primis* depends on the overall objectives of the evaluative exercise[30]. For instance, if the goal is to measure the general standard of living of the population or a particular phenomenon (i.e. undernutrition, illiteracy, exclusion from the own community, *etc.*) the set of valuable opportunities available to the individual appears to be irrelevant, and the choice of the space will likely focus on achieved functionings[31]. As noted by Robeyns (2005):

> *"… One has to ask whether the relevant dimension of advantage is the standard of living, achieved well-being, agency achievement, well-being freedom, or agency freedom. The central claim of the capability approach is that whatever concept of advantage one chooses to consider, the informational basis of this judgment must relate to the space of functionings and/or capabilities, depending upon the issue at hand" (Robeyns 2005, p. 103).*

After having chosen the relevant space for the analysis, the choice of dimensions and indicators follows. In both cases, it is fundamental to clearly state the criteria and value judgments underlying such choices (Alkire 2008a). The next paragraphs will discuss more in-depth those fundamental steps. Before turning to this purpose, it is opportune to stress that each of these choices is primarily normative and not technical,

[30] Interestingly, often in the CA literature it is argued that functionings are usually preferred in empirical analyses because of the intrinsic difficulties in measuring valuable opportunities, including scarce data availability. Following this line of reasoning, this literature seems to provide the impression that measuring functionings is a sort of *second-best* to measuring capabilities.

[31] This argument will be discussed in depth in the next sections.

as they involve a considerable amount of value judgments that should be clearly pointed out and discussed, as they bear substantial weight on the results of the evaluative exercise. The choice of dimensions, indicators and weights is primarily a normative exercise, and cannot be left totally to any statistical technique, no matter how refined are[32]. If these choices are made without any sound theoretical foundation or justification, there will be problems of *"measuring without theory"* pointed out by Koopmans (1947). In any evaluative exercise, the ultimate issue relate to providing justifications for the particular dimensions chosen in the analysis and to explaining how this process has been reached (Robeyns 2005, Alkire 2008a).

1.4.1. Choice of the dimensions

The choice of dimensions to be included in the analysis involves the selection of some classes of values at the expense of others (Comim 2008). In general, the tension between capturing the complexity of human well-being while avoiding redundancy, and the risk of neglecting relevant aspects is inescapable (Sen 1987; Brandolini & D'Alessio 1998). Given the intrinsic value judgments embedded in this trade-off, different authors have discussed possible alternatives on how to select relevant dimensions of well-being, and whether a consensus about some critical dimensions to be included in empirical assessments of well-being could be reached. On the one hand, Martha Nussbaum (2000) has proposed a list of universally valid capabilities as a basis for a theory of justice in a plural society. She argues that her list is based on the Rawlsian concept of "overlapping consensus" on what it can be of central relevance in any human life (Rawls 1993), and, as such can be justified "*whatever else the person pursues and chooses*" (Nussbaum 2000, p. 74). On the other, other authors such as Alkire (2008a) or Robeyns (2003) argued that the nature of the approach is fundamentally underspecified, which means that it is open to an infinite number of

[32] Naveed and ul-Islam (2010) provide an example of choice of dimensions based on purely statistical techniques: following the advice of the World Bank (2009), the Government of Pakistan has recently chosen the dimensions to include in its poverty measure (BISP Poverty Scorecard) by using OLS regression. In practice, dimensions were selected through a battery of regressions that used household expenditure per capita equivalent. As Naveed and ul-Islam thoroughly discuss in their paper, this approach is bound with theoretical and technical problems.

specifications regarding what constitute valuable capabilities[33] (Sen 1997, 1999a; Alkire 2007). Following the open and context-specific nature of the approach, numerous other commentators argued that the choice of dimensions and indicators that translate them into operational concepts should be dependent on the purposes of each different evaluative exercise[34] (Anand & Sen 1997; Robeyns 2003, 2005; Alkire 2008). In particular, Alkire (2008a) observed that researchers usually follow five main methods to select domains: (i) existing data or convention; (ii) researcher's own assumptions; (iii) public consensus; (iv) empirical evidence regarding people's preferences and values; and, finally, (v) ongoing deliberative participatory processes. While the first bases the choice on data availability or convenience[35], the second method relies on some implicit or explicit assumptions related to what people value or should value. As Alkire notes, these are usually "informed guesses" of the researcher, or based on convention or theory. The third and fourth ways to select dimensions are based on some forms of public consensus, such as, for instance, the Millennium Development Goals, on the one hand, and empirical evidence about empirical values on the other. Finally, the last method is probably the most affine to the nature of the CA, and bases the choice of the dimensions on ongoing participatory processes that elicit the values and perspectives of the relevant stakeholders. Alkire stressed that there is no ready-made recipe to choose dimensions of well-being, and most of the times these processes overlap or are used jointly, and that generally the selection of dimensions/domains ultimately depends on the research objectives and/or operational processes, on practical constraints, and must be relevant to the society or context of reference (Alkire 2008a; Anand & Sen 1997; Sen 2004b). Finally, the selection of relevant dimensions should also take into account their degree of social

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[33] For further discussion, see also Alkire (2002), Gasper (2003), Sen (2004a), Ranis *et al.* (2006) and Liberati (2009).

[34] As Robeyns (2003) noted, in fact, the highlighted differences in perspectives between Sen and Nussbaum have much to do with their respective academic fields of work and to the objectives they assign to the theory itself. On the one hand, Nussbaum explictly aims at influencing constitutional design through the proposal of a list about the most important dimensions that are deemed to define human life in a universalistic way. On the other, Sen's ideas are grounded in social choice theory, and as such he is concerned with the democratic processes that lead to the definition of the relevant dimension to include in analysis and evaluation.

[35] Dercon (2012) has recently criticised what he called as "opportunistic" multidimensional measures of poverty, which include only those dimensions for which data are available.Inevitably, the inclusion of other dimensions would change the results of the avaluative exercise. He suggests that it would be preferable to adopt a "union approach" to identification of the poor by stating that all dimensions included are essential to define poverty, while acknowledging that other dimensions may matter as well.

influenceability, which means that they must be characterized by an appropriate focus for public policy, rather than a private good or a capability like inner peace that cannot be influenced from the outside (Sen 2004b). It is for these very reasons that, in contrast to Nussbaum, Sen never provided a set of universally valid capabilities, as a pre-packed list might not suit all the purposes or different contexts in which the CA can be applied. Additionally, the provision of a 'cemented' set of capabilities would counter the bottom-up nature of the approach, which requires public debate on the objectives of the development policies and on the value judgments embedded in such goals [36]. Despite his general refusal to adopt one-fits-all lists of capabilities or achieving "an overlapping consensus" on the ultimate meaning of human well-being, Sen recognized that in the context of developing countries it is possible to reach a basic agreement on a minimum set of "crucially important functionings up to certain minimally adequate levels" (Sen 1992, p. 44) such as to escape extreme poverty. In this respect, Sen introduces the concept of "minimal capabilities" (Sen 1997), which regards those functionings (and the corresponding basic capabilities) of crucial importance for the life of an individual, (e.g. the ability to be well-nourished and well-sheltered, the capability of escaping avoidable morbidity and premature mortality, and so forth)[37]. In a developing countries context, in which a great share of the population does not possess even those minimal requirements, such an "absolute core of poverty" as defined by deprivation in minimal capabilities is able to reveal much inter-individual variation (Sen 1992; Saith 2001). Attached to the concept of basic capabilities[38] are, respectively, notions of 'urgency' in their satisfaction, and the idea of some minimal levels of intrinsic importance in the context of reference[39] (Sen 1980; Foster & Sen 1997). As Ruggeri Laderchi (2008) noted:

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[36] As Sen (2004a) stressed: *"To have such a fixed list, emanating entirely from pure theory, is to deny the possibility of fruitful public participation on what should be included and why*" (p. 77).

[37] Saith (2001) compared a number of lists of 'basic' capabilities proposed by different researchers, starting from diverse theoretical premises and using differing methodologies. From the review she found out that that health, nutrition and education capabilitiesconsistently appear in all the lists, despite the different criteria for inclusion, reflecting their crucial importance for any investigation of poverty.

39 Furthermore, as noted by Ruggeri Laderchi (2008), basic capabilities are encompassed in other lists this list is encompassed in other lists of fundamental capabilities, such as the one proposed by Nussbaum (2000).

"This implies that an individual able to reach levels of functioning above that minimal level would do so because of the inherent importance of that level of achievement. In other words, when focusing on basic capabilities we can reduce a measure of freedom to achieve to a measure of achievement" (p. 209).

1.4.2. Choice of the indicators[40]

The choice of the indicators for well-being evaluation also deserves careful scrutiny, as it needs to reconcile technical considerations and data availability with the consistency to Sen's model (Ruggeri Laderchi 2008). The key aspect of embracing the CA for measuring well-being relates to the shift of the focus of the analysis from resources to what people are able to do or actually do, and, as such, indicator selection has to reflect such change in perspective. In particular, once the space of the analysis and dimensions have been selected, the researcher has to ask whether the indicator is actually able to capture that specific domain in the selected space (i.e. the functioning "being healthy"). Then, since the dimensions are also complex and multifaceted phenomena, one has to identify which among the possible (and available) indicators are better suited to capture the concept to be measured in the context of reference. These indicators can be either qualitative (i.e. self-reported health status) or quantitative (i.e. number of work days lost due to sickness). A further requirement, in the case of assessments of deprivations of well-being, is to identify a threshold that differentiates between adequacy and deprivation. As noted by Ruggeri Laderchi (2008), the issue of indicator selection and setting the deprivation threshold are deeply intertwined, because the choice of the indicator itself implicitly set the way in which the deprivation is binding across distinct groups. For instance, in the case of education, the choice of an indicator of secondary school completion in a developing country context is implicitly setting a very high deprivation line for a large share of the population (Ruggeri Laderchi 2008).

[40] Chapter 5 presents a more in-depth discussion and methodology on indicator selection starting from the theoretical premises of the CA.

Technically, the researcher needs to select among different types of indicators such as stock vs. flow indicators, static vs. change indicators, individual vs. household indicators by asking whether they are actually capturing the underlying concept[41]. Each of these choices will affect the weighting of indicators, their elasticity of substitution, and will therefore have normative consequences that will need to be considered and discussed in the definition of the overall measure of well-being (Silva Leander 2012). As mentioned earlier, beyond influencing the choice of the space and of the dimension, data availability is also critical for the choice of indicators related to selected dimensions. The demanding information requirements of the approach, as well as the lack of data on many non-monetary dimensions of well-being, are often cited as justifications for the use of more traditional approaches to well-being measurement (Chiappero-Martinetti 2000). However, the broad empirical research on operationalisations of the CA[42], as well as the growing emphasis on collection and dissemination of data on the multiple dimensions of well-being (Stiglitz et al. 2009), leaves space for optimism in this respect. Yet, many efforts to collect timely and quality data are still required, especially to capture those indicators informing the 'missing dimensions of poverty data' (Alkire 2007), such as the quality of work, empowerment, or psychological well-being[43].

1.4.3. Issues in Functioning Measurement

The last step in the operationalisation of the CA relates to the devise of an appropriate aggregation strategy to measure well-being or its deprivations. While the next Chapter will review in depth the different methodologies proposed for this purpose, this section is concerned with sketching some critical issues related to the measurement of functionings. We focus on the latter because they are the most appropriate informational basis for our purposes, which is to measure deprivations of human well-being (Section 1.3). The measurement of functionings can be framed into a formal illustration of the CA theoretical framework (Sen 1985; Kuklys & Robeyns 2005):

[41] Chapter 5 proposes a methodology in order to select indicators for multidimensional evaluations of well-being.
[42] See section 1.3 and chapter 2.
[43] As noted by Biggeri & Mehrotra (2011, p. 54): "... *Applying the CA, however, does not involve just adding neglected domains to the analysis. It also demands a change in the research design starting from spans data collection and methods of data elaboration*".

$$Q_i(X_i) = \{\mathbf{b_i} \mid \mathbf{b_i} = f_i(\mathbf{c}(\mathbf{x}_i) \mid (\mathbf{z_i}, \mathbf{z}_e, \mathbf{z_s}) \quad \forall\ f_i \in F_i \quad and \quad \forall\ \mathbf{x_i} \in \mathbf{X_i}\}$$

where: $\mathbf{b_i}$ is a vector of functionings; $\boldsymbol{x_i}$ is the vector of commodities enjoyed by the individual; **c** is a vector of characteristics of commodities; f_i is a conversion function that maps the characteristics of commodities into the space of functionings; finally, $\mathbf{z_i}$, $\mathbf{z_e}$,, and $\mathbf{z_s}$ are vectors of conversion factors related, respectively, to individual heterogeneity, environmental factors and social characteristics. They all influence the way in which commodities x_i are converted into functionings. Finally, $Q_{i,}$ is the capability set, given the resource constraint X_i and the non-monetary constraints provided by the conversion factors.

Following this characterisation, measuring functionings means allocating a numerical value to $\mathbf{b_i}$**,** the vector of individual achievements in different domains of well-being. As discussed by Kuklys (2005), there are three main issues that arise when measuring functionings: (i) the absence of an established measurement unit for each functioning; (ii) the lack of a natural aggregator to summarise different functionings into a composite measure of well-being achieved; and (iii) measurement error. As we discussed in this Chapter, in traditional resource-based approaches the first two issues are resolved through market prices, act as both unit of measurement and natural aggregators. Utility is then ordinally equivalent to expenditures or income levels, which can be used in mainstream poverty and inequality analysis to compare individuals' welfare levels. Conversely, in the case of functionings there are no established measurement scales for different functionings (e.g. being educated *viz.* being well-nourished), nor do exist some relative evaluations of functionings that could act as shadow prices in welfare analysis that could act as aggregators (Kuklys 2005). In this regard, Chapter 2 will review the different methodologies proposed to overcome the lack of a natural aggregation function in the context of multidimensional spaces.

An additional problem relates to the fact that many functionings are often measured on ordinal scales, which entail the inapplicability of some measurement and aggregation techniques or their transformational in cardinal units, with the additional sets of issues connected to that (Baltagi 2002).

Finally, the issue of measurement error is an inescapable matter in measuring well-being, whether if the assessment is based on income and commodities or in the space of functionings (Kuklys 2005). This issue can be appreciated by two distinct, although interrelated, perspectives. On the one hand, a single indicator is, in most cases, only an imperfect proxy for the concept it aims to capture. For instance, single indicators related to specific diseases (e.g. diabetes, asthma, cardiac diseases…) cannot provide alone a comprehensive picture of the complex functioning "being healthy" (Kyklys 2005). On the other hand, available indicators can be also afflicted by either in-built biases or score unreliability. For instance, 'adaptive preferences' or heterogeneity in respondents' perceptions of the scales can bias subjective indicators of health status (Sen 2002).

1.5. Poverty and food insecurity as deprivations of key capabilities

As thoroughly discussed in this Chapter, for long time poverty and food insecurity have been exclusively conceptualised in the unidimensional space of resources, and, as of yet, unidimensional measures are still the gold standard in their evaluations. The critical question is whether resources-based informational basis are adequate in capturing the complexity of those concepts, which is now widely recognised by policy-makers and academics alike[44] (WFS 1996; CFS 2011; UNDP 1990, 2010, 2012; Narayan *et al.* 2000a, 2000b; World Bank 2000; OECD 2001; Stiglitz *et al.* 2009). According to this perspective, poverty comprises deprivation in many different dimensions such as health, nutrition, employment and education, living standards, but also social inclusion, empowerment, or subjective well-being (Narayan *et al.* 2000a, 2000b; Kakwani & Silber 2007), while food security is, according to the World Food Summit definition, a multidimensional construct encompassing the availability, access, utilisation, and stability of food (WFS 1996). This section aims at discussing the implications for the conceptualisation and measurement of food insecurity and poverty when the CA is embraced as overarching theoretical framework for their analysis.

[44] Some examples of multidimensional conceptualisations of poverty, are: UNDP (2010); Narayan et al. (2000a, b); World Bank (2000); OECD (2001), while for food security: Drèze & Sen (1989); WFS (1996); Barrett (2010); CFS (2011).

As discussed earlier, the CA is an inherently multidimensional approach, and the most immediate consequence of its adoption for the analysis of poverty and food insecurity is that both can be conceptualised as multidimensional phenomena. In evaluative exercises, this implies a shift from the unidimensional spaces of income or calories to multi-faceted informational bases, which include, in the case of poverty, other (often non-monetary) dimensions of well-being, and information on people's access and use of food, as well as their stability, in the case of food insecurity.

However, as already stressed, the CA is much more than a multidimensional approach: the key implication of its adoption for the analysis of poverty and food insecurity does not lie in the recognition of the multidimensionality following from the conceptualisation of both concepts in the multifaceted spaces of functionings and capabilities, but in their new *meaning* that they assume. From a CA perspective, poverty and food insecurity are surely the worst forms of unfreedoms conceivable, especially in a world characterised by unequal levels of wealth in human history (Sen 1999a). Hence, if the ultimate end of development relates to the removal of the substantive unfreedoms that constrain the flourishing of human beings and their actual possibility to live the life they have reason to value, the reduction of poverty and food insecurity becomes one of the key priority in the development agenda. From a capability perspective, poverty can be seen as the lack of the substantive opportunity freedom of escaping hunger, avoidable diseases, premature mortality, homelessness, ignorance, or, more generally, of being able to live the kind of lives someone has reasons to value (Sen 1980; Foster & Sen 1997; Sen 1999a, 2009; Drèze & Sen 1989). In other words, poverty is the most striking failure in achieving a "minimum threshold of adequate capabilities" (Sen 1992). As remarked by Sen:

> *"(...) To have inadequate income is not a matter of having an income level below an externally fixed poverty line, but to have an income below what is adequate for generating the specified levels of capabilities for the person in question"* (Sen 1992, p. 111).

One of those critical capabilities relates to the "capability to be food secure" (UNDP 2012, Burchi & De Muro 2012a), which, by the same token, relates to the substantive unfreedom to reach one of the most basic needs of human beings: an adequate and stable nourishment for an active and healthy life.

It is now clear that multidimensionality is merely one of the direct consequences of the adoption of functionings and capabilities as relevant informational basis for the assessment of poverty and food insecurity. The relationship between poverty and food insecurity, for instance, assumes a new connotation when the approach is adopted. When the two are conceptualised in the capabilities and functionings space, their strong and mutually reinforcing link clearly appears: on the one hand, poverty, understood not only as lack of entitlements to food (Sen 1981), but also of basic health and care facilities, education, access to water and sanitation, or voice in face of governments, is a critical determinant of food insecurity[45] (Drèze & Sen 1989; Burchi & De Muro 2012a; UNDP 2012). By the same token, food insecurity causes capability poverty in various ways, which can last for generations (UNDP 2012): food insecurity weakens children's immune system, and hence puts children at risk of avoidable morbidity or premature mortality due to communicable and preventable diseases, such as diarrhoea, acute respiratory infections, malaria etc. Once they are in school, they tend to learn less and to drop out early, while at work they are less productive. Also, malnourished mothers face more risks of dying during delivery or to give birth to low-birth babies that would survive with more difficulties. As such, food security fosters capability poverty reduction by decreasing mortality and morbidity, enhancing education and people's capability to engage in society, as well as to realise their productive and human potential. In turn, fostering key capabilities such as health, education, the provision of an environment free from infectious disease, etc. through poverty reduction leads to improved food security, contributing to a virtuous circle (UNDP 2012).

Another aspect that follows from the adoption of the CA for the analysis and measurement of poverty and food insecurity relates to the emphasis on individuals and households in contrast to the traditional focus on aggregate resources: the CA is people-centered and, as such, it investigates the way in which people use resources such as income or calories to fulfil basic capabilities, including the one of being food secure (Burchi & De Muro 2012a). The shift from an aggregate to a microeconomic perspective has particularly benefitted the analysis and measurement of food security outcomes: until the early 1980s the concept was inherently an aggregate one (Clay

[45] As it will be discussed thoroughly in Chapter 3.

2002), and food security assessments were essentially based on estimates of the overall availability of calories at the national level. The seminal works of Sen (1981) and Drèze and Sen (1989) substantially changed the emphasis from the analysis of aggregate availability of food to individual and households entitlements and use of the food itself[46] .

As discussed in the previous sections, the rejection of resources-based informational basis is also critically linked to the existence of a variety of individual and environmental *latu sensu* characteristics that render the conversion of resources into functionings ad capabilities extremely heterogeneous. The explicit acknowledgment of differences in achieving well-being of the approach, together with its people-centred perspective, entail that the measurement of both phenomena must overcome the means and focus directly on the outcomes that those means permit to achieve at the microeconomic level.

In sum, there are strong theoretical and policy reasons in conceptualising and measuring poverty and food security as basic capability deprivations. The capability and human development approach, by transcending people's command over resources to focus on the enlargement of the freedom to do what they value or have reason to value, provides a broad and complex framework to conceptualise and evaluate human poverty and food security. However, the explicit recognition of such complexity entails substantial analytical and methodological challenges in the measurement of both concepts. These challenges will be the focus of the next Chapters.

[46] See Chapter 3 for a more in-depth discussion.

Chapter 2

Measuring Deprivations of Human Well-Being: Identification and Aggregation

2.1. Introduction

Once the space of the analysis has been set, the standard framework for the analysis of deprivations of human well-being prescribes two additional steps: identification and aggregation (Sen 1976). While the former address the critical question of "who is the poor?" by selecting a minimum threshold that dichotomises the population in the sets of poor and non-poor, the latter is concerned with the choice of an appropriate functional form for quantifying the extent of poverty in a distribution. The aim of this Chapter is twofold: on the one hand, it examines the two indiscernible issues of identification and aggregation in the context of multidimensional assessments of deprivations of well-being. On the other, the Chapter reviews the different methodologies that have been developed in the context of multidimensional poverty measurement. This literature is growing rapidly, and, although some surveys already exist[47] (Kuklys 2005b; Deutsche & Silber 2005; Bibi 2005), they do not review the entirety of the approaches proposed and the most recent methodological advancements. As such, the Chapter aims at filling this gap by providing a survey of the most recent developments in the measurement of multidimensional poverty and, at the same time, by offering an accessible entry point for those scholars and practitioners that approach the topic for the first time. In particular, it describes the different methods proposed, their main strengths and weaknesses, and, finally, it highlights some directions for future research.

This Chapter is structured in the following way: while Section 2.2 will review the identification and aggregation steps in unidimensional and multidimensional frameworks, Sections 2.3 and 2.4 will respectively review the axiomatic and non-

[47] For an extensive review of each distinct methodology see Kakwani & Silber (2008).

axiomatic and approaches. Finally, Section 2.5 concludes and presents some issues for further research.

2.2. Identification and Aggregation in Unidimensional and Multidimensional Spaces

Identification and aggregation are two unavoidable steps in the measurement of poverty and deprivations of human well-being (Sen 1976). In standard assessments based on monetary metrics, identification relates to the choice of a particular rule that enables to identify the set of poor people. The most common method for identification relates to selection of a poverty line that dichotomises the population into the set of poor and non-poor[48]. In this setting, the poverty line, by providing information on the minimum level of expenditure needed to escape poverty, also allows to make interpersonal comparisons, both across households of different sizes and composition and across families that live in different places (Ravallion 1998). Undoubtedly, the selection of the poverty line[49], as the one of the poverty measure, entails notable value judgments and hence is prone to arbitrariness and disagreements[50] (Atkinson 1987; Deaton 1997). An alternative criterion to identification is given by fuzzy set theory,

[48] In monetary frameworks, the poverty line, which we call *z* for convenience, can be set by one of the following methods: i) the Food Energy Method, in which dietary energy (caloric) intake per adult equivalent has an expected value just enough to meet the requirements (e.g. Sibrian 2008); ii) the Cost-of-Basic-Needs (CBN) approach, which sets *z* as the level just sufficient to buy an exogenously determined low-cost adequate diet plus other cheap, basic requirements; iii) the Food-Share-Method (FSN), which first estimates the minimum cost of a food basket that satisfies some minimum nutritional requirements and then multiply this by the share of non-food expenditure in total consumption of a sub-group defined as poor (e.g. Orshansky 1965). This method is still used to measure poverty in the United States; iv) the relative consumption method sets, which sets *z* as a percentage of national mean or median consumption. This method is currently used in the European Union, where an "at risk of poverty" line is set at 60% of the median of the net national income (European Commission 2011); v) the "Hybrid poverty line" method, which combines absolute with relative poverty line (e.g. Foster 1998; Ravallion & Chen 2009); vi) the International Poverty Line method, developed by the World Bank (1990, 2000; Ravallion and Chen 2001) to allow for global poverty estimates.

[49] Despite the apparent scientificity of the methods mentioned above, there is still considerable debate on how to set the poverty line in monetary frameworks (Ruggeri Laderchi *et al.* 2003; Reddy and Pogge 2010; Ravallion 2010; Deaton & Dupriez 2011). As Wisor (2011) remarked, many poverty lines are not adequately anchored in an underlying idea of what the income or consumption threshold is intended to represent, are insensitive to variations in human needs and to the different abilities of various individuals to convert resources into well-being outcomes.

which, instead of considering poverty as an on-off attribute, treats it as a vague predicate that manifests itself in different shades and degrees. As such, the poverty line is replaced by a membership function that assigns a distinct value to different degree of membership to the fuzzy set of poverty. In this unidimensional environment, aggregation is typically obtained through the use of some functional form that allows for combining the selected information into a summary metrics of well-being (or ill-being) achievement, such as a measure of poverty or inequality. The most common measures of poverty in a unidimensional framework are the headcount ratio, the poverty gap ratio, and the per capita squared poverty gap ratio, which all belong to the Foster-Greer-Thorbecke family of measures[51] (FGT, Foster et al. 1984). Note that monetary measures first aggregate *within* the individuals, then, given the poverty line, they proceed for the identification of the unit of analysis as poor, and then aggregate across the units of analysis in order to determine the overall level of poverty within the population.

2.2.1. Identification in Multidimensional Spaces

By shifting from unidimensional to multidimensional informational spaces, the identification and aggregation steps inevitably become more complicated. Let assume that each person is characterised by a vector of basic attributes. In order to proceed with the identification of the poor, two issues need to be addressed: first, a critical threshold that defines "*the minimally acceptable level*" (Sen 1992, pp. 139) for which the individual is not considered poor in each attribute has to be defined. In the multidimensional framework, the key issue of "*vertical vagueness of poverty*" (Clark & Qizilbash 2005), which relates to setting of a line that dichotomises the distribution in poor and non-poor, is amplified by the necessity of setting a threshold for each of the attributes in order to determine the occurrence of deprivation in that attribute. Then, there arises the conceptual challenge of deciding who is poor (Atkinson 2003; Duclos et al. 2006; Alkire & Foster 2007, 2011b; Thorbecke 2008). Until the milestone contribution of Alkire & Foster (2007, 2011b), the most common

[51] Other key measures are: Watts (1969); Sen (1976); Clark et al. (1981); Chakravarty (1983); Atkinson (1987).

approaches to identify the poor in a multidimensional space were the *counting approach*, which counted the number of attributes in which people suffer deprivation (e.g. Vranken 2002; Gordon et al. 2003), and others that link identification to assumed properties of the social welfare function (e.g Tsui 2002; Bourguignon & Chakravarty 2003) (Atkinson 2003). In the latter group, a distinction can be drawn between the union and intersection approaches[52]: while the former identify as poor an individual that is deprived in at least one dimension, the intersection approach requires deprivations in all the dimensions. The union approach underscores the intrinsic relevance of each dimension of deprivation in the definition of poverty (and the related inadmissibility of trade-offs in some attributes to make up for deprivations in others), but inevitably inflates the number of the poor and can lead to mistargeting of the individuals that are severely deprived. On the other hand, the intersection approach, being extremely stringent, can lose track of individuals that experience extensive, but not global deprivations[53]. By building on both the counting and social welfare function approaches, Alkire & Foster (2007, 2011b) proposed an intermediate alternative, which identify the poor on the basis of a poverty cutoff *k*, which expresses the number of deprivations required in order to be considered poor (Section 2.3.1).

Ultimately, the issue of identification in a multidimensional framework relates to critical issues of interaction across attributes and how the different attribute should be integrated into a measure of overall poverty (Atkinson 2003; Thorbecke 2008). It is hence clear that the boundary between identification and aggregation now becomes more blurred than in the standard unidimensional case, and it for this reason that many of the approaches proposed in the literature address the two issues jointly (e.g. Maasoumi & Lugo 2006, 2008; Alkire & Foster 2007, 2011b; Rippin 2010).

2.2.2. Aggregation in Multidimensional Spaces

The choice of multidimensional spaces for the analysis of deprivations of well-being also renders the aggregation step more demanding. Firstly, the fundamental question

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[52] *"Some people are concerned about those who have* either *low income* or *poor access to housing* or *a low level of education? Other people are concerned with those who have low income* and *poor housing access* and *a low level of education"* (Atkinson 2003, p. 51, *italics in the original).*

[53] Alkire & Seth (2009) in a study of multidimensional poverty in India that uses ten dimensions of deprivation, show that the union approach led to identifying 97% of the population as poor, while the intersection merely 1%,

of whether *aggregating or not* elementary indicators of achievement (or deprivation) into a single multidimensional index arises. When dealing with multidimensional assessments of well-being (or the lack of it), the available information can be presented either through a well-being (or poverty) profile by presenting a battery of indicators that show how distinct indicators vary across dimensions of well-being, or through a measure that summarises the elementary indicators into a single index. The former approach has the advantages of avoiding informational loss and of providing a transparent assessment of the performance in each indicator. However, suites of indicators do not allow for building complete rankings for policy targeting. Moreover, the general public may have difficulties in interpreting and assessing the trends of multiple indicators that vary across countries (and possibly over time), while policy-makers may struggle to design appropriate strategies that can simultaneously address the joint distribution of deprivations.

On the other hand, multidimensional indexes that summarises the selected information in a single metrics have the advantages of providing an overall picture of the phenomenon under investigation, and consequently, to allow for rankings and being easy and powerful to communicate. These benefits necessarily come at the costs of losing information and introducing further value judgments in the assessments on the basis on how the aggregation is conducted[54] (i.e. selection of weights, parameters, method of normalisation of the indicators, and functional form) (Micklewright 2001). Inevitably, this leads to decreasing the transparency of the evaluative assessment, which in turn can undermine the credibility and use of the measure by the relevant stakeholders and scientific community[55] (OECD-JRC 2008), as well as re-introducing unidimensionality (Giovannini 2004).

Secondly, if a multidimensional measure is preferred, aggregation can be conducted on different and/or subsequent levels. Firstly, if they are available, elementary indicators can be combined in order to capture a single dimension (e.g. health). Then there is the issue of aggregation order (Atkinson 2003; Dutta et al. 2003), which

[54] For further discussion on composite indicators, see Chapters 3, 4 and 6.

[55] As stressed by Giovannini (2004), although composite indicators *"…seem more attractive […], as they can combine a wide range of indicators – even "apples and oranges" – into a single measure […] on the other hand, they can be very misleading, depending on the selection of indicators and weights used to aggregate the results"* (p. 246).

relates to the choice of whether aggregating attributes first at the individual level in order to obtain a measure of individual deprivation and to aggregate individual into a societal level of multidimensional poverty, or to collapsing societal achievements in each single attributes first and then combine all the population-level one-dimensional indices in order to yield to a multidimensional measure[56].

Finally, the adoption of a specific aggregation method influences the results of the assessments in terms of cardinal values, and sometimes, the ordinal rankings of the distribution (Maasoumi & Lugo 2006). Aggregation can vary according to: (i) way in which the indicators are normalised; (ii) choice of weights and relevant parameters; (iii) the functional form in which the selected information is synthetised into an overall measure of deprivation. As each of these choices entail substantial normative implications, not always fully explicit, it is crucial to examine their consequences in terms of robustness of the resulting measure to changes in the underlying choices. Robustness tests and sensitivity analysis are hence fundamental to check the validity of the policy prescriptions that follows the evaluative exercise (Duclos *et al.* 2006; Ravallion 2010). As such, a very promising frontier of the literature relates to multidimensional extensions of the dominance stochastic conditions that were developed for the unidimensional case (Atkinson 1987; Foster and Shorrocks 1988a, 1988b) in order to generate poverty orderings that are robust to the choice of the poverty measure over broad classes of indices (e.g. Duclos et al. 2006; Batana & Duclos 2008).

Finally, some authors have criticised aggregate measures by arguing that the value judgments embedded in what is essentially a social choice and political exercise may be concealed by technical considerations (Marlier & Atkinson 2010). A same concern was also expressed by Sen (1999), although he argued that the heterogeneity of the elements constituting a multidimensional metrics is not problematic in itself insofar the evaluative exercise is participatory and transparent regarding the normative implications of each choice involved[57] (Sen 1999a). As stressed in the previous

[56] Smeeding et al. (1993) and the axiomatic measures of poverty adopt the former strategy, while the second is used by UNDP (1997). Both of them will be discussed below.

57 As noted by Alkire et al. (2010): “Amartya Sen, among others, sees the need to set weights in multidimensional measures as a strength, not an embarrassment: “There is indeed great merit… in having public discussions on the kind of weights that may be used” (1997). After all, any national budget implicitly sets weights on many dimensions of welfare, often with little debate. Yet given the legitimate diversity of

Chapter, in the capability framework all the steps involved in evaluative exercises of well-being are intrinsically normative and informed public debate should be always involved in those choices.

2.2.3. A Basic Taxonomy of Different Aggregation Methods for Multidimensional Measures of Deprivation

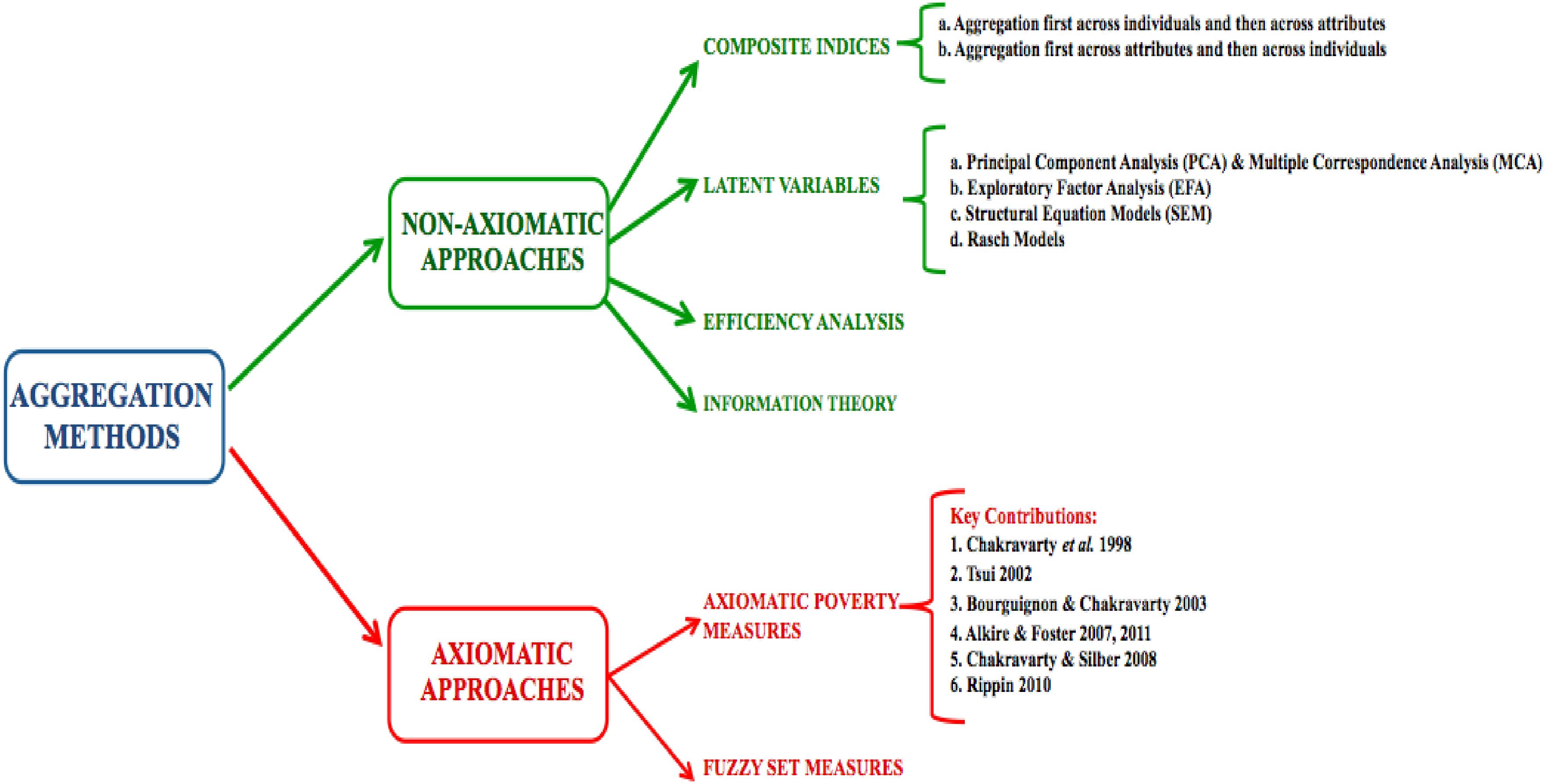
Many different methodologies have been proposed to address the issue of aggregation in a multidimensional space. Such a great variety of methods stresses the intrinsic ethical, theoretical, and methodological difficulties involved in the conceptualisation and measurement of human well-being and its deprivations. The diversity of available approaches in the field of measurement reflects that, even among practitioners, there is no agreement on whether to collapse different dimensions of well-being into a summary measure, and, if this is the case, on which is the best way to synthetise the selected information into a multidimensional measure. Aggregation methods differ both in terms of theoretical standpoints and use of diverse technical tools. In order to review the ways in which multidimensional poverty can be measured, it is useful to start by sketching a general taxonomy that classifies different methodologies. The most general distinction lies between (a) axiomatic and (b) non-axiomatic approaches to aggregation. In turn, axiomatic measures can be further distinguished in (a.1) axiomatic poverty measures; (a.2) fuzzy set theory. On the other hand, under the tag of non-axiomatic methodologies, the literature has proposed four different approaches: (b.1) Composite indexes; (b.2) Efficiency analysis; (b.3) Latent variables methods; (b.4) information theory.

Figure 1 provides a synthetic overview of the different aggregation methods proposed. The next sections will review the theoretical and methodological differences of the different approaches without passing any judgement on the relative value of each one of them compared to the others. Coherently with the methodological openness of the CA, the choice of one method viz. another ultimately depends on the overall purposes of the analysis, including the value judgments embedded in the evaluation, as well as data availability. Additionally, even though weights are a key building block of the

human values, Sen also argues that it may not be necessary to agree on a precise set of weights: ideally, measures would be developed that are robust to a range of weights" (p.1).

aggregation step, different approaches to weighting will not be discussed in depth here, as an accurate discussion of this issue goes far beyond the scope of the present review.

Figure 1 Different approaches to Multidimensional Measurement



2.3. Axiomatic Approaches

The objective of this section is to present a brief overview of the different approaches that, following the seminal work of Sen (1976), adopt an axiomatic framework to the measurement of poverty phenomena. As discussed in the first Chapter, poverty is a highly complex and vague phenomenon that is difficult to conceptualise and measure (Chiappero-Martinetti 2008), and these inherent difficulties can easily lead disagreement on the estimates based on different poverty measures. Axioms circumvent this fundamental problem by forcing the poverty measure to fulfil a set of desirable postulates, the axioms, which represent joint retrictions on identification and aggregation. Withi the axiomatic framework, each different method is assessed on the basis of the properties it satisfies (Alkire & Foster 2011b). Hence, the axiomatic structure fulfils two main purposes: on the one hand, it avoids that the poverty measure reacts in a casual or contradictory way with respect to the event it is trying to measure; on the other, it allows comparisons of evaluations based on distinct measures that satisfy the same *desiderata*[58].

Beyond the multidimensional axiomatic poverty measures that will be discussed below, there is another family of measures that has recently adopted an axiomatic approach (Chakravarty 2006), the one on Fuzzy Sets Theory[59]. Before reviewing both methodologies, the next section will present the axioms, but first, let introduce notation. Let matrix $X = \begin{bmatrix} x_{11} & \cdots & x_{1d} \\ x_{21} & \cdots & x_{2d} \\ \cdots & & \cdots \\ x_{n1} & \cdots & x_{nd} \end{bmatrix}$ of size *n*x*d* the multidimensional distribution of *d* attributes among *n* individuals, with non-negative elements. x_{ij} is the achievement of individual *i* for attribute *j*, with $i = 1, \ldots, n$ and $j = 1, \ldots, d$. Let M be the set of all *n*x*d* matrices, and vector $\mathbf{z} = (z_1, z_2, \ldots, z_d)$ the cutoff vector containing the thresholds for each attribute, with $\mathbf{z} \in R^d_{++}$. Those thresholds represent the

[58] This last point is the essence of "partial poverty orderings": i.e. under which circumstances two distributions can be unambiguously ranked according to an entire class of poverty measures (Zheng 1997).

[59] Deutsch & Silber (2005) empirically compared these three approaches plus the one on efficiency analysis and found a fair degree of agreement among the four approaches regarding the identification of poor households, which points to the coherence of the axiomatic approaches with other non-axiomatic methodologies (Chakravarty & Silber 2008).

minimum quantities of the *d* attributes necessary to not being considered deprived in the attribute[60]. In this framework, person i will be defined deprived in attribute j depending on whether $x_{ij} < z_j$.

As discussed in Section 2.2.1, different approaches to identification, which can be expressed through the chosen 'identification function' ρ, will then deal to the categorization of the set of the multidimensional poor. The application of ρ to each individual achievement vector in x yields the set Z $\subseteq\{1, \ldots, n\}$ of the multidimensional poor in X given Z. Let ρ: $R^d{}_+ \; x \; R^d{}_{++}$ $\{0,1\}$, where $\rho(x_i;\ z) = 1$ if i is multidimensional poor and $\rho(x_i;\ z) = 0$ otherwise.

The purpose of the aggregation step is to choose a functional form F that, given the deprivation cutoff vector **z**, will associate to the matrix X an overall measure $P(X;z)$ of multidimensional poverty in the population, with P $\in$ R$_{++}$. The most general form of a class of multidimensional poverty measures can be given by the following equation (Bibi 2005):

$$P(X;z) = F\,[\,f(x;z)] \qquad (1)$$

Where $P(X;z)$ is the poverty measure, which associates a level of poverty with X, given the poverty line z; $f\,(\cdot)$ is an individual poverty function, which specifies the way in which the many aspects of poverty must be aggregated at the level of each individual or household, and $F\,(\cdot)$ reflects the various functional forms in which individual poverty levels can be aggregated in order to yield a societal-level measure of poverty. Generally, the properties that both $f\,(\cdot)$ and $F\,(\cdot)$ fulfill will depend on the set of axioms that both functions satisfy.

After having set in general terms the issue of aggregation in multidimensional spaces, let's turn to the axioms. In this case, we can distinguish between a core set of axioms, which have been inherited from unidimensional poverty measurement, and a set of additional axioms that are specific to the multidimensional case. A further distinction relates to those axioms that reflect the introduction of issues related to inequality in the poverty measurement.

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[60] Such a quantitative specification excludes the possibility that the indicator is purely descriptive.

i The Core Axioms

(1) Continuity (CN): CN requires P to vary continuously with x_{ij}[61]. This is a technical assumption that precludes oversensitivity of the poverty index, i.e. dramatic increases in the poverty orderings for small changes will not abruptly affect the index. Therefore, a continuous poverty index will not be oversensitive to minor observational errors on the attributes or on the thresholds[62].

(2) Anonymity or Symmetry (AN): If X is obtained from Y by a permutation[63] of attributes between individuals, then $P(X;z) = P(Y;z)$.

The axiom imposes that all characteristics other than the attributes used to define poverty do not ultimately impact poverty. This ensures that the poverty measure P does not place greater emphasis on some particular individuals or group of persons.

(3) Replication Invariance or Principle of Population (PP): If a matrix X is obtained from Y by a *replication*[64], then $P(X;z) = P(Y;z)$.

This means that if a matrix of attributes is obtained by replicating the original distribution Y a finite number of times, the overall poverty level remains unchanged. This axiom is necessary in order to compare between populations of different sizes, as the poverty index does not depend on population size but on the actual distribution of the attributes[65].

(4) Scale Invariance or Zero-Degree Homogeneity or Unit Consistency (SI): If X is obtained from Y by a *proportional change*[66], then $P(X;z) = P(Y;z)$.

This property forces the poverty measure to be a homogenous function of degree zero in X and z. In this way, the poverty measure is insensitive to a change in the unit of

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[61] For any sequence X^k, if X^k converges to X, then $P(X^k; z)$ converges to P(X; z).

[62] The Headcount Ratio is an example of poverty index that violates this axiom.

[63] The permutation is obtained through: X=PY, where P is a nxn permutation matrix, i.e. a square matrix having a single "1" in each row and column, and a "0" for all remaining entries.

[64] X is obtained by Y by a *k-replication of people* if it is constructed by replicating each *i*th individual's attributes distribution a number of times (i.e. a replication of each row in matrix). This has the effect of reshuffling the vectors of achievements across individuals.

[65] Recently, some scholars have questioned the validity of this apparently innocuous axiom, which is used in both poverty and inequality measurement literature. For a review and a discussion of such implications, see Hassoun and Subramanian (2011). In particular, they showed that in a unidimensional case it is not possible to satisfy simoultaneously replication invariance, poverty focus and transfer.

[66] (X'; z') is obtained from (X; z) by a *proportional change* if (X'; z') = (αX; αz) for some α > 0.

measurement of both the poverty line and the set of individual attributes. In other words, only the relative distance of each attributes to their poverty thresholds ultimately matters.

(5) Normalization (NM): For any (X; z) $\in$ MxZ if $x_{ij} \geq z_j$ for all i and j, then $P(X;z)=0$.

Normalisation is a cardinality property of the poverty index. It merely requires that when no individual is poor, the measure is equal to zero.

(6) Non-decreasingness in Subsistence Levels Attributes (NSD): For any X $\in$ M, P(X;z) is non-decreasing in z_j for all j. This implies that the poverty measure should not decrease as the poverty line rises.

(7) Non-Poverty Growth (NPG): For any (X;z) $\in$MxZ, if X is obtained from Y by adding a rich person to the society, then P(X;z)≤P(Y;z) (Kundu and Smith 1983).

(8) Nontriviality (NT): P has at least two values.

(9) Subgroup Decomposability (SD) (Chakravarty *et al.* 1998): For any

$X^1, X^2, \ldots, X^k \in$ M and z $\in$ Z, $P(X,z)=\sum_{i=1}^{d}\frac{n_i}{n}P(X^i;z)$, where X=($X^1, X^2, \ldots, X^k$) $\in$M

and n_i is the population size associated with X^i and $\sum_{i=1}^{d} n_i = 1$.

This axiom requires that, if a population is divided in k subgroups defined along gender, geographic, ethnic or other characteristics, then the overall poverty measure is the weighted mean of poverty levels within each subgroup, where the weights are the population shares of the subgroups. This property is particularly useful to assess the contribution of each population subgroup to overall poverty, and thus in turn to formulate targeted anti-poverty policies.

ii Axioms specific to the Multidimensional Case

(10) Subgroup Consistency, SC (Tsui 2002): Let $X\begin{bmatrix} X^\alpha \\ X^\beta \end{bmatrix}$ and $Y\begin{bmatrix} Y^\alpha \\ Y^\beta \end{bmatrix}$ with X^α and Y^α (X^β and Y^β) being $n^\alpha \times k$ $(n^\beta \times k)$ matrices. If $P(X^\alpha;z) > P(Y^\alpha;z)$ while $P(X^\beta;z) = P(Y^\beta;z)$, then $P(X;z) > P(Y;z)$. A multidimensional measure of poverty conforms to this axiom if it can be formulated as follows: $P(X;z) = F\left[\sum_{i=1}^{n}\frac{1}{n}f(X;z)\right]$.

Subgroup consistency implies that if an increase in the level of poverty in a given population subgroup occur, *ceteris paribus* the overall poverty measure will increase accordingly (Foster & Shorrocks 1991).

(11) Factor Decomposibility, FD (Chakravarty *at al.* 1998): Under certain conditions[67], overall poverty is a weighted mean of the poverty levels in each single attribute, where $a_j > 0$ (with $\Sigma a_j=1$) is the weight attached to attribute j, $j = 1, \ldots d$, reflecting the importance attached to each attribute j.

An implication of the joint fulfillment of subgroup and factor decomposability is that the poverty measure is additive across sub-groups and factors, which means that it has to be characterized by the following functional form[68]:

$$P(X; z) = \sum_{j=1}^{d} a_j P(x_j;\ z_j).$$

If a measure is additive, it is possible to proceed to "two-way poverty breakdowns" (Chakravarty *et al.* 1998), which measure the contributions with respect to different attributes of different subgroups to total poverty. The poverty measure can be rewritten as follows:

$$P(X; z) = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{d} f_j\left(x_{ij}; z_j\right),$$

which means that it can be obtained by averaging the measure for each individual i or by taking population share weighted average of the measure with respect to the attributes. In this case, the latter are independent, which means that the condition regarding the first mixed derivatives below is automatically met (Bibi 2005):

$$\frac{\delta^2(x_i; z)}{\delta x_{ij}\delta x_{i,j}}$$

As Chakravarty *et al.* (1998) noted, this kind of poverty breakdown is finer than the ones done for subgroups or factors. Identification of most afflicted subgroup-attribute

[67] These conditions relate to a subgroup decomposable index which respects the One-Dimensional Transfer Principle (OTP), and at the same time possesses first-order partial derivatives (Bourguignon & Chakravarty 2003).

[68] As opposed, for instance, to the following multiplicative extension of a FGT measure, which is not additive: $P(x_i; z) = \prod_{j=1}^{d}\left(\frac{z_j - x_{ij}}{z_j}\right)^{\alpha_j}$ (Bibi 2005).

combination becomes particularly important when the resources to implement antipoverty policies are particularly limited. An example of two-way poverty profile is the following (Chakravarty *et al.* 1998):

Table 2.1. Two-way poverty profile.

	Subgroup		
Attribute	1	2	Average Poverty
1	P11	P12	P1.
2	P21	P22	P2.
Average Poverty	P.1	P.2	P

Source: Chakravarty et al. (1998), p. 181.

In this simple case, the poverty measure can be obtained by taking the simple average of $P_{1\cdot}$ and $P_{2\cdot}$ or by taking population share weighted average of $P_{\cdot 1}$ and $P_{\cdot 2}$.

(12) Focus: Bourguignon and Chakravarty (2003) introduced a differentiation between strong and weak focus as follows. In their papers, Alkire & Foster (2007, 2011b) adopted such a distinction, but called it poverty and deprivation focus respectively[69].

12a) Weak or Poverty Focus, WF: If X is obtained by Y from a simple increment to *a non-poor person*[70], then: $P(X;z) = P(Y;z)$.

The poverty measure does not change if an attribute j increases for an individual i characterized by $x_{ij} \geq z_j$.

If this axiom is imposed, poverty measurement – as opposed to inequality measurement- depends exclusively on the outcomes of the poor only while ignoring the rest of the population. The intuition underneath this axiom is directly opposed in

[69] The two forms of focus axioms are related in certain cases. When the union approach to identification is used, it can be shown that the deprivation focus axiom implies the poverty focus axiom. When an intersection approach is used, the poverty focus axiom implies the deprivation version. Bourguignon and Chakravarty (2003), for example, assume the deprivation focus axiom (their 'strong focus axiom') along with union identification, and so their methodology automatically satisfies the poverty focus axiom.

[70] X is obtained from Y by a simple increment among the non-poor if:
$x_{i'j'} > y_{i'j'}$ for some (i, j) = (i', j') if i' $\in$ Z
$x_{i'j'} = y_{i'j'}$ for (i, j) $\neq$ (i', j').

spirit the Non-Poverty Growth one, which requires that poverty should decline with the addition of a non-poor person to the population.

12b) Strong or Deprivation Focus, SF: If X is obtained from Y from a *simple increment among the non-deprived attributes*[71] or dimensions, then $P(X;z) = P(Y;z)$.

In contrast with the weakest version of the axiom, the strong focus requires the index be indifferent of the attribute levels in which the individual is not deprived – even if this person is poor with respect to other attribute(s). As Lugo & Maasoumi (2008) stressed, the strong focus reflects the idea of essentiality of attributes embedded in the union approach.

(13) Monotonicity: According to this axiom, the poverty measure declines, or at least does not arise, following an improvement in a poor's individual attributes. There are three versions of the axiom: a first, standard one, mutuated by the unidimensional case, which consider a simple increment (*weak monotonicity).* There are also two stronger requirements, which are extensions of the former. If X is obtained from Y by a *deprived increment among the poor* in addition to a simple increment, we will have *monotonicity* tout court or *monotonicity within dimensions*. Moreover, if X is obtained from Y by a *dimensional increment* among the poor, we will have *dimensional monotonicity* (Alkire & Foster 2007, 2011b). In other words, a deprived increment among the poor improves a deprived achievement in one attribute of a poor person, while a dimensional increment removes entirely her deprivation in that attribute.

13a) Weak Monotonicity (WM): if X is obtained from Y by a deprived increment, then $P(X;z) \leq P(Y;z)$.

13b) Monotonicity or Monotonicity within Dimensions (MN): if X is obtained from Y by a deprived increment among the poor[72] then $P(X;z) < P(Y;z)$.

13c) Monotonicity across Dimensions (DM): if X is obtained from Y by a *dimensional increment among the poor*[73], then $P(X;z) < P(Y;z)$.

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[71] X is obtained from Y by a simple increment among the non-deprived if:
$x_{i'j'} > y_{i'j'}$ for some (i, j) = (i', j') if $y_{i'j'}$
$x_{i'j'} = y_{i'j'}$ for (i, j) $\neq$ (i', j').

[72] X is obtained from Y by a deprived increment among the poor if:
$x_{i'j'} > y_{i'j'}$ for some (i, j) = (i', j'), where
$y_{i'j} < z_{j'}$ and i' $\in$ Z
while $x_{i'j'} = y_{i'j'}$ for (i, j) $\neq$ (i', j').

[73] X is obtained from Y by a dimensional increment among the poor if:

As noted by Bibi (2005), a consequence of the monotonicity axiom is that isopoverty[74] curves are not increasing; this implication reflects the obvious fact that the relation between poverty and its constituents must be of an inverse type, i.e. that as achievements in each attribute improve, resulting poverty will be decreasing:

$$\frac{\delta P(x_i; z)}{\delta x_{ij}} \leq 0 \ if \ x_{ij} < z_j.$$

iii ***Distribution-sensitive Axioms***

The next set of axioms reflect to different extent the argument advanced by Sen (1976) when suggesting that poverty measures should be sensitive to inequalities within the poor population. Sen pointed out that, whenever inequality among the poor decreases following a Pigou-Dalton transfer, poverty should at least not increase. This argument leads to the extension of the Pigou-Dalton principle to the multidimensional case, which in turn establishes a partial poverty ranking based on the degree of inequality of the distributions of attributes.

Poverty measures satisfying the axiom of transfer have become known as distribution-sensitive poverty measures. These measures satisfy the twofold goal of distinguishing between poverty eliminating, alleviating and redistributing policies on the one hand; and prioritizing assistance to the poorest individuals on the other. Conversely, some distribution insensitive measures, such as, for instance, the headcount ratio, have the counterintuitive characteristic of prioritizing the least poor.

(14) Uniform Pigou-Dalton Transfer or One-dimensional Transfer Principle (UPD): If X is obtained from Y by a Uniform Pigou-Dalton Progressive Transfer of attribute *j* among the poor[75] (an *averaging* of achievements between the two people), then $P(X;z) \leq P(Y;z)$

In other words, matrix X and Y are exactly the same, except for attribute *j* – where the more deprived individual has obtained, after the transformation, λ units more of *j* in X

$x_{i'j'} \geq z_j > y_{i'j'}$ for some (i, j) = (i', j') where i' ∈ Z,
while $x_{i'j'} = y_{i'j'}$ for (i, j) ≠ (i', j').

[74] An isopoverty curve indicates the various vectors $\boldsymbol{x_i}$ that yield the same level of individual poverty, i.e. P (x_i ; z)= P

[75] X is obtained from Y by a Uniform Pigou-Dalton Transfer among the poor (UPD) if X=TY where T=λE+(1-λ)P (with 0<λ<1), with t_{ii}=1 for every non-poor person *i* in Y; E is an identity matrix and P is a permutation matrix that interchanges two rows. Through this transformation, the distribution of the attributes has been smoothed between the individuals.

than Y, while the less deprived has λ units less of that attribute. It is quite reasonable that overall poverty should not increase after such a progressive transfer.

The following axiom is an extension of the UPD principle to the multidimensional case. Tsui (2002) generalized the multidimensional transfer principle introduced by Kolm (1977), according to which a distribution of set of attributes summarized by matrix X is more equal than another matrix Y if and only if X=BY, where B is a bistochastic matrix and X cannot be derived by a permutation of the rows of Y. In other words, X is less unequal than Y because it is the result of a transformation equivalent to replacing the original bundles of attributes in Y of any pairs of individuals with their convex combination.

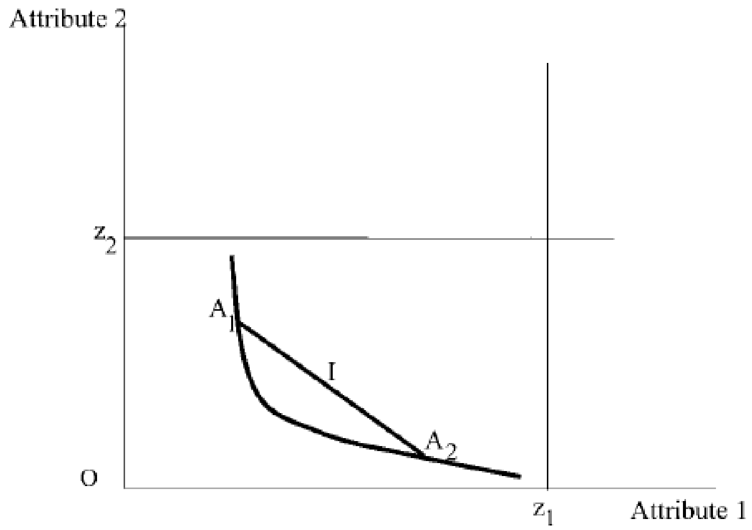
(15) Uniform Majorization or Multidimensional Transfer Principle (UM): If X is obtained from Y by a *uniform majorization among the poor* [76] (an averaging of achievements among the poor), then $P(X;z) < P(Y;z)$.

As

[76] X is obtained from Y by a *Uniform Majorization among the Poor* (an averaging of achievements among the poor) if X=BY, where B is a *nxn* bistochastic matrix but not a permutation matrix and b_{ii}=1 for every non-poor person *i* in Y. As bistochastic matrices of order n are the convex hull of the set of permutation matrices (of order n), the resulting distribution of the attributes has been smoothed among the two individuals. It has to be stressed that any permutation matrix T is a bistochastic matrix B, but the converse is not true. Then UDP implies UM, but the converse does not hold.

Figure 2 shows, this axiom states that the convex combination of of attributes (point I) is preferred to more extreme solutions such as the ones provided by points A1 and A2 (Bourguignon & Chakravarty 2003).

Figure 2 Convexity of isopoverty contours in the two-attributes case. Source: Bourguignon and Chakravrarty (2003, p. 33)



Hence, the transfer principle requires that isopoverty curves must be convex to the origin, which can be expressed by the following condition:

$$\frac{\delta^2\pi(x_i;z)}{\delta x_{ij}\delta x_{i,j}}0, \qquad \forall\, x_{i,j}<z_{i,j}$$

The axioms presented so far have only provided two different information on isopoverty contours: first, they are decreasing as a consequence of monotonicity, and secondly, they are convex as a result of the transfer axiom. However, the transfer principle and its multidimensional extension in the form of uniform majorization perfectly accounts for poverty severity in a one-dimensional framework, but in multidimensional spaces they cover only inequality *within* the poverty dimensions, but not *between* them (Rippin 2010, 2011). For this reason, a further set a set of axioms were introduced to model the responses of the poverty measure when in the cases of switches of attributes between two individuals, which can affect (i) the inequality and (ii) the correlation between the dimensions of poverty.

With respect to the first case, Rippin (2010) provided an illustration of a (cardinal) case in which inequality is decreasing after a switch of one attribute among two individuals, which is not covered by the UM axiom:

$$i = 2,\ j = 3,\ z = (4 \quad 4 \quad 4)$$

$$Y_1 = \begin{pmatrix} 3 & 4 & 4 \\ 1 & 1 & 4 \end{pmatrix}; \quad X_1 = \begin{pmatrix} 2 & 4 & 4 \\ 2 & 1 & 4 \end{pmatrix} \qquad a) \quad Transfer$$

$$Y_2 = \begin{pmatrix} 3 & 4 & 4 \\ 2 & 1 & 4 \end{pmatrix}; \quad X_2 = \begin{pmatrix} 2 & 4 & 4 \\ 3 & 1 & 4 \end{pmatrix} \qquad b) \quad Switch$$

In the case of transfer, the poorest individual is better off in X_1 since she has been provided with an additional unit of an attribute in which both individuals are deprived. As required by the UM, overall poverty will decrease. Conversely, in the second case, the switch between the two individuals renders the poorer one better off in X_2 with respect to the initial situation Y_2. Intuitively, poverty should decrease as well, but unfortunately the UM does not cover the eventuality of a switch in attributes. This is the reason why the following axioms were introduced. Before presenting the axioms, let introduce two basic definitions first.

Definition a: Weak Inequality Decreasing (Increasing) Switch: X is obtained from Y by a weak inequality decreasing (increasing) switch[77] of attribute *l* from one *poor* individual *g* to another poor individual *h* if, after the switch, the poorer individual is left with a higher (smaller) amount of an attribute with regard to which both individuals are deprived.

Definition b: Strong Inequality Decreasing (Increasing) Switch: X is obtained from Y by a strong inequality decreasing (increasing) switch[78] of attribute *l* from one *poor* individual *g* to another poor individual *h* if, after the switch, the number of dimensions in which the poorer individual is deprived are reduced (increased).

(16) Nonincreasingness under Weak (Strong) Inequality Decreasing Switch (NIW(S)): For any (Y; *z*) $\in$ K x Z, if X is obtained from Y by an inequality

[77] For some individuals *g* and *h:*
$d_g > d_h > 1$, $x_{ij} < z_j$;
$y_{gl} < y_{hl} < z_j$;
$x_{gl} = y_{hl} < z_l$; $x_{hl} = y_{gl} < z_l$;
$x_{ij} = y_{ij}\ \forall i \neq g, h;\ \forall j \neq l.$

[78] For some individuals *g* and *h:*
$d_g > d_h > 1$, $x_{ij} < z_j$;
$y_{gl} < z_j \leq y_{hl;}$
$x_{gl} = y_{hl} \geq z_l$; $x_{hl} = y_{gl} < z_l$;
$x_{ij} = y_{ij}\ \forall i \neq g, h;\ \forall j \neq l.$

decreasing switch between two poor individuals, then $P(X;z) \leq P(Y;z)$ (or $P(X;z) \geq P(Y;z)$).

These two axioms render the measure sensitive to the number of dimensions in which the person is deprived. Moreover, note that a measure that fulfills Uniform Majorization will automatically also require NIW, in order to avoid possible anomalous judgments on poverty rankings (Rippin 2011).

The second aspect of inequality that is not covered by the UM relates to the issue of the *relation* between the attributes. According to Chakravarty and Silber (2008), the following properties tackle the "*essence of multidimensional measurement*" (p. 196).

Tsui (2002), by building on Atkinson & Bourguignon's work (1982), was the first author to take into account of this aspect in the case of substitute attributes for multidimensional poverty measurement. Later on, Bourguignon & Chakravarty (2003) extended Tsui's formulation to the case of complement attributes. In particular, the following axiom deals with the implications in terms of poverty measure in the case that after a switch the correlation between the attributes increase. As pointed out by Bourguignon and Chakravarty (2003), the effect of a correlation increasing switch on the poverty measure, as well as policy responses to multidimensional poverty, will ultimately depend on the relationship between the attributes, i.e. whether they are substitutes, complement, or independent from each other[79].

For instance, if *a* and *b* are two substitute attributes (in the sense they lead to similar outcomes), the more an individual already has of *a*, the less overall poverty will decrease when her quantity of *b* increases after the switch. The overall decrease would have been more pronounced whether the individual was more deprived in *a*. Additionally, the decrease in poverty for the individual who has gained from the switch does not offset the overall loss of the other individual who participated in the

[79] In standard microeconomic theory, whether two goods x_1 and x_2 are substitutes, complements, or independent depends on the behavior of the cross derivatives of the utility function. In the former case, if cross derivative is non-positive, attributes are substitutes. Conversely, if cross derivative is non-negative, attributes are complement. Finally, when the cross-derivative is equal to 0, the two attributes are independent from each other, i.e. the utility deriving from an increase in attribute x_1 does not affect the utility deriving from the available quantity of attribute x_2. Analogously, the literature on axiomatic approaches to poverty has identified two attributes as substitutes, complements or independent in case the second partial cross-derivative of the poverty measure with respect to these attributes is, respectively, positive, negative, or zero. In other words, substitute (complement) attributes are such that the marginal utility of one attribute decreases (increases) when the quantity of the other increases.

switch, who is now deprived in both the attributes. Substitutability hence implies that governments should target first the ones who suffer from multiple deprivations, even though it may be harder to reach them[80] (Tsui 2002; Bourguignon & Chakravarty 2003): for instance, an increased access to health services for those who are poorer in the income dimension can be more justifiable than for those who are relatively better off from a monetary perspective (Duclos et al. 2006).

Conversely, when two attributes are complementary in the process of expanding well-being, there may be ethical reasons to target people who already own a fair amount of *a* in order to increase their dotation of *b*. For instance, there may be strong complementarities between children's cognitive and non-cognitive inputs in the production of later skills[81] (Cunha et al. 2006; Heckman & Cunha 2007), or between nutrition and other human development dimensions. If such complementarity is strong enough, policy-makers may decide to target those individuals that are better off in one attribute in order to increase the correlation between well-being dimensions and penalize the multiply deprived ones, so that overall poverty can be reduced by increasing the incidence of multiple deprivations[82] (Bourguignon & Chakravarty 2003; Duclos *et al.* 2006).

(17) Non-Decreasing Poverty Under a Correlation-Increasing Switch (NDCIS)[83]: For any $(Y;z)\in M\text{x}Z, (X;z)\in M\text{x}Z$, if $X\in K$ is obtained from Y by a correlation increasing switch of two *substitute* attributes between two poor individual, then:

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[80] Bourguignon & Chakravarty (2003) also discuss the possibility that the degree of substitutability between two attributes is not fixed, but increases of decreases depending on the extent of poverty. It is plausible to assume that the elasticity of substitution between dimensions of poverty is of minor importance when one is very deprived in one of the two dimensions. For instance, if somebody is extremely far below the poverty line in terms of food, the contribution of a small shortfall in education is probably rather immaterial for evaluating his overall poverty. On the contrary, if both attributes fall shortly of the poverty line for a small amount, the contribution of the deprivation in education will become stronger in determining overall poverty. Analytically, a way to allow for substitutability of attributes be linked to the levels of poverty is to render the parameter on the elasticity of substitution between the attributes a function of the level of poverty.

[81] The issue on complementarities across deprivations and their reflections on later human development outcomes will be discusssed in more depth in Chapter 7.

[82] This possibility, by overcoming the ethical considerations that would favour the multiply-deprived, shows how much value judgments and ethical considerations are embedded in poverty analysis and measurement.

[83] This axiom has been called in various ways: from Y to X: association increasing rearrangement (Alkire and Foster 2007); from X to Y: association decreasing rearrangement (Boland and Proschan 1988); correlation increasing transfer (Tsui 1999), correlation increasing switch (Bourguignon and Chakravarty 2003).

$P(X;z) \geq P(Y;z)$.

(18) Non-Increasingness under Correlation Increasing Switch (NICIS): For any $(Y;z) \in MxZ$ and $(X;z) \in MxZ$, if $X \in K$ is obtained from Y by a correlation increasing switch of two *complement* attributes between two poor individual, then:

$$P(X;z) \leq P(Y;z).$$

Poverty is non-increasing subsequent to a rise in the correlation between two attributes when these attributes are complements.

To wrap up, the axiom of UM only takes into account inequality *within* dimensions, while it leaves out the issues of inequality *between* dimensions and of the *relationship* between the attributes. For this reason, the axioms of inequality decreasing switch and correlation increasing switch were later introduced in the literature by Tsui (2002), Bourguignon & Chakravarty (2003), and Rippin (2010).

2.3.1. An Overview of the Most Common Functional Forms for Axiomatic and Multidimensional Poverty Indexes

Each set of axioms adopted leads to a different class of measures, as the fulfilment of one set will necessarily lead to the violation of another. For this reason, there is no “best poverty measure” in absolute terms: as many other decisions involved in poverty measurement, the choice on whether preferring one measure with respect to the others is dependent on the overall purposes of the analysis and on the context in which the overall measurement is conducted.

Additionally, even though the empirical literature on the topic has been flourishing over the last fifteen years, the theoretical papers that developed different classes of measures can be counted on one’s fingers. Different contributions can be described according to (i) the selected approach to identification or (ii) the set of axioms fulfilled by the measure. In this review, we adopt a chronological approach to the presentation of those contributions, starting from the first, seminal paper that proposes a multidimensional and axiomatic class of poverty measures by Chakravarty *et al.* (1998). The basic premise of this work was to develop a class of multidimensional measure that could be decomposable with respect to both subgroups of population and different attributes, in order to derive those useful “two-way poverty profiles” that have been discussed in the previous section. In doing so, Chakravarty and collegues adopted a union approach to identification, i.e. one deprivation in one attribute is sufficient in order to identify the person in the set of the poor. The resultant class of poverty measures is characterised by the following general form:

$$P(X;z) = \frac{1}{n}\sum_{i=1}^{n}\sum_{j}^{d} a_j\, f\left(\frac{x_{ij}}{z_j}\right) \qquad (2)$$

Chakravarty *et al.* (1998) demonstrated that (1) is the only family of measures satisfying CN, SD, FD, SI, SF, MN, UM, NM. In particular, depending on the functional form f selected, the index will assume different characterizations[84]. In particular, when:

$$f(t_{ij}) = (1 - t_{ij})^{\theta_j}$$

where $t_{ij} = \frac{x_{ij}}{z_j}$ and $\theta > 1$ is the parameter of inequality aversion, the index results as being a multidimensional extension of the FGT (1984) class of measures:

$$P_\theta(X;z) = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{d} a_j\left(1 - \frac{x_{ij}}{z_j}\right)^{\theta_j} \qquad (2a)$$

When the individual poverty function f is logarithmic, such as:

$$f(t_{ij}) = -ln(t_{ij}),$$

where $t_{ij} = \left(\frac{z_j}{x'_{ij}}\right)$ and $x'_{ij} = min\{z_j, x_{ij}\}$, the resulting index is the multidimensional extension of the Watts (1968) index:

$$P_W(X;z) = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{d} a_j \ln\left(\frac{z_j}{x'_{ij}}\right) \qquad (2b)$$

Finally, when $f(t_{ij}) = 1 - t_{ij}^{cj}$ and $0 < c_j < 1$, the resulting index is a multidimensional extension of the subgroup decomposable Chakravarty (1983) index:

$$P_C(X;z) = \frac{1}{n}\sum_{i=1}^{n} a_j \sum_{j=1}^{d}\left(1 - \left(\frac{x_{ij}}{z_j}\right)^{c_j}\right) \qquad (2c)$$

Note that the additivity of the Chakravarty *et al.* (1998) family of measures rules out the possibility of fulfilling correlation-increasing switch axioms. In other words, the

[84] This section heavily draws on Chakravarty & Silber (2008).

attributes are considered independent from each other. A few years later, the works by Tsui (2002) and Bourguignon and Chakravarty (2003) contributed in the direction of understanding the effects on the resulting poverty measure when the hyphotesis of independence is abandoned and the correlation between the attributes is taken into account.

In particular, Tsui (2002) by building on the seminal contribution by Atkinson and Bourguignon (1982), made a first attempt to understand the way in which how different deprivations tend to be associated rather than being independently distributed one from the other through the following

These features are reflected in following measure, which is a non-additive multidimensional extension of the index developed by Chakravarty in 1983:

$$P_{C2}(X;z) = \frac{1}{n}\sum_{i=1}^{n}\left(\prod_{j=1}^{d}\left(\frac{z_j}{x'_{ij}}\right)^{r_j} - 1\right) \qquad (3)$$

with $r_j \in [0,1]$. By allowing for the correlation across the attributes, the possibility of factor decomposability is inevitably ruled out, as cross-derivatives are now different from zero. In particular, the latter are negative, implying that the attributes can be only substitutable in Tsui's formulation. Additionally, as the measure is multiplicative, no individual weighting function is required because NIW is automatically fulfilled. This not only means that all the deprived individuals are considered poor (as Tsui adopted an union approach to identification), but also that they are implicitly weighted on the basis of their degree of deprivation.

Bourguignon and Chakravarty (2003) pushed further Tsui's idea regarding correlation across attributes by allowing the attributes being either substitutes or complements in a new general class of subgroup decomposable poverty measures. By taking transformations (obviously, not necessarily additive) of the individual poverty gaps in different attributes, they specified the new class of poverty indexes that fulfills NDCIS or NICIS, depending on the functional form f adopted. In particular, they explored the implications of adopting the appealing constant elasticity of substitution (CES) functional form, resulting in the following measure:

$$P_{\alpha,\gamma}(X;z) = \frac{1}{n}\sum_{i=1}^{n}\left(\sum_{j=1}^{d} a_j\left(1 - \frac{x'_{ij}}{z_j}\right)^{\gamma}\right)^{\frac{\alpha}{\gamma}} \qquad (4)$$

With $a_j > 0$; $\sum_{j=1}^{d} a_j = 1$; $\alpha \geq 1$; $\gamma \geq 1.$ For each individual the poverty shortfalls in each attribute are first aggregated into an average shortfall with parameter γ and weights a_j (Chakravarty & Silber 2008). As γ increaseas, the isopoverty curve becomes more convex. Multidimensional poverty is then defined as the average of those shortfalls raised to the power α in the population. The latter is a measure of sensitivity towards extreme poverty. $\alpha \geq 1$ ensures that the transfer principle for a single dimension is fulfilled, while when $\alpha \geq 1, \gamma \geq 1$ extends this principle to individuals that are simultaneously poor in many dimensions. In the case of only two attributes, the index becomes the following (Bibi 2005):

$$P_{\alpha,\gamma}(X;z) = \frac{1}{n}\sum_{i=1}^{n}\left(\left(\frac{z_1 - x_{i,1}}{z_1}\right)^{\gamma} + a^{\frac{\gamma}{\alpha}}\left(\frac{z_2 - x_{i,2}}{z_2}\right)^{\gamma}\right)^{\frac{\alpha}{\gamma}} \qquad (4a),$$

where the positive value of a reflect the relative weight of the second attribute viz. the first one.

Bourguignon & Chakravarty's index requires the fulfilment of either NDP or NIP depending on the relationship between the two parameters γ and α: when attributes are considered substitutes ($\gamma \geq \alpha \geq 1$), the poverty measure will fulfil NDCIS. Conversely, when attributes are complement ($\alpha \geq \gamma$), the measure will then satisfy NICIS. Additionally, for very high values of γ ($\gamma \rightarrow \infty$), attributes are considered perfect complements[85]. On the other hand, when γ is equal to 1, attributes then become perfect substitutes. This is equivalent to the hypothesis underlying the monetary approach, in which all the constituent dimensions are deemed being substitutes[86] (Chapter 1). With respect to Tsui's methodology, Maasoumi and Lugo (2006) noted that the formulation proposed by Bourguignon & Chakravarty has the twofold advantage of rendering explicit the role of the weights, whether explicit or implicit, in the measure, and of being broader by providing a more general form for F in (1) above.

Up to now, all the indexes reviewed took a union approach to identification, which, has discussed earlier, entails an inflation of the number of the poor, and a mistargeting of the most severely deprived people. In order to counter those disadvantages, Alkire

[85] In the case of d=2, the isopoverty contours wills assume the shape of Leontief curves.

[86] In the bidimensional case, the isoverty countours are straight lines.

& Foster (2007, 2011b) proposed a new, intermediate approach to identification, the dual cutoff method. The innovation brought about by Alkire and Foster relies on a simple, yet powerful, idea: if only one deprivation and all deprivations are respectively too weak and too strict requirements in order to identify the set of the poor, an intermediate cutoff, k, can be used for identification. As 1< k < d, both the union and the intersection approaches are special cases of the 'dual cutoff' method of identification. The 'duality' of the identification process lies in the fact that now two main thresholds are needed: the first one is the dimensional poverty line z_d, i.e. the minimum threshold to set the deprivation within each attribute, while the other is the cross-dimensional cutoff k, which aims at counting in how many dimensions the person is deprived. Basically, after having identified *deprivations* through dimension-specific cutoff, deprivations are aggregated in order to identify the poor. In particular, the aggregation is allowed through the following class of measures that extend in multidimensional spaces the well-known FGT family:

$$P_{AF}(X;z) = \frac{1}{nk}\sum_{i=1}^{n}\sum_{j=1}^{d} a_j^{\beta} f(x_{ij}) \qquad (5),$$

with $\beta \geq 0;\ w_j > 0; \sum_{j=1}^{k} w_j = k; f(x_{ij}) = \begin{cases} 1 & if\ x_{ij} < z_j \\ 0 & if\ x_{ij} > z_j \end{cases}$.

In her contribution, Rippin (2010) criticized the Alkire & Foster method by arguing that the setting of the dimensional cutoff k introduces a further element of arbitrariness in the measure. She then deals with the issue of identification directly in the aggregation step through the introduction of the axioms related to the inequality decreasing switches (NIW(S)). When the latter are imposed to the measure, an identification function $\psi(d_i)$ that is increasing in the number of attributes in which the individuals are deprived is implicitly introduced. $\psi(d_i)$ identifies as poor all the individuals that are deprived in at least one dimension, and then weight them on the basis of the number of dimensions in which they are deprived. By doing so, Rippin (2010) obtains a new family of decomposable poverty measures that is sensitive to the distribution among different attributes:

$$P_R = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{d} a_j \zeta(d_i, x_{ij}) \qquad (6),$$

with $a_j > 0$; $\sum_{j=1}^{d} a_j = 1$; $\zeta(d_i; x_{ij}) = \begin{cases} \psi(d_i) & if\ x_{ij} < z_j \\ 0 & if\ x_{ij} > z_j \end{cases}$ and $\varphi(d_i) \in (0, 1]$ non-decreasing in d_i.

The advantage of Rippin's measure is that it is the only family of additive measures that satisfies NDS, which means that is also distribution-sensitive. This follows the two-step procedure she developed in order to measure multidimensional poverty. First, individuals are identified as poor through the union method, and then they are are weighted according to the degree of deprivation they experience. As a second step, individual poverty levels are aggregated in a population-level poverty measure[87].

2.3.2. Measures based on Fuzzy Set Theory

Although many of the contributions in the literature of fuzzy set theory do not explicitly refer to some axioms, this approach can be still considered as part of the broader family of axiomatic measures as some authors have offered a fuzzy reformulation of the axioms for inequality (Basu 1987) and poverty measurement (Chakravarty 2006). Measuring poverty through Fuzzy Set Theory has been gaining increasing attention since the beginning of the 1990s. The basic idea behind the approach is that poverty is a "broad and opaque concept" (Sen 1993), which can be seen as a continuum of different deprivation states: *"Poverty is certainly not an* attribute *characterising an individual in terms of* presence *or absence but it is rather a* vague predicate *that manifests itself* in different shades and degrees*"* (Cheli & Lemmi 1995, p. 118, *italics in the original*). For instance, the assessment of a given attribute can be conducted either through determining whether the person is completely deprived in that attribute or her endowment is above the deprivation threshold, or by assessing the actual degree of achievement in the attribute itself. By following the second route, fuzzy set methods go beyond the dichotomous identification of the poor imposed by poverty lines or deprivation thresholds through the use of a generalised membership function, which assigns a value between 0 and 1 based on the degree of deprivation experienced by the person in the attribute (Chiappero-Martinetti 2000). In this way, fuzzy methods are able to better capture the intrinsic complexity of the

[87] Rippin also showed that the other indexes presented in this review can be modified in order to fulfill the NDS axiom.

poverty concept, and, at the same time, to avoid the discard of precious information that would have been otherwise lost in the case of clear-cut dichotomisations[88].

More formally[89], given a set X of elements x ∈ X, any fuzzy subset A of X is defined as follows: $A \in \{x, \mu_A(x)\}$, where $\mu_A(x)$: X → [0,1] is the *membership function* in the fuzzy subset A. The value $mA(x)$ indicates the degree of membership of x in A. Thus , $\mu_A(x) = 0$ indicates that x does not belong to A, while $\mu_A(x) = 1$ that x completely belongs to A. With $0 < \mu_A(x) < 1$, x only belongs to A partially and its degree of membership of A increases as $\mu_A$tends to 1. This means that the fuzzy formulation encompasses the standard dichotomous case, which now becomes a special case of the fuzzy approach (Cheli & Lemmi 1995). The choice of the membership function is hence a critical step if this approach, and will depend on the context and purposes of measurement (Chiappero-Martinetti 2000). A second challenge regards the rules for manipulating the resulting fuzzy sets, which is critically linked to the set of axioms chosen to identify and aggregate the resulting sets (Betti *et al.* 2008).

2.4. Non-Axiomatic Approaches

Under the general tag of 'Non-Axiomatic Approaches' there are four main families of highly heterogeneous methodologies for multidimensional poverty measurement: (i) Composite indexes; (ii) Efficiency analysis tools; (iii) Latent variables methods; (iv) Information theory. Their commonality lies in the fact that neither of them requires the measure to fulfil a set ox axioms.

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[88] An early attempt to incorporate these concepts in multidimensional poverty measurement was conducted by Cerioli and Zani (1990) by building on the seminal contributions by Zadeh (1965) on "Fuzzy Sets Theory". Their approach was later developed by Cheli and Lemmi (1995), which called it *Totally Fuzzy and Relative Approach* (TFR), and then by Cheli (1995), Brandolini and D'Alessio (1998) and Chiappero-Martinetti (2000, 2006). Since the first contribution by Cerioli and Zani (1990), the approach basically pursued two distinct research agendas (Betti et al. 2008). The first is related to track poverty over time and poverty dynamics (Cheli and Betti, 1999; and Betti *et al.*, 2004) via the use of transition matrices. Another focused more on capturing the multi-dimensional aspects of poverty and developed the concepts of 'manifest' and 'latent' deprivation to reflect the intersection and union of different dimensions (Betti & Verma 1999) and Verma and Betti (2002).

[89] This section draws on Cheli & Lemmi (2005).

2.4.1. Composite Indexes

Composite indexes represent the most basic way to combine multiple attributes into a summary measure. The analysis of the order of aggregation (as discussed in Section 2.2.2) is useful to distinguish between two main types of composite indices: a first that combines indicators which were previously aggregated across individuals (e.g. data at the national level), while a second one aggregates multiple indicators or dimensions at the individual or at the household level first, and then across individuals next in order to derive a measure for the whole population (Bibi 2005).

With respect to the first group, the UNDP *Human Poverty Index*[90] (*HPI*, Anand & Sen 1997, UNDP 1997), represents the first tentative to provide national-level estimates of human poverty in three main dimensions of deprivations[91] (health, education and standards of living) based on the CA . National-level indicators on life expectancy (HPI_1), adult literacy (HPI_2), and a composite index aimed at capturing material welfare (composed by three indicators on access to health care and safe water, and the percentage of malnourished children) (HPI_3) are combined in the following way:

$$HPI = (w_1 HPI_1^{\theta} + w_2 HPI_2^{\theta} + w_3 HPI_3^{\theta})^{\frac{1}{\theta}},$$

Where w_i is the weight attached to dimension i; $w_1 + w_2 + w_3 = 1$, and $\theta \geq 1$.The value of the parameter θ is of critical importance for the rankings the HPI conveys. Analogously to FGT (Foster *et al.* 1984) indexes, when θ is equal to one, the HPI reduces to a mere arithmetic mean, whereas as θ increases greater weight is attached to the most deprived dimensions. Finally, as θ goes towards infinity, the index will tend to assume the value of the indicator in which deprivation is greatest. In the actual calculations of the HPI θ is equal to 3. As such, cardinal and ordinal comparisons will be sensitive to the arbitrary values assigned to both the weights and the parameter θ.

A second type of composite indicators employs micro data in order to aggregate first across dimensions for the same unit of analysis, and then across units. An example is the measure of multidimensional poverty in the European Union provided by Smeeding *et al.* (1993), which summarises information on multiple deprivations

[90] In 2010 the index has been substituted by the Multidimensional Poverty Index based on the Alkire-Foster methodology (Alkire & Santos 2010).

[91] There is also another version of the HPI that was developed in order to capture poverty in advanced economies. See UNDP (2011).

(health, housing, education, and income poverty). . Although the authors refer to their index as a "multidimensional metrics", in practice it does not differ much from standard monetary assessments because the price values of non-income dimensions have been imputed for aggregation. Through their methodology, Smeeding *et al.* (1993) merely extended the traditional income approaches by incorporating into the measure a set of non-monetary dimensions, which is different from using the "direct method" of multidimensional evaluation advocated by Sen (1992) (Chapter 1). This is also complicated by the difficulties of imputing monetary values for some dimensions that have the nature of public goods or quasi public goods, such as education, which is deeply problematic.

2.4.2. Methods Based on Efficiency Analysis or Distance Functions

Lovell *et al.* (1994) borrowed from the literature on efficiency analysis and distance functions used in production models to develop an original framework for aggregating multiple dimensions of well-being in a CA framework. Distance functions are a tool typically employed in production economics to measure the distance between a set of inputs and a set of outputs. The innovation of Lovell and his colleagues was to extend a methodology typically used in microeconomics to measure productivity through distance functions to the measurement of the well-being obtained from a given bundle of resources. The two problems, in fact, share the goal of obtaining a summary measure of achievement starting from a wide range of information (Ramos 2005). With this aim, Lovell et al. (1994) estimated three different distance functions, which respectively capture various aspects of well-being: (i) standards of living; (ii) quality of life; (iii) transformation efficiency. While the former index captures material well-being, the second provides a measure of achieved functionings, and they were respectively calculated through inputs and outputs distance functions. Finally, the third one provides a measure of the individual proficiency in converting available resources in well-being outcomes, or in the CA framework, of the individual conversion factors through an additional output distance function. As for the purposes of this Chapter, the reader will be provided merely with the intuition behind this work, while formal aspects of the methodology will not be covered. An input distance function measures the radial distance θ of the well-being achieved by an individual with respect to a given baseline. The latter is an iso-wellbeing curve, i.e. the set of inputs that all yield the same functioning or well-being level, which, for simplicity, is set equal to one. The higher the value of the input distance function (or alternative, the farthest is from that baseline), the higher the levels of well-being achieved for that individual. Hence, by construction, the input distance function θ will be equal or higher than one, for those individuals that have large resources vectors. The concept is exemplified in Figure 3. Consider a simple case, where we have only two inputs (say, caloric availability and access to safe water) that contribute to the achievement of a given functioning (i.e. being adequately nourished). Points A = ($y1A$,$y2$A) and B= ($y1B$, $y2B$) represent the resources available to two different individuals. In this example, individual A is superior to B in terms of inputs availability as the former lies above the baseline that allows for achieving a decent level of nutritional capability, i.e. the iso-wellbeing curve. An alternative interpretation of θ is the extent to which the input vector available to A could be potentially contracted in order to reach the isoquant.

Analogously, the construction of the output distance function φ – interpreted by Lovell *et al.* (1994) as a quality of life index - is exactly the same of the input distance function, and the only difference lies in the way in which the baseline is conceived. As opposed to the input distance function, which captures the amount of resources that could be shrunk in order to reach the iso-wellbeing curve, the output distance function measures the extent to which an individual's output vector (a combination of functionings, in this case) could be potentially expanded to the most efficient output achievable given the vector of resources available and the individual efficiency in converting inputs in quality of life. In this case, the baseline of the model reminds a standard production possibility frontier (Mas-Colell *et al.* 1997), which, in this case, bounds the functioning space from above rather than from below the resources space. In microeconomics, the production possibility frontier indicates the most efficient combination of outcomes achievable, given a input vector and the available technology in the economy. In this case, the value of φ will be equal or minor than one, for those individuals who do not achieve the best combinations of outcomes possible. Figure 4 illustrates this idea. Instead of two inputs however, Lovell *et al.* (1994) introduced two functionings, i.e. literacy and nutrition. The frontier represents all the efficient combinations of those outputs that produce the same level of well-being, given the same amount of inputs available to both the individuals. Now is individual A which is inefficient in converting her available resources into achieved well-weing, as her value for the composite index of multidimensional well-being achieved lies inside the output set. The value of the output distance function, or, in the authors' terminology, the "standard of living index", for A measures how much A's well-being could be potentially expanded in order to achieve the maximum level of well-being, which in this case relates to the frontier. Finally, the 'transformation efficiency' curve provides the measure of how much A is inefficient in converting the resources available to her multi-dimensional well-being.

The authors claim that the advantages of using distance functions are mainly three: first, given that they are ratios, they are independent of the unit of measurement, so that the issue of absence of a common measurement unit for different functionings[92] is overcome. Second, there are no *a priori* weights on the different dimensions of well-being, as they are determined by the distance functions[93]. Last, but not least, estimates of the individual conversion factors are also provided, which is probably the most interesting aspect of their application with respect to the operationalization of the CA. In their paper, Lovell and colleagues showed that individuals are not equally proficient in transforming resources into functionings, as the rankings between the standard of living and quality of life differ, pointing to the individual heterogeneity in conversion factors pointed out by Sen. As such, relatively resource-deprived individuals were found to lead a relatively high quality of life, and vice versa well-endowed individual to conduct quite miserable existences, as measured by the same functioning frontier[94].

The main drawback of the methodology relates to the estimation of the parameters of the functions employed in the calculation of the distance functions. Lovell *et al.* (1994) and the following authors who adopted this method for the measurement of multidimensional well-being (Delhausse, 1996; Deutsch et al. 2003; Ramos 2005; Ramos & Silber 2005) used Corrected Ordinary Least Square (COLS) to estimate the parameters of the distance functions. These are then employed to provide a scalar measure for both the standard of living and quality of life indexes. However, this

[92] As discussed in the first chapter.

[93] As it will be thoroughly discussed later, some commentators may not see this as an advantage of the method, as they consider the setting of the weights as an inherently normative issue that cannot be entirely left to empirical tools.

[94] An interesting point Lovell *et al.* (1994) found is that inequality in the standard of living understates inequality in the quality of life. In their empirical application on Australian data, they found that resources are more equally distributed than functionings.

method can lead to significant problems of endogeneity[95], which has not been addressed satisfactorily in the context of the COLS procedure (Deutsch & Silber 2003; Ramos 2005). Moreover, the methodology suffers from another major drawback: it can yield very equal distributions that may display exceedingly low levels of poverty (Ramos 2005). Ramos and Silber (2005) argued that such high degrees of concentration are probably a consequence of the qualitative nature of the data of the variables typically employed in multidimensional studies of well-being, and of the two aggregating stages required to arrive at the overall index of well-being.

To sum up, the distance function approach is an interesting attempt to tackle the issue of aggregation. However, as Ramos (2005, pp. 28-29) recognised:

> *"as it stands today, Lovell et al.'s methodology does not provide, as yet, an entirely satisfactory answer to the many methodological challenges raised by the multidimensional analysis of poverty. Therefore, further developments are required if it is to become a widely used method and not to remain as the ever promising candidate".*

[95] In econometrics the problem of endogeneity occurs when the independent variable is correlated with the error term in a regression model. This implies that the regression coefficient in an Ordinary Least Squares (OLS) regression is biased.

Figure 3 An Example of Input Distance Function. Source: Ramos (2005, p. 39)

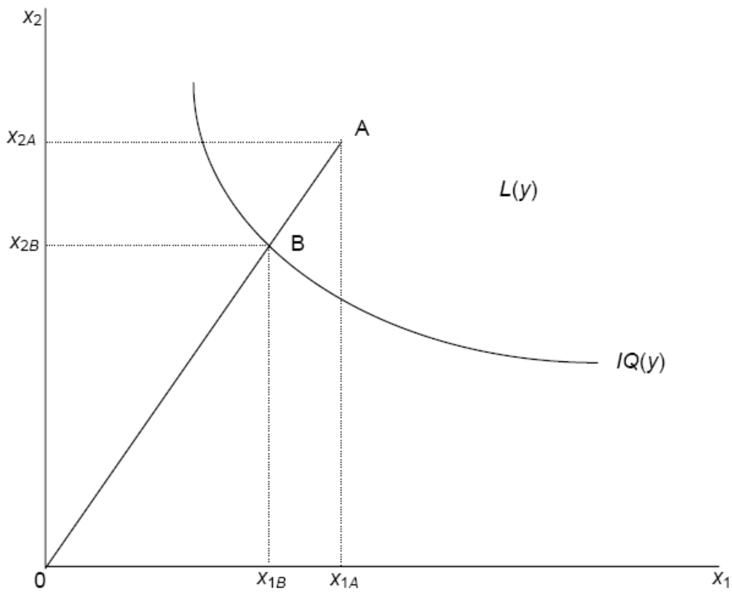
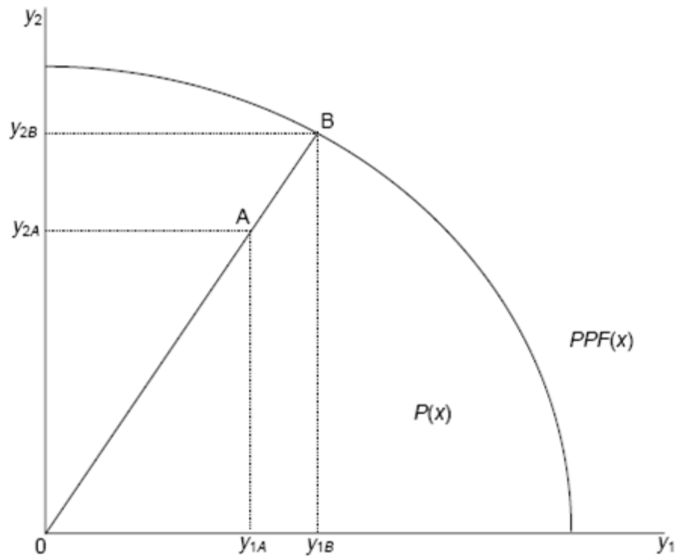


Figure 4 An Example of Output Distance Function. Source: Ramos (2005, p. 38).



2.4.3. Latent Variable Methods

As shown in Figure 1, under the general tag of 'latent variable models', there are many different methods based on various statistical tools (Khrishnakumar 2007, 2008). The underlying assumption that they share is that capabilities are latent or unobservable phenomena, which can be proxied through a set of observable indicators (Kuklys 2005; Di Tommaso 2006; Krishnakumar 2008; Khrishnakumar & Ballon 2008). In particular, many authors addressed the measurement of multidimensional concepts through the use of the following statistical tools: (i) Principal component analysis (PCA) or Multiple Correspondence Analysis (MCA); (ii) Exploratory Factor Analysis; (iii) Structural equation models; and finally, (iv) Rasch Models.

Even though apparently they may seem more 'objective', as the aggregation and weights are based on statistical techniques, some commentators may question empirically devised aggregation strategies, as they see the choice of weights and parameters is inescapably theoretical matter and argue that these choices cannot be left entirely to any statistical technique, no matter how refined it is: without any sound theoretical foundation or justification, inevitably problems of "measurement without theory" (Koopmans 1947) will arise.

i ***Measures derived from Principal component analysis (PCA) or Multiple Correspondence Analysis (MCA)***

Principal Component Analysis (PCA) is a standard tool in multivariate statistical analysis that aims to reveal how different variables change in relation to each other and how they are associated (OECD-JRC 2008). Basically, the key idea behind PCA is to determine orthogonal linear combinations of the variables in order to capture the greatest variance in the dataset. A related goal is the description of the available information in a synthetic way, without imposing any *a priori* hypothesis on the structure of correlations of the data. As such, PCA is not strictly speaking a latent model (as it does not presuppose any models!), but it is nonetheless included in this section for two main reasons (Khrishnakumar 2008): first, this technique has been widely used in the context of multidimensional well-being measurement as well in the CA literature (Ram 1982; Slottje 1991; Klasen 2000; Collicelli & Valeri 2000; Noorbaksh 2003; McGillivray 2005; Ferro-Luzzi *et al.* 2006); and second because, under some specific conditions, PCA can be assimilated to factor models (Jolliffe 2002; Khrishnakumar & Nagar 2008). In empirical applications, the first derived component[96] (i.e. the one that captures the most of the variance) is usually interpreted as a multidimensional index of the concept under investigation. A related procedure that has been explored in the literature is the one of Multiple Correspondence Analysis

[96] Components in PCA are by construction the linear combination of the indicators weighted by their component loadings (i.e. the correlation between the indicator itself and the principal component).

(MCA) (Asselin & Ahn 2008; Asselin 2009). MCA is essentially the counterpart of PCA in the case of categorical data. Analogously to PCA, it has been used to detect and represent underlying structures in a data set, and, given the high variety of categorical indicators usually employed in poverty measurement, it seems a particularly useful in this context.

PCA and, to a lesser extent MCA, are ones of the most frequently used statistical methods in the empirical literature of multidimensional poverty measurement. This is probably due to their relative computational simplicity relatively to other methodologies (Krishnakumar 2007). Nonetheless, it is important to stress that they are mainly data reduction techniques based on correlations and no statistical inference can be drawn from upon these types of analysis. Moreover, as PCA results are based on the existing correlations of the indicators included in a given dataset, results are highly data-driven. This means that both comparisons over time or across countries[97] based on PCA are problematic.

Most importantly, some indicators that are normatively relevant can be excluded from a measure computed through these techniques because of the absence of correlation with the other indicators of the analysis. This possibility stresses that the exclusive reliance on those statistical technique may clash with the theoretical soundness of the analysis itself. The same caution should apply in those cases when weights that are derived from PCA, especially, again, when they are used for comparison between different datasets or different points in time. Assessments are particularly sensitive also to slight changes in the dataset (e.g. the inclusion of new households) and to the presence of outliers.

ii. Measures Based on Exploratory Factor Analysis (FA)

In Exploratory Factor Analysis models (EFA), observed values are seen as linear function of a certain number of unobserved latent variables (i.e. the factors). As opposed to PCA, factors analysis provides a linear model that explains the observed indicators as expressions of the latent construct plus an error term. For instance, a one factor model is the following[98]:

[97] As for instance, Asselin & Vu (2008) did to analyse the multidimensional poverty dynamics in Vietnam.

[98] The notation follows Kuklys (2005)

$$b_{if} = \Lambda_j b_{if}^* + \varepsilon_f^j$$

where Λj is a vector of factor loadings that are estimated from the covariance matrix and that represents the correlation between each indicator and the underlying factor, b_{if}^*. The model relies on the assumption that ε, the error term, is independent and identically distributed, which can be particularly stringent in some cases. By modelling the error term, EFA treats explicitly the issue of measurement error, which may reflect the inadequateness of the indicator to capture the latent construct and/or low score reliability. However, as noted by Walker et al. (2007), factor analysis may lead to exaggerated estimates of measurement error and usually entails additional mathematical manipulation (rotation). This could prevent meaningful comparison of the multidimensional phenomenon over time, thereby limiting the ability to assess policy impact.

As PCA, EFA is a widely used technique in empirical works measuring multidimensional measures of well-being and poverty (Massoumi and Nickelsberg 1988; Schokkaert & Van Ootehgem 1990; Balestrino and Sciclone 2001; Sahn & Stifel 2000; and Lelli 2001; Ferro Luzzi *et al.* 2008[99]), which are usually derived from the first factor. Weights are also statistically based on the variance of the indicators themselves. Walker *et al.* (2007) outlined three main problems of analyses based on this methodology: first, composite index based on EFA are sensitive to the measurement error in the original variables. This issue is further amplified when the latter are used to develop factor score and the factor scores are used across several years, and, for this reason, these measures cannot be meaningfully used to make comparisons over time (Loelhin 1992). Second, factors are often rotated in order to ease interpretation and improve fit with a theoretical model. As a result, factors are not necessarily comparable over space and time (Haase & Prarschke 2005). Finally, as the name makes explicit, EFA is essentially an exploratory technique, as opposed to structural equation approaches such as Confirmatory Factor Analysis (CFA), which seem to provide more promising solutions to overcome those problems.

[99] Ferro Luzzi et al. (2008), after having derived their poverty measure from EFA, then use cluster analysis to determine population's subgroups that are unevenly affected by the various dimensions of poverty, which they use as to identify the set of the poor.

iii. Structural Equations Models (SEM)

Under the general tag of SEM, there is a variety of distinct methodologies that differ on the basis of the statistical tools employed and on the assumptions they make regarding the nature of the associations between the variables and their causal links. Nonetheless, CFA (Bollen 1989; Kline 2011), Multiple Indicators and Multiple Causes (MIMIC, Jöreskog & Goldberger 1975; Zelldner 1970; Muthen 1979) and full SEM models all share the key assumption that a latent construct can be estimated through a set of observable indicators[100] (Bollen 1989; Khrishnakumar & Nagar 2008; Kuklys 2005; Kline 2011).

As in EFA, latent variables in SEM represent hypothetical constructs or factors, which are explanatory variables assumed to reflect a continuum that is not directly observable. In turn, those constructs are measured through a set of observable indicators, which are modelled as linear and indirect expressions of the latent phenomenon[101] (Kline 2011). This structure allows for simultaneously tackling the two issues of lack of aggregator into a composite measure of achieved well-being and of measurement error: on the one hand, estimates of the latent variables can be derived through observed indicators, and the distinction between observable indicators and unobservable variables allows one to test a wide variety of hypotheses regarding construct validity (i.e. whether all the observed indicators are coherently measuring the designed construct) (Kline 2011). On the other hand, the issue of measurement error is directly addressed through the introduction of a residual term that represents the variance left unexplained by the factor and the corresponding indicator[102] (Jöresdog & Goldberger 1978; Jöresdog 1981; Kline 2011). By modelling explicitly random measurement error, the latter can be isolated and controlled for in a way that it is not possible in EFA (Walker *et al.* 2007).

[100] For a discussion on "myths and realities" of SEM see also Everitt & Dunn (2001).

[101] However, as noted by Walker *et al.* (2007) aggregation through EFA involves a weighted sum of the variables that tends to exaggerate measurement error. Moreover, EFA usually involves rotation, which prevents meaningful comparison of the composite score over time, thereby limiting its use to assess policy impact.

[102] More precisely, MIMIC models allow measurement error only in the endogenous variables (measurement part), while full SEM models allow for measurement error in both endogenous and exogenous variables.

Most importantly, SEM's fundamental prerogative is to build on strong theoretical foundations before the model is specified (Bollen 1989; Walker *et al.* 2007; Kline 2011). Unlike EFA, it is up to the researcher to put forward hypotheses on the number of latent factors and how they are associated with the observed indicators, and later to check the consistency of his theory with sample data. In this way, not only the typical problems of instability of rotated solutions, prevalent in EFA, are eluded (Walker *et al.* 2007), but also the key issue of "measuring without theory" (Koopmans 1947), common to many empirical techniques for aggregating indicators, is avoided.

Additionally, MIMIC and full SEM models also aim at explaining what causes the latent variables to change by introducing some exogenous variables that are believed to have a causal influence on the latent factors (Jöreskog 1973; Jöreskog and Goldberger 1975; Khrishnakumar 2008; Khrishnakumar & Nagar 2008). In this framework, observed variables are function of the latent factors, which, in turn, depend on some exogenous variables. In particular, MIMIC allows for the simultaneous estimation of the measurement model and the incorporation of a set of causal variables in the structural model for the latent construct (Lester 2009). Pushing this concept further, SEM also allow for interplay between latent variables and exogenous factors[103]. The solution of a SEM model leads to the simultaneous determination of all the latent dimensions considered in the model. Given that these models provide the simultaneous determination of the relations between the many dimensions of well-being, poverty, or other multidimensional concepts, SEM go beyond one-way causal relationships usually found in empirical works as they allow for the reciprocal feedback among the different latent dimensions that are constitutive of overall well-being achieved. Moreover, a full structural equation model is an efficient tool to deal with measurement error in both endogenous and exogenous variables (as opposed to MIMIC, which only captures error in the endogenous terms). Given these characteristics, SEM appears as particularly suitable for the analysis of multidimensional phenomena[104] (Khrishnakumar 2007; Khrishnakumar & Ballon 2008; Sabatini 2008), such as well-being (Cracolici et al. 2010).

[103] For instance, if the aim is to measure the latent dimension of individual empowerment, it is plausible to argue that the latter is also influenced by some exogenous factors, such as the social and the political context.

[104] For a discussion on "myths and realities" of SEM see also Everitt & Dunn (2001).

Works adopting the MIMIC framework are Di Tommaso (2006) and Kuklys (2005), while Khrishnakumar (2007) and Khrishnakumar and Ballon (2008) adopted the SEM framework to estimate human development and capability poverty respectively.

iv. Rasch Models

Rasch models are traditionally employed in psychometrics, in order to measure latent traits such as intellectual quotient, sociability or self-esteem, which in turn cannot be observed directly. Rasch estimates provide the test-taker's probability of answering a specific test item correctly. The probability of success is estimated through a logistic function of the difference between the individual's ability and the item difficulty. In this way, the Rasch model allows for the determination of an interval scale of scores for both the item's difficulty and the latent construct to be measured.

Rasch models have been applied to poverty as well as to food security measurement (e.g. Fusco & Dickes 2006; Deitchler et al. 2011). The application of psychometric models to define aggregate measures of multidimensional well-being or poverty is possible if one considers poverty as a latent construct and the positive answer to an item as a deprivation. If the set of items selected on theoretical grounds as indicators of poverty conform to the Rasch model, then a poverty or deprivation index can be estimated from the simple sum of the dichotomous items. Although Rasch models usually presume unidimensionality in the construct they are measuring, recent developments of the psychometric literature have tried to overcome the assumption of unidimensionality through the design of appropriate techniques (Bartolucci 2007).

2.4.4. Axiomatic methods based on Information Theory

Information theory was first developed as a discipline in theory of communication, which aimed at measuring how much data can be transmitted without significant loss or entropy. In this framework, the latter stands for a measure of the uncertainty in a random variable, and, when comparing two probability distributions, the relative entropy is an index to measure the distance between them. Theil in 1968 was the first author in economics that borrowed the conceptual framework of information theory in order to measure inequality (Theil 1968). In particular, the index measures the distance of the actual distribution of incomes and the ideal one in which everybody receives an equal income share.

Almost 20 years later, Maasoumi (1986) adopted the concepts of generalised entropy in order to derive a measure of multidimensional inequality that aggregates the vector x_{ij} of individual i achievements in j attributes into a scalar measuring overall individual achievement [105]. According to Maasoumi & Lugo (2006), this formulation is "efficient", in the sense it uses all the information available on the distribution of the attributes considered in the summary or aggregation function. From a statistical point of view, any poverty index is a function of the distribution of the considered attribute(s), or in other terms, is function of the moments of the distribution of the attributes[106]. As such, any poverty index entails some loss of information, as it does not exploit the whole distribution of the attribute(s), unless it relies on the moment-generating (or characteristic) function (which is equivalent to the whole distribution). Information theory measures provide accurate and complete information on the divergence between the empirical realisation of a casual variable and its uniform rectangular distribution, which is a measure of the differences between their entropies, or "relative entropy". As no other poverty index can provide the same information. Maasoumi and Lugo (2006) argued that entropy or other information theory measures can be considered as the "second-best" inequality measures (Maasoumi & Lugo 2006). Starting from this premise, the two authors adapted the information theory apparatus to the measurement of multidimensional poverty and provided an empirical application on Indonesian data (Maasoumi & Lugo 2006, 2008). Their methodology entails two steps: first, they construct a summary measure of the relative entropy at the individual level S_i, where the latter denotes the aggregate function for individual i, based on her vector of j attributes $x_i = (x_{i1}, x_{i2}, \dots, x_{id})$. Then, they provide a weighted average of the individual relative entropy divergences S_i and each $x_j = (x_{1j}, x_{2j}, \dots, x_{nj})$ in the following way:

$$D_\theta(S, X; w) = \sum_{j=1}^{d} w_j \left(\sum_{i=1}^{n} S_i \frac{\left(\left(\frac{S_i}{x_{ij}} \right)^{-\theta} - 1 \right)}{\theta(\theta - 1)} \right),$$

[105] The first contribution in the domain of multidiemensional measures of poverty based on axiomatic theory is Miceli (1997), which used a relative approach to poverty and estimated the share of poverty in the population by using the distribution of an index of achievement related to entropy.

[106] From this view, poverty analysis is concerned with the lower tail of the distribution of the selected attribute(s) (Maasoumi & Lugo 2006).

where w_j are the weights attached to the generalised entropy divergence for each attribute. In order to derive the "optimal information theory" aggregation function, $D_\theta\ (\cdot)$ is then minimised with respect to S_i such that $\sum S_i = 1$:

$$S_i \propto \begin{cases} \left(\sum_j^d w_j x_{ij}^{\theta}\right)^{1/\theta} & \text{when } \theta \neq 0 \\ \prod_j x_{ij}^{w_j} & \text{when } \theta = 0 \end{cases} \qquad (7).$$

In this way, the index can allow for a certain degree of substitutability between attributes that are below or above the corresponding thresholds, which means that it satisfies the weak version of the focus axiom. One of the main critiques that the authors address to Tsui (2002) and Bourguignon & Chakravarty's (2003) methodologies relates to their adoption of both the focus axiom and the union method to identify the poor[107]: according to Maasoumi and Lugo (2008), the double requirement for the index to be insensitive not only to the *individuals* above the poverty threshold *z* (as the weak version of the axiom requires) but also to those *attributes above* the poverty thresholds for individuals who are deprived in other dimensions (due to the strong focus) and the idea of *essentiality* of all the attributes (required by the union approach) is too strict too be plausible and leads to exaggerate poverty rates. As such, they opt for an intermediate position that allows for some degree of substitutability.

Following Sen (1992), however, the question that may arise from this approach in the context of extreme poverty in developing countries (as discussed in Chapter 1), is whether there could be a degree of substitutability and to which extent it can be allowed, or if there is indeed a core set of deprivations that could not be traded-off, to which extent compensability can be allowed. Another relevant question relates to whether the parameters related to the elasticity of substitution should be considered the same for each individual, or there are different degrees for different groups of

[107] Maasoumi & Lugo (2006) also show where and under which conditions the Tsui (2002) and Bourguignon & Chakravarty indices can be subsumed by the broader information theory approach they propose.

population due, for instance, to individual heterogeneity in the conversion of resources into well-being.

2.5. Conclusions and Issues for Further Research

The aim of this Chapter was to review the different aggregation methods explored in the literature in order to derive multidimensional measures of well-being or poverty, which are widely seen as multidimensional phenomena. The empirical analyses stemming from those different methodologies showed that rankings may substantially vary depending on whether the aggregation is done in unidimensional or mutldimensional spaces. In the case of poverty, all the empirical analyses reviewed agreed on showing that households that are multidimensionally poor may not be monetary poor, and vice versa (Lovell *et al.* 1994; Klasen 2000; Duclos *et al.* 2006; Deutsch & Silber 2005; Betti et al. 2008; Massoumi & Lugo (2008); Alkire & Santos 2010), which point to the necessity of integrating traditional welfare assessments with multidimensional evaluations. The widespread recognition of multidimensionality of these phenomena has important implications for antipoverty policies and the identification and targeting of different groups of population who may need diverse types of interventions.

A second key question that requires further research is to understand how much different methodologies overlap. In other words, although the overall picture that they provide is similar, it is relevant to understand whether they can identify the same households as multidimensional poor. Deutsch & Silber (2005) partially tried to answer this question in their empirical application of four of the different methods reviewed in this paper, and they found out 11 per cent of the households are defined as poor according to all the indices. Nonetheless, in their paper they adopted an 'asset-based' definition of multidimensional poverty, which is still unsatisfactory in many ways from a theoretical perspective. An issue for further research would be to replicate the same exercise in the space of basic well-being deprivations such as health, nutrition, education instead of merely assets.

Part B – Measuring Food Security

Chapter 3

Measuring Food Security: Conceptual Framework

3.1. Introduction to Part B of the Thesis

Food security, as poverty, is an inherently multidimensional phenomenon. By explicitly acknowledging the four interdependent pillars of food availability, access, utilisation, and stability, the World Food Summit (WFS, WFS 1996) marked a milestone contribution in the analysis of food security, which, until then, used to be identified with food availability (UN 1975; Thompson & Metz 1997; FAO 2004). A key role in such a paradigm shift was played by the pioneer contributions by Sen (1981) and Drèze & Sen (1989), which advanced the understanding of food security by highlighting the complexity and multidisciplinary of the subject[108] (Burchi & De Muro 2012b).

Undoubtedly, the WFS recognition of food security as a multidimensional phenomenon represented a significant theoretical advancement, as it broadened the scope of food security analysis and policies from the previous focus on food availability. At the same time, it also brought about a number of additional analytical and methodological issues. These are particularly marked in the field of measurement. Given the critical role that measures play in evidence-based policy-making, the debate on how to measure countries' food security is now, unsurprisingly, as heated as ever[109] (Barrett 2010; Masset 2011; De Haen *et al.* 2011; CFS 2011a).

[108] As noted by Burchi & De Muro (2012b), the influence of Amartya Sen's *entitlement approach* to the analysis of food secuirty is evident in two important food security definitions: "All people at all times have both physical and economic access to the basic food they need" (FAO 1983), and "Access by all people at all times to enough food for an active, healthy life" (World Bank 1986).

[109] For instance, Heidhues and von Braun (2004) argued that the lack of an international, widely accepted and comprehensive measure of food security is one of the key hindrances on the way to eradicate hunger and malnutrition, while Sumner and Lawo (2010) expressed the growing dissatisfaction in both academic and policy circles with the measures commonly used to monitor progress towards these goals. Such a 'measurement gap' was also recently pointed out by Barrett (2010) and the British Council of Science (Foresight 2011), and restated during the 2011 consultations of the *Committee of Global Food Security* (CFS, CFS 2011) and the 2012 *International Scientific Symposium on Food & Nutrition Security Information* (ISS).

Measuring food security is a complex task for various reasons: (i) elusiveness of the concept (Barrett 2002, 2010; Mason 2002); (ii) lack of a widely accepted operational definition (Barrett 2010, CFS 2011a); (iii) absence of a 'gold standard' or baseline measure (Maxwell & Frankerbergen 1992; Mason 2002; CFS 2011a); (iv) poor data availability across country and over time (Wiesmann *et al.* 2000; CFS 2011a); and finally, (v) discontent/disagreement regarding the quality of available indicators (Smith 1998; Svedberg 2000, 2011; Klasen 2008; Headey 2010; De Haen *et al.* 2011; Masset 2011; Cafiero & Gennari 2011).

In order to provide valuable information for policy making, metrics for food security must necessarily be multidimensional, as no single indicator can adequately capture the complexity of the concept (De Haen 2003; Heidheus & Von Braun 2004; CFS 2011a). However, the quest for capturing the multidimensionality of food security led to the mushrooming of either lengthy suites of indicators (e.g. FIVIMS 2003; CONSEA 2010; Feed the Future 2010) or of composite measures (Hicks 2001; Wiesmann 2006; Gentilini & Webb 2008; Maplecroft 2011; EIU 2012), whose theoretical or methodological foundations are not always clearly defined (CFS 2011a). With respect to the former, the main criticism relates to the lack of any theoretical distinction among the way in which each single indicator enters in the process of achievement of food security, as most of the available suites tend to gather tens of different indicators without differentiating among those related to the 'inputs' and the ones pointing to 'results' or 'consequences' of food insecurity[110]. As they equate the 'means' with the 'ends' in the food security process, it is difficult to synthetise and interpret the informative content of those lists in order to provide an overview of the performance of each country that can be used as basis for policy-making.

On the other hand, composite indicators, while providing a summary figure of overall food security performance, are also criticised on theoretical and methodological bases (OECD-JRC 2008; Ravallion 2010). In particular, Burchi & De Muro (2012a) noted that multidimensional measures often suffer from three interrelated shortcomings: firstly, they are not always based on sound theoretical foundations; secondly, they do not provide a rigorous definition of the concept under investigation; and finally, they also fail to distinguish between the 'inputs' and the 'outcomes' of the multidimensional phenomenon they are attempting to describe. Further, the lack of a natural aggregation function to combine different dimensions into a summary measure raises the question of devising appropriate aggregation and weighting schemes

[110] For instance, FIVIMS (2003). A notable exception is Feed the Future (2010).

(Kuklys 2005; CFS 2011a), as well as to transparently convey the tradeoffs involved in the construction of the index (Ravallion 2010). With respect to the measurement of food security, many participants at the 2011 Committee on Global Food Security (CFS) *Roundtable on Monitoring Food Security* and at the 2012 *International Scientific Symposium on Food & Nutrition Security Information* pointed out those drawbacks in order to reject *tout court* the use of composite indices use in favour of suite of indicators (CFS 2011b).

Finally, the noted proliferation of measures, together with the recent errors in projecting the number of undernourished people in the world by FAO (FAO 2009), fostering uncertainty about the magnitude, trends and nature of global food security, and triggered a general sense of dissatisfaction about the current state of food security measurement among policy-makers, academics, and the general public (Sumner & Lawo 2010; CFS 2011a; De Haen *et al.* 2011; Massett 2010; Easterly 2010; King 2011; Headey 2011; Banerjee & Duflo 2011; Provost 2012; Swinnen & Guicciarini 2012). As Smith *et al.* (2006) effectively have pointed out:

> *"(...) arriving at an accurate measure of food insecurity that is comparable both within and across countries is a challenge" (p. x).*

This part of the thesis aims at addressing the meausurement of food security issues on theoretical, methodological and empirical grounds.

On the theoretical side, it first attempts to carefully clarify the concept of food security and then to lay strong analytical foundations to the evaluative exercise, in order to avoid "*measuring without theory*" (Koopmans 1947). With respect to the former objective, we found that much of the dissatisfaction in the current debate on food security measurement is due to a widespread confusion around the very concept of food security. Misunderstandings pertain to both (i) the *terminology commonly used*; and (ii) the *analytical concept* of food security. Regarding the former, the CFS (2011a) noted that terms such as "hunger", "food insecurity", "undernourishment", "malnutrition", "food deprivation", and "food crisis", are used interchangeably as if they point to a same underlying concept. Yet, they are not, as each of them describes a different characterization of the phenomenon [111]. Ultimately, semantic

[111] For instance, hunger is the feeling of discomfort caused by the lack of food, and somebody that is suffering from involuntary hunger is classified as food insecure. However, the reverse is not necessarily true: even though an individual may have access to food in sufficient quantities, she could still be food insecure due to the poor nutritional content of her diet, also known as hidden hunger.

confusion can be ascribed to a more general lack of a clear conceptualization of food security. Conceptual clarity on the definition of food security adopted and on the reference conceptual framework is critical for measurement purposes: concepts guide indicators selection, and shape the way metrics is constructed. The degree of confusion around the terminology used to describe food security has probably contributed to the proliferation of 'shopping lists' of indicators, which, in turn, foster a vicious circle of additional confusion regarding levels and trends, as well as on the nature of the concept of food security. By acknowledging these issues, the present Chapter carefully explores the concept of food security and then tackles the issue of lack of operational definition of food security by providing one that will be used as a basis of the measurement purposes of the next chapters.

With respect to the second goal, we ground the measurement of food security into an original theoretical framework that combines insights from UNICEF's framework (1990) and Sen's CA. We show that this analytical skeleton is able to provide guidance in all the steps of the evaluation, from indicators selection (Chapters 6 and 7) to the interpretation of the empirical results (Chapter 7).

Methodologically, we argue that the dichotomy between suite of indicators and composite indices that is often used to back the selection of one *viz*. the other is only apparent. Indeed, we show that the two tools are complementary in order to provide an overall metrics for food security. Depending on the different policy purposes on hand, suite of indicators can be used to monitor progress in each distinct facet of food security, whilst composite indicators to provide summary snapshots of the overall performance in the many dimensions of the concept. Quoting Amartya Sen:

> *"The job of a 'measure' or an 'index' is to distill what is particularly relevant for our purpose, and then to focus specifically on that" (Sen 1989, quoted in Alkire & Foster 2011a, p. 290).*

For this reason, the methodological contribution of this part of the dissertation focuses on both tools: on the one hand, Chapter 6 proposes a methodology to select a core set of food security indicators that is grounded in the theoretical bases of the CA. On the other, Chapter 7 originally uses Structural Equation Modelling techniques in order to develop a summary measure of food security.

The remainder of Part B of the dissertation is organised in the following way. Chapter 4 provides the theoretical skeleton for the subsequent analysis: first, it explores the concept of food security by pointing out its main characterizing features. Then, it presents an original conceptual framework grounded in the CA. Finally, the chapter concludes with a proposal of an operational definition of food security that will constitute the baseline for the development of the food security metrics in the next chapters. Later, Chapter 5 provides a literature review of the metrics developed to measure food security at the country level, while Chapter 6 and 7 measure food security by respectively proposing methodologies to develop a suite of indicators and a composite index.

3.2. Unfolding the Concept of Food Security

"What is badly defined is likely to be badly measured"
(OECD-JRC 2008, p. 22)

The evolution of the concept of food security over time reflected the paradigm shifts from a supply-based approach based on food availability (UN 1974) to a multidimensional approach encompassing the additional dimensions of food access, utilisation, and stability[112] (Barrett 2002; Clay 2002; Burchi & De Muro 2012). In particular, the 1996 WFS definition (WFS 1996) represented a significant theoretical advancement from the conceptual frameworks adopted in the past, as it explicitly acknowledged the multidimensional, dynamic and complex nature of food security. The conceptual framework presented in this paper builds on the 2003 FAO definition of food security (FAO 2003), which, by broadening the 1996 WFS conceptualisation though the inclusion of the social acceptability of food[113], is the most comprehensive definition of food security available so far. According to FAO, food security is:

> *"A situation in which all people at all times have social access to sufficient, safe, nutritious food to maintain a healthy and active life" (FAO 2003).*

On the other hand, the explicit recognition of the complexity of food security requires the adoption of more sophisticated analytical and methodological tools for its measurement. An

[112] In this respect, Barrett (2002) noted that there are three main "generations" in the conceptualisation of food security. A first one basically identified food security with food availability, while a second, post-Sen, tended to focus on households' entitlements to food. Then, a third, emerging generation emphaises uncertainty, vulnerability, as well as some complementary nonfood inputs, such as health care, sanitation, education and nutritional knowledge, as well as infrastructure to market and stock food. For a comprensive review of the evolution of the food security concept, see Clay (2002) and Burchi & De Muro (2012b).

[113] With respect to the previous WFS definition, this one also emphasised the social and cultural acceptability of the food consumed. This aspect shifts the focus from 'enough food' to 'preferred food' (Pinstrup-Andersen 2009).

analytically and operationally useful conceptual framework for food security has to take into account of the key elements characterising the concept: (i) multidimensionality; (ii) dynamics; (iii) behavioural nature; and (iv) layeredness.

3.2.1. Many, Interdependent Dimensions

Food security is a fundamental component of human well-being, and, as well-being, it is also a many-sided concept. The WFS definition explicitly recognized the multidimensionality of food security by highlighting four underlying pillars: availability, access, utilization, and stability. *Availability* refers to the *"physical supply of food from all possible sources"* (e.g. all forms of domestic production, commercial imports, food aid, etc.). Although it can be measured at the macro (global, regional, and national), meso (sub-national or community), and micro (household) levels of aggregation, availability mostly refers to food supplies at the national or sub-national level. By contrast, *access* is an inherently microeconomic concept, which refers to the set of "*food entitlements*" enjoyed by either individuals or households (Sen 1981). Access represents the *"economic, physical, and social ability to acquire adequate amounts of food"* through a combination of different sources (e.g. own stocks, home production and collection, purchases, barter, gifts, borrowing, remittances, food aid, etc.). In turn, access is also multifaceted (WFP 2009), and the following sub-dimensions can be distinguished:

i. *Physical access*: food is accessible at the location where people need it (e.g. through good infrastructure facilities, proximity to markets etc.).
ii. *Economic/financial access*: financial ability to acquire adequate food to meet requirements.
iii. *Social access*: food is acquired and/or consumed in socially acceptable ways.

Food security outcomes, however, do not only depend on the access to food, but also on the ability of the individuals in converting acquired food into adequate nutrition for a "*healthy and active life". Utilisation* points to "*households' use of the food to which they have access, and to individual efficiency in biologically converting nutrients in order to meet their specific nutritional and health needs*" (WFP 2009). In order to determine nutritional outcomes, two sub-dimensions can be distinguished: the first relate to *diet quality***,** i.e. the nutrient adequacy of the diet (in terms of balance between essential macro and micronutrients), in order to minimize the risk of nutrient deficit[114] and hidden hunger (FAO 2008a). There is a vast body of empirical evidence that shows the long-term effects of lack of micronutrients on a variety of outcomes such as education and cognitive development[115] (Bigsten *et al.* 2000; Glewwe & King 2001; Behrman *et al.* 2003; Behrman & Rosenzweig 2004; WFP 2006; SUN 2009 XXX; Gao *et al.* 2011), health and decreased morbidity (Lozoff *et al.* 2000; Viteri & Gonzalez 2002), labour productivity and earnings (Basta *et al.* 1979; Hass & Brownlie 2001; Horton & Ross 2003; Thomas *et al.* 2004), and mental well-being (Weinreb 2002; Wunderlich & Norwood 2006; Whitaker *et al.* 2006). The second pertains to the use of the food households' acquire (i.e. preparation, conservation, etc.) and their nutritional knowledge about healthy diets (Nurul *et al.* 2010). "*Non-food items"* play a fundamental role in determining actual nutritional outcomes (Drèze & Sen 1989). These factors – which condition the *"requirement, absorption, assimilation, and utilization of the nutrients of the diet"* (Gopalan 1993, p. 3) relate to:

i Health and sanitary conditions (i.e. access to good quality basic health and sanitation services, eradication of infectious diseases, etc.);

ii Education (formal and informal, i.e. nutritional and food choosing/processing/storing knowledge, etc.);

iii Care and feeding practices (i.e. related to infants and children, the elderly, sick people etc.);

iv Food storage and processing facilities.

In turn, non-food elements, together with inter-individual and intra-individual variations in terms of metabolic rate, activities level, age and health status determine the micro-level 'conversion factors' of food consumed into adequate nutritional outcomes. It is due to these factors that the correlation between dietary intakes and actual nutritional outcomes is far from being perfect (Drèze & Sen 1989; Gopalan 1993). Finally, trough the introduction of the nutritional dimension in food security analysis, a demarcating line was implicitly drawn between the two related, albeit theoretically different, concepts of food security and hunger.

114 Often scientific publications and conferences refer to 'food security' and 'nutrition security' as two linked, yet separate, concepts (e.g. SUN 2008). It is clear, however, that the introduction of the utilisation dimension in the WFS definition, through its focus on nutritional outcomes, renders this distinction fictitious, as food security is an encompassing concept which already embodies both food and care-related aspects of good nutrition.

115 See also Chapter 7.

While the latter relates to the feeling or discomfort of not having enough calories to cover minimum nutritional requirements (Barrett & Lentz 2008), food security is more a pervasive concept, encompassing the analysis of those elements (included care practices, education and health status) that enhance humans' ability to absorb the essential nutrients from the available food and to adequately convert them into a good nutritional outcomes (Drèze & Sen 1989; Gopalan 1993; Osmani 1993; WFS 1996; Svedberg 2002; WFP 2009).

Finally, there is a hierarchical interdependency among those dimensions (Barrett 2010, Burchi & De Muro 2012b): availability is a necessary, yet insufficient, condition for access, which in turn is necessary, however insufficient, condition to reach adequate nutritional outcomes. In turn, the fourth dimension of stability emphasises the permanency and sustainability of the three dimensions over time (Maxwell & Frankerbengen 1992; Barrett 2010; Burchi & De Muro 2012b). In other words, availability, access, and utilization can be interpreted as "snapshots" of food security outcomes in a given point in time, while stability focuses on the "whole movie", i.e. their past evolution of those dimensions and their likely advancement in the future.

3.2.2. The Dynamics of Food Security

The explicit reference to food security at "*all times*" in the WFS definition emphasized the dynamic component of food security: time is an inherent characteristic of the concept. There are two main ways in which time enters in the analysis of food security. On the one hand, there is a *valuational component*, as food security can be assessed by taking both an *ex post* and an *ex ante* perspective. As of yet, concepts and metrics for food security have been mainly focused on the former element[116], probably due to a lack of longitudinal data necessary to address these issues empirically (Downing 1990; Frankerberger 1992; Barrett 2002). However, if food security is defined as *'access at all time to enough and nutrient food'*, food insecurity can then be defined as *temporal uncertainty* in the access and utilization dimensions[117] (Chambers *et al.* 1981; Andersen 1990; Maxwell & Frankerbergen 1992; Chambers 1995; Barrett 2002, 2010; Kennedy 2003; b& De Muro 2012a). Uncertainty stems from a multitude of factors: inter-temporal variation in prices and quantities produced; fluctuating incomes;

[116] Notable exceptions are Frankerbergen (1992); Christiansen *et al.* (2000); Barrett (2002) and Troubat (2011).

[117] Such an element of uncertainty is explictly captured in the definition of food insecurity provided by the American Institute of Nutrition: *"Food insecurity is the limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire food in socially acceptable ways"* (Andersen 1990).

instable or highly seasonal employment patterns; biological lags inherent to food production, absence of adequate storing facilities; and, finally, covariate and idiosyncratic shocks. By taking a forward-looking perspective that includes the elements of risk and uncertainty, food security can be interpreted as '*freedom from the risk of hunger*' (Barrett 2002; Burchi & De Muro 2012b). The term *security* explicitly points to "*safety from chronic threats (...) and protection from sudden and hurtful disruptions in the patterns of daily life*", as defined by the UNDP (1994, p.1). Accordingly, measures of food security should not focus merely on past outcomes, but also at those factors that place people and countries at risk of worsening or changing their current food security status, as well as at those elements that let them counter adverse events. The dynamics of food security is therefore extremely relevant for policy making: as noted by Barrett, *"The basic aim of food assistance programs (FAPs) is to reduce food insecurity, i.e., to avert rather than to reverse nutritional problems"* (Barrett 2002, p. 2108).

In such a dynamic characterisation, food insecurity outcomes result from the interaction between stochastic and structural elements, i.e. *ex ante* risk exposure (vulnerability) and *ex post* coping capacity (resilience) (Chambers 1989; Barrett 2002; Baro & Debuel 2006; Devereux 2007; Alinovi *et al.* 2009; UNDP 2012). By focusing on the concept of *security* as defined by the UNDP (1994), it is clear that the analysis of vulnerability and resilience is relevant in order to understand food security in all its complexity, and that evaluative assessments should accordingly take these elements into account[118]. Nonetheless, most food security literature has so far overlooked those aspects of risk and uncertainty. Finally, linked to the resilience aspect, there is the issue of sustainability over time of food security outcomes. This feature points to the capability "*to cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future*" (DFID 1999, quoted in Burchi & De Muro 2012b, pp. 14-15).

On the other hand, time also enters in the analysis of food security as *duration* of the food security status, which could be either *chronic* or *transitory*. In the former case, food insecurity persists over time, and such persistence is linked to some structural economic, institutional, and social factors. Transitory food insecurity, can be further characterized as *temporary* or *seasonal* (Barrett 2002). Temporary food insecurity occurs for a limited period of time due to a shock (e.g. weather-related, or civil unrest) that exacerbates longer-term deprivation (e.g. HIV,

118 This conceptualization counters the prevalent, static vision of food security and vulnerability as two different, albeit related, concepts (e.g. FAO 2008).

poverty…), and its duration will depend on both the extent and nature of pre-existing deprivation and on the capability to cope through private and public mechanisms. Seasonal food insecurity, on the other hand, points to cyclical patterns of food and nutrition deprivation in agrarian low-income economies (e.g. during the pre-harvest period) is generally linked to weaknesses in the food storage and marketing systems, as well as seasonality of employment (Chambers *et al.* 1981; Reardon & Matlon 1989; Devereux *et al.* 2012).

3.2.3. The behavioural dynamics of food security

The characterization of food security as a dynamic and evolving concept is inextricably linked to the analysis of behavioural dynamics, i.e. people' s capability to respond and adapt to stress in order to cope with exogenous shocks that lead to decreased food availability or access (de Wall 1990; Frankerbergen 1992; Maxwell 1995; Maxwell et al. 1999; Hoddinnott & Kinsey 2001; Bengtsson, 2010).). This capability, reflected in current behaviour and perceptions related to their food security status, is a function of food security occurred in the past and of expectations for the future (Barrett 2002). Risk and behavioural responses matter because people may have different attitudes towards perceived hazard[119] (Vakis & Cafiero 2006). In particular, as noted by Barrett (2002), the empirical literature points to two basic features of people's attitudes towards risk: first, individuals have different preferences with respect to risk; in particular, empirical research points to the risk adverseness of most people; and, second, regardless of individual risk preferences:

> *"temporal risk induces behavioral changes that affect consumption, production, marketing, savings, and investment patterns with long-term consequences for food security. Risk may thus be both intrinsically and instrumentally detrimental" (ibidem, pp. 2108-2109).*

A related point that it is often overlooked, as the literature mostly take a static stand in its analysis of food security, is related to the irreversibilities and non-linearities associated with adverse food security outcomes over time (Barrett 2002, pp. 2109; CFS 2011a; UNDP 2012). For instance, a large body of empirical literature showed persistence of food insecurity occurred in the past on the evolution of many human development outcomes, such as, for instance, adults' attainments in education and health (Behrman 1996; Alderman *et al.* 2001,

[119] See Dercon (2005) for a review.

2006, 2009, Behrman *et al.* 2004; Grantham-McGregor *et al.* 2007; see Pollitt 1990 and Behrman 1996 for reviews); labour productivity and earnings (Behrman & Deolalikar 1989; Deolalikar 1988; Behrman 1993; Foster & Rosenzweig 1994; Schultz 1996; Thomas & Strauss 1997; Strauss & Thomas 1998; Behrman *et al.* 2004; Hoddinnott *et al.* 2008) or households' investment behavior or labour and crop portfolios (Dixit and Pindyck 1994; Dercon, 1996; Larson & Plessmann, 2009; Kochar, 1999; Beegle et al.h 2006). With respect to the latter, much literature has explored the implications of the joint existence of sunk costs and uncertainty for households' investment behavior (Barrett 2002), as well as the long-term consequences of health and nutrition due to abrupt food security shocks. In Barrett's words:

> *"If food is a source of nutrients that are an input into the production of physical well-being - a type of human capital - the literature on investment under uncertainty applies to issues of food security as well. The key irreversibilities to be considered relate to death and permanent cognitive or physical impairment. Behaviors may change radically as one approaches the threshold of adverse, irreversible states, thereby introducing important nonlinearities into many economic and nutritional relationships, and helping provide an explanation for anomalous observations such as Giffen goods" (Barrett 2002, p. 2109).*

Without taking into account the aspect of how people respond to food insecurity over time, monitoring may lead to misleading results that can in turn affect the way in which policies are formulated. For instance, if the focus of the metrics is exclusively on patterns of caloric consumption, the results of the evaluative exercise may point to an apparent status of stability in food security outcomes. However, it may be the case that, in order to preserve the caloric content of the diet, people may switch to cheaper calories (such as in the case of Giffen goods), or adopt other behaviours that may lead to adverse consequences in terms of other dimensions of food security[120] (i.e. utilisation or stability of access) (Barrett 2002; Maxwell *et al.* 2008). In order to capture the behavioural dynamics of food security, the joint adoption of qualitative

[120] For instance, recent empirical research (Hossain & Green 2011) showed that, in the face of a shock such as the recent 2008/2009 food price crises, poor people tend to maintain their caloric intake at the expense of variety and quantities of food consumed (i.e. switching to cheaper staples, or cutting consumption of protein and vegetables. By the same token, other behavioural responses (such as women eating less in order to favour consumption of children and men, limiting intakes to avoid selling vital assets, skipping meals, etc.) may lead to a perpetuation of future food insecurity through a worsening of health and sanitary conditions, labour productivity, or switching to low-risk/low-return activities (Hossain & Green 2011).

and quantitative research methods seems promising (e.g. Hossain & Green 2011). These methods could also capture the consequences on subjective well-being of distress due to food insecurity (Kennedy 2003; Wunderlich & Norwood 2006). For this reason, many authors argued the need for integrating food security information systems with some reliable and cross-validated measures of the subjective aspects linked to the feeling of food insecurity (i.e. Kennedy 2003; Deichtler *et al.* 2011; Headey 2011), and of the coping strategies adopted by the households to manage food insecurity and distress[121] (e.g. Maxwell *et al.* 2008).

3.2.4. A Multi-layered Concept

The analysis of the different pillars shows that food security is also a multi-layered concept. Food security outcomes, in fact, can be analysed at a plurality of levels, spanning from global and national trends in availability, to households' access to food entitlements and individual nutritional capabilities. In principle, food security is an intrinsically individual concept, as it points to the dietary requirements for maintaining a healthy and active life. Aggregation – both at national and household levels - suppresses variability in food security outcomes, as resources are not distributed equally between and within socio-economic groups in a country, nor in the household, as the distribution of food and care may be highly inequitable across different household members (Pitt & Rosenzweig 1985; Haddad & Kanbur 1990; Pitt *et al.* 1990; Devereux 2001). However, until the early 1980s, food security has been mainly conceptualised and measured at the national level, and only after Sen's contribution on food entitlements, at the household level (Sen 1981; Maxwell & Frankerbergen 1992).

3.3. A Capability Approach To Food Security

In the pathbreaking book *Hunger and Public Action*, Drèze and Sen (1989) elaborated a CA approach to food security. In this contribution, the authors overcame the *entitlement approach*

[121] This need has been recognised by the Sarkozy commission (Stiglitz *et al.* 2009), when arguing that: *"Research has shown that it is possible to collect meaningful and reliable data on subjective as well as objective well-being. Subjective well-being encompasses different aspects (cognitive evaluations of one's life, happiness, satisfaction, positive emotions such as joy and pride, and negative emotions such as pain and worry): each of them should be measured separately to derive a more comprehensive appreciation of people's lives. Quantitative measures of these subjective aspects hold the promise of delivering not just a good measure of quality of life per se, but also a better understanding of its determinants, reaching beyond people's income and material conditions. Despite the persistence of many unresolved issues, these subjective measures provide important information about quality of life. Because of this, the types of question that have proved their value within small-scale and unofficial surveys should be included in larger-scale surveys undertaken by official statistical offices"* (Stiglitz *et al.* 2009, p. 34).

previously proposed by Sen in *Poverty and Famines* (1981). In the latter Sen elaborated the concept of *food entitlements,* i.e. people's *command over food* and shifted the focus of food security analysis from food availability at the macroeconomic level to individual and households' ability to actually access food. However, despite the conceptual advancement of *Poverty and Famines*, Drèze and Sen argued that the analysis of people's entitlements alone was not sufficient in order to adequately capture the complexity of food security[122], mostly because distinct individuals may convert the same quantities of food in different nutritional outcomes (Drèze & Sen 1989). The variation in food security outcomes depends on a series of micro and macro conversion factors. As discussed in Section XXX, the former relates to individual heterogeneities in gender, age, health and pregnancy status, metabolic and activity rates, as well as the access to a series of non-food complementary factors (i.e. health care and medical facilities, clean drinking water and sanitation, adequate care practices and basic education). In Sen's approach, conversion factors constitute the "technical synthesis" of a set of individual characteristics, some of which readily detectable (as sex and age), while others more difficult to pinpoint (as, for instance, the metabolic rate and the individual caloric requirements) (Sen 1985, 1999; Chiappero-Martinetti & Pareglio 2009). As different combinations of conversion factors will determine the way in which individuals convert the available resources into actual nutritional outcomes, it is fundamental to take such heterogeneity into account in policy design (Chiappero Martinetti & Pareglio 2009).

On the other hand, macroeconomic factors, such as variation in social climate and institutional arrangements, climatic factors, and social protection systems, are also relevant in determining inter-individual and intra-individual variations in nutritional status[123] (Drèze & Sen 1989; Sen 1999). For this reason, the authors suggested to overcome former approaches based on the dimensions of food access (and availability), in order to include the "utilization" dimension. This conceptual shift is possible through the analysis of the "*nutritional capability"*, i.e. the capability to achieve good nutrition. Drèze and Sen (1989) explained why the focus food entitlements is not sufficient and utilization is crucial:

> *"(...) it is important to link up the question of entitlement guarantees with the importance of non-food items in ensuring the capability to be nourished, as well as other capabilities closely associated with nourishment, e.g. avoiding escapable morbidity and mortality. [...] It is a mistake to view hunger in terms of food deprivation only. This is not merely because there are significant*

[122] For an in-depth analysis of Sen's entitlements approach, see also Devereux (2001).
[123] The next section will explore this point in the depth.

> *interindividual and intraindividual variations in food requirements for nutritional achievement. But also, the capability to be nourished depends crucially on other characteristics of a person that are influenced by such non-food factors as medical attention, health services, basic education, sanitary arrangements, provision of clean water, eradication of infectious epidemics, and so on. If we compare different countries, or different regions within a country, we may find considerable dissonance between the ranking of food intakes and the ranking of nutritional achievements" (Drèze and Sen, 1989, p. 13).*

Through its focus on actual food security outcomes achieved by the individuals and through the explicit recognition of the complex interrelations among different dimensions that ultimately contribute to nutritional capabilities, the CA is the most advanced framework for the analysis and measurement of food security[124] (Burchi & De Muro 2012b). There are many theoretical reasons that support this claim. First, the CA aims at identifying the root causes of food insecurity by framing the analysis within the broader area of human wellbeing. In this framework, food security can be the result of the lack of other basic capabilities that constitute people well-being, such as for instance, the capability to access quality health care or to live in an environment free from infectious diseases (Burchi & De Muro 2012b). Second, through the analysis of individual 'conversion factors' of food acquired into good nutrition, the CA focuses on individual food security achievements. By focusing on those nutritional functionings, the CA is particularly relevant for the analysis of conversion factors of: (i) particularly disadvantaged groups of people, which, in view of socio-economic or geographic factors, could be less efficient in converting available resources into food security outcomes; (ii) most vulnerable people, such as women, children, and the elderly, which may need additional resources in order to be food secure. Third, the focus on individual outcomes is particularly useful to shed light on the intrahousehold distribution of resources (e.g. Sen 1985; Das Gupta 1987; Pitt *et al.* 1990; Haddad & Kanbur 1990; Devereux

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[124] *"The analysis of food security through the capability approach allows a more comprehensive examination of the phenomenon. While the income-based approach would take income as focal variable, the entitlement/capability approach provides information on how income is used to ultimately reach the capability to be food secure depending on personal and external conversion factors, food choices and behaviors. Unlike the food-first approach, the capability approach takes into account the quality, utilization and social acceptability of food, and the interaction with other basic capabilities such as health and education. The capability approach also differs from the "mechanical" view of food insecurity as a lack of micronutrients or other food properties generally advocated by nutritionists"* (Burchi & De Muro 2012b, p. 27).

2001). Fourth, the CA is context-sensitive (Anand & Sen 1997; Sen 1999). This feature of the CA is, again, particularly relevant for the design of food assistance programmes, as many of them failed in the past because they did not take into account the aspect of social or cultural acceptability of food, i.e. people preferences or cultural traditions in the use or consumption of food. People might have sufficient quantity of food of the right quality, but might as well not being able to consume it because of cultural, traditional, or religious reasons (Crocker 2008). From a measurement perspective, context-sensitivity is also fundamental in order to choose relevant food security indicators (Habicht & Pelletier 1990). Fifth, though its emphasis on freedom and agency, the adoption of the CA involves a conceptual shift in the role played by people in the process of development. From passive recipients of aid, people became active agents in their own development (Sen 1999). This view has significant implications in food security policies, especially in the design of food assistance programmes and other interventions that may enhance people capability to cope with food insecurity and smooth exogenous shocks (UNDP 2012; Devereux et al. 2012). This point is linked to the contribution that the adoption of the CA can bring in the analysis of the dynamics of food security: the capability to be food secure, as introduced by Burchi & De Muro (2012b) points to a long-term perspective, which includes the stability, vulnerability, and sustainability dimensions.

3.3.1. A Proposal of a Capability-Based Conceptual Framework for the Analysis of Food Security

The aim of this paragraph is to discuss and present an original conceptual framework for the analysis of food security through the CA lens, on the model of Drèze & Sen (1989) and Burchi & De Muro (2012b). The framework illustrated in Diagram 1 is an original re-elaboration of the UNICEF (1990), FIVIMS (2003), and USAID (Riely et al. 1999) conceptual frameworks for the analysis of food security, and the integrated micro-macro model proposed by Chiappero Martinetti & Pareglio (2009) to conceptualise the impact of public policies on functionings. The latter is particularly interesting for our purposes, as it offers a theoretical model in which the *process* according to which food security is achieved can be easily conceptualised. As mentioned, food security is a multi-layered concept, i.e. it can be analysed at different levels of analysis. In Figure 5, this feature is clear: availability of food - a necessary condition for food security outcomes to occur at any level of analysis - is a dimension that can be defined and measured at the macroeconomic level (i.e. regional, national, and sub-national levels of aggregation). By contrast, the dimensions of access and utilisation are mostly microeconomic:

in particular, access is usually defined at the household level, while utilisation is an inherently individual concept, as it focuses on the way in which the food consumed is transformed in optimal nutritional outcomes. At the microeconomic level it is possible to observe that "*the capability to be food secure*" (Burchi & De Muro 2012b) is the result of the joint and complex action of macroeconomic and social constraints, functional limitations and other contextual characteristics of the household environment. A part from households' own entitlements to food (Sen 1981), food available is actually accessed by the households in virtue of the variety of economic, institutional, social, political, and environmental factors tcharacterising the country that have been discussed in the former section (UNICEF 1990; FIVIMS 2003; Timmer 2000). Sen (1999, p. 38) referred to these elements as "*instrumental freedoms*[125]", and represent the social, institutional, and environmental conversion factors of commodities into functionings (Robeyns 2005). In this section, these factors will be referred to as *'macroeconomic conversion factors'*, as opposed to the '*individual'* or '*microeconomic*' ones, which relate to the individual heterogeneity in converting resources into valuable functionings. The CA perspective, with respect to other theoretical frameworks, has the advantage of taking into account of the broader country context in the analysis of how people are entitled to food and in turn can convert it into food security outcomes[126] (Burchi & De Muro 2012b). Process freedoms, and in particular the dimension of 'protective security' also play a key role in ensuring the dynamic dimension of food security, in order to ensure sustainable and stable food security outcomes over time in face of climatic and economic shocks or conflicts (Devereux 2007; UNDP 2012). As Barrett (2002) noted:

> *"Adverse shocks to an economy rarely affect all people equally. Nature may not discriminate among people, but intermediate social and economic institutions certainly do" (p. 2118).*

[125] These include: (i) political fredoms; (ii) economic facilities; (iii) social opportunities; (iv) transparency guarantees; (v) protective sectuity. Each of them help to expand people freedom, and they may also serve to complement each others (Sen 1999, p. 10).

[126] As noted by Robeyns (2005): *"There are other means that function as 'inputs' in the creation or expansion of capabilities, such as social institutions broadly defined. The material and non-material circumstances that shape people's opportunity sets, and the circumstances that influence the choices that people make from the capability set, should receive a central place in capability evaluations. (...) The capability approach not only advocates an evaluation of people's capability sets, but insists also that we need to scrutinize the context in which economic production and social interactions take place, and whether the circumstances in which people choose from their opportunity sets are enabling and just"* (p. 88).

For this reason, at the country level, the ultimate balance between risk exposure and resilience will depend on the entirety of economic and social institutions that buffer periodic shocks and render the system able to prepare for, adapt and live through shocks while preserving its essential structures, functions, and people capabilities (Frankerbergen 1992; Sen 1999; UNRISD 2009). In situations of distress or shocks, public interventions can mitigate hardship and build resilience for the poorest and most vulnerable household, avoiding in this way that the damage would become permanent (UNDP 2012; Drèze & Sen 1989; Devereux et al. 2012).

By focusing on the household level, Figure 5 shows that the complex "*capability to be food secure*" (Burchi & De Muro 2012b) depends on a series of other basic capabilities, such as the health, education, care, *etc.*, the intrahousehold distribution of resources, and the individual conversion factors that allow people to convert food accessed in individual nutritional outcomes (Drèze & Sen 1989; Burchi & De Muro 2012b). As following Burchi & De Muro (2012b, p. 21), the distinction between 'basic' and 'complex' capabilities points to the fact that the former are foundational to the latter. In turn, if the capability of being food secure is available, whether or not it would be activated into a real functioning would depend exclusively on people's choices*:*

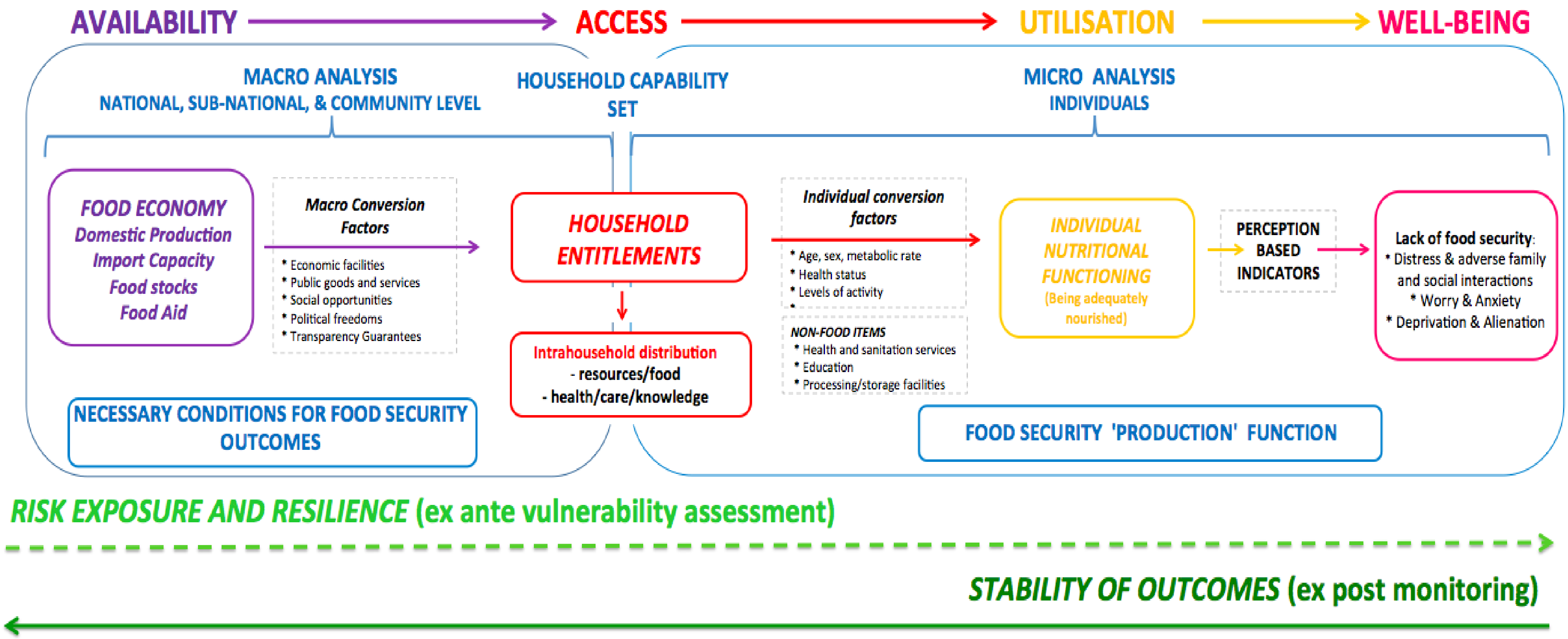
> *"Although being food secure is such a basic capability that the largest proportion of the people having such capability would decide to activate the related functioning, there might be cases in which people would choose not to be food secure. It can be the case of an anorexic person "deciding" to fast or, as already outlined in previous paragraphs, a person making inter-temporal choices in order to ensure long-run food security. This situation can be properly captured only by examining simultaneously capabilities and functionings" (Burchi & De Muro 2012b, pp. 23-24).*

Finally, the functioning of "being well nourished" can be measured at the individual level by either anthropometric or other indicators of nutritional status (Svedberg 2002), or subjective indicators related to perceptions of food security (Kennedy 2003; Migotto *et al.* 2005; Wunderlich & Norwood 2006; Deichtler *et al.* 2011; Headey 2011).

We argue that our framework has a number of advantages: first, it is built on the theoretical foundations of the CA, which, for the reasons explained above, allows a more comprehensive examination of the phenomenon than the other existing frameworks (Burchi & De Muro 2012b). Second, by incorporating the subjective consequences of the lack of food security, such as psychological distress and alienation from the community (Wunderlich & Norwood

2006), it expressly points to the fact that food security is not an end in itself, but a fundamental component of the broader concept of human well-being (OECD 2001; Weinreb *et al.* 2002; Withaker *et al.* 2006; Stiglitz et al. 2009; UNDP 2012). Additionally, by highlighting the elements of *ex ante* assessment of risk and vulnerability, as well as those of *ex post* evaluation of past outcomes, it emphasizes the dynamic nature of food security (Barrett 2002, 2010). Fourth, it shows that like well-being, food security is not only multidimensional but it is also the outcome of a *process* of achievement, which is the result of the joint and complex action of macroeconomic and social constraints, functional limitations and other contextual characteristics of the household environment. Following this conceptualisation, dimensions of food security are interdependent, rather than merely additive (Burchi & De Muro 2012b). Finally, by explicitly introducing different levels of analysis this conceptualisation shows that food security is a phenomenon that can be analysed at a plurality of levels (global, national, household, and individual) (CFS 2011a; Burchi & De Muro 2012b).

Figure 5 An integrated macro-micro, dynamic to the analysis of food security



3.4. Operational Definition Of Food Security Adopted In This Thesis

In order to incorporate the complexity and all the possible characterizations of food security, the WFS definition is deliberately general. However, such universality is somewhat in tension with the operational clarity necessary for measurement: is it referring, say, to global, national or household outcomes? To chronic deprivation or temporary food crisis? And again, to *ex post* assessment or *ex ante* vulnerability to food insecurity? Part of the confusion surrounding concepts and metrics for food security can be ascribed to the lack of a clear, operational definition of food security tailored to the purposes of the analysis. As Barrett (2002) noted,

> *"(...) Food security is an inherently unobservable concept that has largely eluded a precise and operational definition" (p. 2106).*

By acknowledging this issue, the aim of the present section is to provide a clear definition of food security by operationalizing the WFS definition along three main axes: (i) duration; (ii) perspective of assessment; and (iii) level of disaggregation.

i ***Duration: Food security as chronic deprivation***

The durational aspect of food security is an essential variable to consider in order operationalizing the WFS framework for measurement purposes. The distinction between chronic hunger and acute food crisis is particularly relevant for policy purposes, as different temporal characterizations will call for different types of policy interventions and instruments[127]. For the purposes of our analysis, the

[127] For instance, chronic food insecurity may require actions that can tackle the 'structural' determinants of the situation of permanent deprivations (i.e. enhancing the access of the poor to food and public services, and improving their overall quality; asset redistribution; tackling social exclusion; regional infrastructural development, *etc.*) while temporary food crises may be better dealt with other tools (such as, emergency food distribution, social protection and welfare programmes, reskilling, microcredit, temporary social safety nets, health services).

focus is to identify indicators of food security as *chronic deprivation* of well-being, as opposed to temporary or seasonal food insecurity.

ii *Evaluation: Food security is evaluated ex post*

Available data report about food security outcomes occurred in the past. For this reason, the framework and related suite of indicators necessarily adopts an *ex post* perspective[128].

iii *Level of Disaggregation: Food security is measured at the country level*

Although food security outcomes can be analysed at different levels of aggregation (e.g. global, national, subnational, household, individual), this paper focuses on the measurement of food security at the country level, as in the case of MDG objectives

By combining these three elements, it is possible to sketch out an operational definition of food security[129] that will be adopted in this and the following chapters:

> *"A country is considered food secure when its population does not live in hunger or hidden hunger. Food security in a given point in time is defined as having three main components: availability, access, and utilization. Supply of food must be sufficient in quantity and quality; families and individuals require a reliable and consistent source of nutritious food, as well as sufficient resources to purchase it and an adequate enabling environment that allows for the actual conversion of the food acquired into actual nutritional outcomes."*

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[128] Although we recognise that the increasing insecurity linked to climate change and price volatility calls for the development of forward-looking information system focusing to the set of structural conditions that render a country vulnerable to food insecurity in the future[128]. Another reason for adopting an ex ante perspective in the analysis of food security is linked to the modeling of potential effects of some policy-interventions. As such, the development of prospective food security metrics is a critical area for further research.

[129] This definition also builts on the definition of household food insecurity proposed by Feed the Future (2010).

3.5. Conclusions

This Chapter aimed at providing the theoretical and conceptual framework for the measurement of food security of the next chapters. In doing so, it first explored the concept of food security by highlighting its distinguishing features. Then, it provided an originally theoretical framework for the analysis and measurement of food security and later an operational definition of the concept that will be the basis of the evaluative exercises of Chapters 5 and 6. Before turning to actual measurement, the next chapter will briefly review the literature on the metrics for food security.

Chapter 4

Measuring Food Security: Literature Review

4.1. Introduction

Before turning to the actual contribution of this thesis in terms of the measurement of food security (Chapter 5 and 6), this Chapter aims at taking stock of the main methods currently used to measure food security at the country level. As of yet, there is still no 'gold standard' or agreement on the way to measure food security, and the five broad methodologies are currently used in the literature:

(i) Parametric approaches to estimate the Prevalence of Undernourishment (PoU);

(ii) Non-parametric estimates based on Household Budget Surveys (HBS) and Household Income/Expenditure Surveys (HIES);

(iii) Anthropometric measures;

(iv) Perception-based indicators;

(v) Composite Indicators.

Each methodology differs on the basis of the operational definition of food security adopted, as well as on its applicability and policy responses that it call for., which will be discussed in the next sections As such, distinct methods are complementary in depicting the complexity of the food security.

4.2. Parametric approaches to estimate the Prevalence of Undernourishment (PoU)

The Food and Agriculture Organization of the United Nations (FAO) estimates the Prevalence of Undernourishment (*PoU),* i.e. the share of population not meeting their minimum dietary energy requirements, by relying on three key inputs: (i) data on dietary energy supply retrieved from Food Balance Sheets (FBS); (ii) a log-normal distribution; (iii) a threshold of minimum energy requirements based on the demographic structure (by age and sex class) of the population[130]. The model relies on a log-normal distribution, in which the mean value is characterized by the Dietary Energy Supply (DES), i.e. the average quantity of food available for human consumption converted in kilocalories through food consumption tables. The shape of the distribution is determined by a coefficient of variation of energy expenditure, which measures the inequality in caloric consumption or food expenditure from national-level household surveys (Naiken 2003). Once the shape of the distribution and the threshold are determined, the resulting estimate – the *PoU* - is the probability that, by randomly selecting an average individual in the population, she will be found to consume (on average and over the year) a level of food energy below the minimum required to maintain a healthy life[131]. In this way, FAO measures food insecurity as *chronic undernourishment* at the population level, i.e. the percentage of population who is deprived in dietary energy supply during one year (CFS 2011a). The operational definition of food security embedded in the FAO index focuses only on food availability and access, and does not aim at capturing nutritional concerns (in terms of both diet quality and diversity), or considerations of risk to future food insecurity. Moreover, by construction, the measure cannot: (i) provide disaggregated estimates at the sub-national levels or for population sub-groups; (ii) capture short-term fluctuations in the access to

[130] A similar model is adopted by the United States Department of Agriculture. However, while FAO uses data from Household Expenditure Surveys containing information on food consumption, USDA estimates Engel curves linking food consumption to income. The following discussion, however, will focus on the FAO methodology, as it is the one adopted to measure hunger in the context of the MDGs (UN 2000).

[131] An aspect that is often overlooked about the FAO measure is that the measure is probabilistic in nature and, as such, measurement error is inescapable.

food (i.e. seasonal fluctuations, variation in prices, famines etc.) as the estimates are three-years averages; (iii) measure abrupt changes in the within country distribution in the access to food, as data from household surveys from which the inequality parameter is computed are not frequently available (or updated); (iv) provide real-time monitoring due to the lagged intervals in which FBS data are released.

The FAO index has been harshly criticized in the literature of food security measurement (Dasgupta 1993; Svedberg 2000, 2002, 2011; Smith *et al.* 2006; Masset 2011, De Haen *et al.* 2011). Gennari & Cafiero (2011) framed the main criticisms under three main profiles: (i) the appropriateness of the operational definition of hunger embedded in the concept of undernourishment; (ii) the soundness of the methodological approach on which the estimate is obtained; and (iii) the reliability of the elementary data, in particular the ones relates to food balance sheets, which are used to construct the estimate. Having already discussed the limitations of the operational definition embedded in the FAO indicator, the discussion that follows will focus on the second and third types of critiques. Regarding the methodological argument, two main criticisms have addressed the FAO undernourishment indicator. On the one hand, Svedberg (2000, 2002) argued that the FAO methodology generates systematically upward biases in the estimates[132], which are also very sensitive to slightly changes in the parameters of reference. On the other extreme, Dasgupta (2003) and Smith *et al.*

[132] Svedberg's (2002) critique relied on two main arguments. First, he claimed that the underlying distribution is not univariate, but is a joint distribution of households' consumption levels and caloric requirements. Secondly, building on Dasgupta (1993), Svedberg (2002, 2011) argued that the estimates are extremely sensitive to slight changes in the underlying parameters, due to issues of data quality and lack of transparency on the calculation of the parameters. On this basis, Svedberg argued that FAO estimates are subject to two types of biases: a downward "methodological bias", as estimates are based on the "biased" univariate distribution formula rather than the "unbiased" joint distribution; and an upward "data bias" resulting from the systematic errors in the input data. The resulting estimates will then be biased either upwards or downwards, depending on the relative magnitude of the two types of errors. Basing his estimations on the "corrected" input data and the bivariate distribution, he found that the "data bias" was greater than the "methodological bias", and hence concluded that FAO mostly overestimated the prevalence of undernutrition. In particular, he argued that high levels of *PoU* for Sub-Saharan Africa are due to the underreporting of food production levels in the FBS, especially by taking into account the magnitude of subsistence production of agricultural commodities in those countries.

(2006) claim the opposite, i.e. that FAO estimates are systematically underestimating the prevalence of undernourishment[133].

The debate on the methodological and empirical soundness of the FAO indicators is still open: recently, the methodology has been updated, while there has been an effort to improve the quality of the data and the parameters (FAO 2012). Also FAO acknowledged the need to measure food security in a multidimensional way, and a suite of indicators that capture its different dimension has been included as part of its methodology (Chapter 5).

4.3. Non-parametric methods based on Household Budget Surveys and Household Income Expenditure Surveys

Smith (2003) and Smith et al. (2006) proposed an alternative methodology to estimate food deprivations levels through households' food acquisitions that has gained considerable attention by the profession (e.g. Anriquez et al. 2010; De Haen *et al.* 2011; Ecker & Qaim 2011). Much in the tradition of the literature on unidimensional poverty metrics discussed in Chapter 1, this approach uses nationally representative Household Budget and Expenditure Surveys in order to derive 'head-count' measures of food deprivation. In practice, quantities of food acquired by the household are first converted in calories by using food composition tables, in order to obtain an estimate of household caloric consumption. Then, consumption estimates are compared to a threshold based on the average energy requirement of the household, calculated by considering its age and sex structure. Households falling below the caloric cutoff are classified as food insecure, and the resulting headcount measure interpreted as the prevalence of undernourishment in the country.

As for the FAO index, the operational definition of food insecurity embedded in the non-parametric approaches is of dietary energy deprivation[134]. Advocates of

[133] Smith *et al.*'s method, as well as the related critique to the FAO methodology, will be discussed in more depth in the next paragraph.

[134] It has to be acknowledged, however, that in their study Smith *et al.* (2006) also considered the extent of dietary diversity for the households. Nonetheless, their method, as well as the following

the methodology sustain that estimates from Household Budget Surveys provide more accurate and reliable figures on national food insecurity with respect to the FAO index. In particular, their argument revolves around five main points (De Haen *et al.* 2011). First, food consumption is directly measured at that the household level, fewer assumptions about missing data on agricultural production, trade, post-harvest losses and non-food uses are required. Second, the reliance on micro data allows for generating disaggregated estimates according to sub-national levels or social groups. Third, the high level of disaggregation of food items in many of the surveys allows for a better reflection of what is actually consumed, thus making the conversion of food quantities into calories more precise. This also allows to analyse the degree of dietary diversity and the prevalence of micronutrient deficiencies (Babatunde and Qaim, 2010). Fourth, as opposed to the FAO index, the method does not require distributional assumptions related to food access across households and income levels, because the data themselves determine the distribution. This is the reason why these methods are often referred to as non-parametric (Sibrian *et al.* 2007). Fifth, while FAO uses data on the population structure at the country level to derive the cutoff point related to the population minimum dietary energy requirements, the survey-based approach takes the actual demographic structure of households into account.

In principle, then, this method may seem the classical "Columbus's egg" to measure food security. At a closer look, however, criticalities arise. First, from the CA standpoint, this methodology, as the FAO index, focuses on the "inputs" (i.e. caloric availability, whether at the household or at the national level) rather than on the actual "outcomes" of food insecurity (i.e. individual nutritional statuses). In this way, the issue of different conversion factors of food into actual nutritional outcomes is not taken into account (Sen 1985, 1999; Drèze & Sen 1989). Second, it is questionable whether household survey data can measure correct levels of dietary food energy consumption: for instance, estimates often neglect food consumption acquired outside the household, whether in the private

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studies that applied this kind of methodology, prevalently or only focused on caloric shortfalls from an average household's requirement.

(from street vendors, restaurants…) or public sectors (as food consumption in the public sector (e.g. in hospitals, schools, prisons…) because the surveys do not always collect these data as their primary purpose is not to measure food security. Moreover, issues of cross-country or time comparability of the estimates may arise, depending on different survey designs. Finally, there may be errors in the classification of the households as food insecure or not for two main reasons (Cafiero 2011). Firstly, non-parametric approaches first classify each household in the sample as being undernourished or not, and then infer from the proportion of undernourished in the sample an estimate of the prevalence of undernourishment in the population. As no sophisticated inferential model is assumed, only national representativeness of the sample is required, in principle, to ensure un-biasedness of the estimate. However, there may be many features of the surveys that render the hyphothesis of randomness of the difficult to hold. These elements may relate to a series of issues related to the design, implementation and processing of survey data, such as the identification and treatment of outliers, the correction for the seasonality of data, and the accurate appreciation of prices to correct for the difference between reported acquisition and normal consumption. Secondly, the determination of adequate caloric thresholds through which to classify household is controversial[135] (Deaton 1997; Cafiero 2011). Cafiero (2011) noted that the standards for calculating human energy requirements are designed to be applied to groups of individuals of the same sex and age and no single individuals. As such, the combination of the potentially large imprecision and possibly systemic bias in measuring single household level dietary energy consumption levels, and of the improper usage of the energy requirement norms in classifying households seem to point that the head-count method is far from being a robust method to measure the proportion of households that are actually undernourished in a population. Estimates of the

[135] As noted by Deaton (1997): *"(...) the minimum adequate calorie levels are themselves subject to uncertainty and controversy, and some would argue that resolving the arbitrariness about the poverty line with a calorie requirement simply replaces one arbitrary decision with another".*

prevalence of undernourishment based on this method could be plagued by large errors, the direction of which is difficult to predict (Sibrian *et al.* 2007).

4.4. Anthropometric indicators

Anthropometric measurements are commonly used for the diagnosis of undernutrition throughout the life cycle (i.e. infants, children, adolescents, adults, pregnant and lactating women, and elderly) (WHO 1995; Shetty 2003). In contrast to the first two methods that focus on resources, anthropometric indicators measure the outcomes of food and nutritional security at the individual level. While a great variety of anthropometric measures exist (WHO 1995), the most common ones focus on the relation between height and weight of individuals. In particular, the greatest scientific consensus and common application relates to anthropometric measures on body development of children aged 0-5, because for other groups the debate on the cross-country comparability of reference standards is not settled[136] (De Haen *et al. 2011).* As such, the discussion below will focus on anthropometric indicators related to early-childhood wasting, stunting and underweight. Although these indices are related, each has a specific meaning in terms of the process or outcome of growth impairment (WHO 1995). Wasting (low weight for height) is an indicator of acute malnutrition that reflects recent of continuing severe weight loss, which is able to detect situations of acute food insecurity. Conversely, stunting (low height for age) measures retarded growth due to long-term malnutrition and poor health and sanitary conditions. Finally, underweight (low weight for age) is a summary indicator that combines both aspects. The latter, together with the FAO index on the Prevalence of Undernourishment, monitors progress towards the Millennium Development Goal 1 on Poverty and Hunger Reduction. Data related to anthropometric indicators are collected at regular intervals from the Demographic and Health Surveys (DHS) and the UNICEF Multiple Indicators Cluster Surveys (MICS) by using standardized techniques.

[136] In this respect, the WHO recently proposed a new reference standard to evaluate the nutritional status of school-aged children and adolescents, aged 5-19 (De Onis *et al.* 2007).

Deprivation in anthopometric indicators is determined on the basis of the distance expressed in standard deviations[137] between the child's measurement and the median of the reference population[138] (WHO Multicentre Growth Reference Study Group 2006). Note that malnutrition may not only be the outcome of macro or micronutritents deficits, but also of an increased rate of nutrient utilization (as in many infectious diseases), and/or to impaired absorption or assimilation of nutrients. In other words, it depends on the broad set of "conversion factors" that enable the individual to convert food in nutrition (Sen 1985; Drèze & Sen 1989). As such, malnutrition itself can be interpreted as a multidimensional phenomenon, which is summarised by the anthropometric indicators.

As for the other measures, there are merits and disadvantages of anthropometric indicators. With respect to the advantages, most prominently from the theoretical perspective of the CA, anthropometric indicators directly focus on the ultimate object of interest, people's nutritional status[139]. Second, these measures are highly correlated with other morbidity and mortality indicators (Pelletier 1994; Svedberg 2000, 2011; Klasen, 2008; Deaton and Drèze 2009, De Haen et al. 2011). Third, as they are collected from household surveys, there is scope for disaggregating the prevalence of anthropometric deficiency by sub-national levels and/or groups of particular interest for policy analysis and targeting. Moreover, surveys that usually collect those data also include a variety of covariates that can be used to assess the factors that impact on nutritional outcomes, which can be used to design programmes and monitor nutritional interventions. Linked to this

[137] Usually -2 standard deviations for moderate cases, and -3 standard deviations for extreme deprivation.

[138] It is hence clear that the choice of reference population, on which basis the cutoffs are calculated, is critical. Up to 2006, the WHO reference standard for child growth had been based on a sample of children developed by the Centers for Disease Control and Prevention (CDC) Growth Reference in the United States. In order to overcome a number of conceptual and technical criticalities (WHO 1995), in particular the cross-country comparability of a reference based on United States children (Klasen 2008), the WHO decided to undertake a multi-centre child growth study to derive a new reference standard. The aim of the study was to provide a single, comparable reference that represents the best description of physiological growth for all the children under five years of age and to establish the breastfed infant as the normative model for growth and development (WHO Multicentre Growth Reference Study Group 2006).

[139] As Anand and Sen (2003) remarked: "*Since our ultimate concern is with the nature of the lives that people can lead, there is a case for going straight to the prevalence of undernutrition, rather than to the intake of calories and other nutrients*" (Anand & Sen 2003, p. 209).

last point, from a policy perspective is very important to understand which are the main drivers of the low nutritional status[140] (i.e. insufficient food intake or low quality or dire health and sanitary conditions).

A critical issue relates to data availability for cross-country comparisons[141], as the MICS and DHS are usually conducted only in intervals of 3-5 years. For this reason, they can be used only for medium-term nutritional assessments, and not for short-term evaluations, or frequently updated statistics on global hunger. Also, available data only cover early childhood and sometimes women. All the other groups of population are neglected. As such, the development of comparative standards for assessing the nutritional status of other vulnerable population groups (i.e. the elderly or adolescents) would be welcomed.

Moreover, in the light of nutrition transition and of the double burden of malnutrition, anthropometry indicators (especially underweight) may lead to biased estimates that in fact did not occur (Pingali 2007). In many developing and transition countries (in particular in Latin America and Asia) diets are changing fast by including high fats and sugar contents, and children may be erroneously classified as adequately nourished because they gain sufficient weight, but they may be still lacking critical micronutrients and be malnurished. This problem seems to affect particularly the underweight indicator, which is currently the only anthropometric indicator used for monitoring the MDGs. In line with this hypothesis, there has been more progress over time in underweight rates with respect to the other anthropometric indicators. For this reason, the United Nations (2000) and Misselhorn (2010) proposed to measure children malnutrition through the stunting indicator because it is not significantly affected by the 'nutrition transition bias' (Misselhorn 2010).

[140] By the same token anthropometric indicators do not take into account physical activities levels (Svedberg 2011). This is a limitation, as there may be coping mechanisms on how children adjust to unduly low intakes of calories and other nutrients. If the first reaction is weight loss, anthropometric measurements will be also capturing the effects of physical activity. Conversely, anthropometrics may miss the children who are inactive in order to maintain energies, which can have adverse consequences for health and has well cognitive and motoric development (Svedberg 2011).

[141] For instance, in the dataset of food security that I built over a period of 20 years (1990-2009) and across 181 countries, only for 25% of total observations there were data on children's anthropometric status.

4.5. Self-reported food security assessments

Starting from the 1960s, policy makers have been increasingly looking for measurement techniques for food insecurity and hunger that are simple to use and easy to analyse (Kennedy 2003). In particular, they focused their attention to subjective indicators of perceptions of hunger and food insecurity. Qualitative indicators may be related to emotional dimensions, such as anxiety over not being able to meet basic food requirements of the household, or behavioural changes due to variations in the household's capability set, such as reducing food quantities or quality or skipping meals. The major experiences in the field of qualitative measures of food insecurity relate to the work of the United States Department of Agriculture on the "Food Security Measurement Scale" (Hamilton et al. 1997); the "Household Food Insecurity Access Scale" (Coates et al. 2007) and the "Household Hunger Scale" (Deitchler et al. 2011) developed to assess food insecurity in different cultural contexts[142]; and, finally, the hunger module inserted in the Gallup World Poll indicators, which were recently employed by Heady (2011) as an alternative indicator of the impact of food crises on the poor.

Within the United States, self-reported indicators are able to provide insights into the way in which households experience food insecurity, which is defined mostly on the basis of the access and stability dimensions (Kennedy 2003). In particular, research focused on the social dimension of food insecurity, as inability of obtaining "*an adequate amount of food, even if the shortage is not prolonged enough to cause health problems"* (President's Task Force on Food Assistance 1984, quoted in Kennedy 2003).

According to Kennedy (2003) qualitative indicators provide direct measures of food insecurity, as they incorporate the perceptions of food insecurity and hunger by the people most affected, and are quick to administer and well-understood by policy-makers. Moreover, validation research shows that they are highly correlated with income and consumption expenditure, as well as dietary energy intake (Kennedy 2003). A critical issue, however, relates to the validation of

[142] Other measures developed for the context of developing countries are Webb *et al.* (2001); Vargas & Penny (2010).

those measures for cross-country comparisons: hunger is a deeply cultural phenomenon and perceptions may vary according to the cultural, economic, social and educational background of reference[143] (Deitchler *et al.* 2011; Headey 2011).

Other disadvantages relate to the comparability over time of trends in food insecurity based on these measures, as the underlying concept they capture may change, and on the one of *adaptive preferences* in respondents' perception about their hunger levels (Elster 1982; Sen 1985a,1985b, 2002; Nussbaum 2000), due, for instance, to their income and education status[144].

Finally, Barrett (2010) pointed out two important issues related to perceptions-based indicators of food insecurity. First, because most food insecurity is seasonal or aperiodic – correlated with episodes of temporary unemployment, ill-health or other adverse events – perceptions-based survey measures consistently find food insecurity rates several time higher than related hunger or insufficient-intake measures (National Research Council 2005). Second, qualitative assessments may not suffice to capture the utilization aspect of food insecurity, such as the one associated with lack of micronutrient in the diet.

To sum up, further refinement and validation of all these qualitative methods could be extremely rewarding in terms of providing complementary and easy to monitor data for national and global food security monitoring. However, the drawbacks that characterise these measures should be kept in mind when attempting to measure food insecurity relying exclusively on perception-based indicators.

143 An interesting effort to develop a measure of the access component of food insecurity household explicitly intended for cross-cultural uses is the recent work by Deitchler *et al.* (2011). It is noteworthy that among the 18 initial proposed indicators, only three of them – all related to deprivation in the access domain - were validated for cross-country comparability.

144 This hyphotesis has been confermed empirically by Headey (2011), which found that when analyzing self-reported indicators of food security from the Gallup Poll, former communist countries with high levels of literacy reported higher levels of food insecurity with respect to Sub-Saharan Africa countries.

4.6. Composite indices of food security

The literature on multidimensional indexes of food security is rather heterogeneous, in terms of unit of analysis, methodology, and dimensions involved into the various indexes proposed. For this reason, the present review will only focus on indices using national-level data, which is coherent with our operational definition of food security presented in the previous chapter. The literature review highlighted six different composite indicators of food security: (i) IFPRI's Global Hunger Index (GHI) (Weismann 2006); (ii) the Nutrition Index (NI), developed by Wiesmann *et al.* (2000); (iii) the Hunger Index, published in 2001 by the Bread for the World Institute; (iv) the Poverty and Hunger Index proposed by Gentilini and Webb (2008); (v) Maplecroft's Food Security Index (Maplecroft 2011); (vi) the Economist Intelligence Unit's Global Food Security Index (EIU 2012). Below the best known composite indicator of food security, the Global Hunger Index will be reviewed.

4.6.1. IFPRI's Global Hunger Index

The Global Hunger Index (GHI) was launched for the first time in 2006 by IFPRI (Weismann 2006). The 2012 GHI was calculated for 120 developing and in transition countries (IFPRI/Concern Worldwide/ Welthungerhilfe and Green Scenery 2012). The GHI combines three equally weighted indicators as an arithmetic mean: (i) the share of population with insufficient dietary intake, as estimated by FAO; (ii) the prevalence of underweight in children under the age of five as compiled by the World Health Organization (WHO); and (iii) the under-five mortality rate. Wiesmann (2006) justified the choice of these indicators with three main arguments. First, all of them were selected to track progress towards the achievement of the Millennium Development Goals (UN 2000). Second, the indicators related to children – child underweight and mortality – are assumed to be associated with or partly caused by micronutrient deficiencies. In this way, the index aims at capturing another dimension of food security, *utilization*, which is usually difficult to include in food security analyses due to scarce data availability. Finally, the index, by aggregating information on the entire population and on a particularly vulnerable subgroup, is believed to provide a comprehensive view on the overall state of food security in a given country (Wiesmann 2006; IFPRI 2010).

Regarding the choice of weights, Weismann showed that they were first derived empirically through a principal components analysis and then they were later adjusted in the way to calculate the composite index as a simple mean. The GHI is built on a 100-point scale, from 0 (no hunger) to 100 (complete famine), although neither of those extremes are realistic. The higher the index, the worst is the situation in terms of food security of a given country.

According to Wiesmann (2006), there are many advantages from using the GHI: to start with, the multidimensionality of the index allows to better capture the complexities involved in food security analysis with respect to a single indicator based only on per capita availability of food. In particular, she states that the index tries to capture three out of four of the constituents of the food security concept: availability of food (though the first indicator, share of population with insufficient dietary intake); access (through the indicators related to children well-being); and utilization of food, which can be partially explained by both the malnutrition indicator and to the better correlation of the index to the consequences of some micronutrient deficiencies. However, it is unsure whether the construct that the index is actually capturing is food security and to which extent.

4.7. Conclusions

The aim of this Chapter was to introduce and discuss the different methodologies proposed in the literature to measure food security at the country level in order to provide a background for the choice of the indicators of the evaluative exercises of the next chapters.

Chapter 5

Measuring Food Security: A Suite of Indicators Approach

5.1. Introduction

In this Chapter, we propose a methodology to select a suite of core indicators for food security assessments, which can nonetheless be applied to the measurement of other multidimensional phenomena.

Our methodology was formulated in order to respond to a very practical exigency, which arose during the consultations of the Committee for Global Food Security (CFS) in September 2011. In this occasion, both policy-maker and academic communities manifested their strong desire for a new and multidimensional metrics for food security assessments, in the form of a suite of core indicators to monitor countries' performances over time, which could go beyond the unidimensional metrics of the FAO index (CFS 2011b). This need reflected the wide acknowledgement of the multifaceted nature of food security: as the CFS explicitly recognized, in order to provide meaningful information for policy-making, metrics for food security must necessarily be multidimensional as no single indicator can alone capture the complexity of the concept.

After the consultations, FAO Statistics Division decided to take the lead and to select a core set of key indicators to monitor food security. The suite of key indicators had a twofold objective: on the one hand, to provide a core set of essential indicators, which alone can provide an exhaustive picture of magnitude and trends in global, regional, and national food security; on the other, to enhance clarity and improve communication regarding food insecurity to a wide audience, ranging from policy-makers, through the general public, to any other relevant stakeholder. Before this initiative was launched, other institutions or researchers have already made attempts to capture the multidimensional nature of food security through battery of indicators (i.e. Maxwell & Frankerbergen 1992;

FIVIMS 2003; Panelli-Martins et al. 2008; FAO/RAP 2010; CONSEA 2010; Feed the Future 2010). Many of the available suites, however, assemble tens (if not hundreds) of indicators without considering the way each single measure enters in the process of achievement of food security[145], or without any clear reference of the normative criteria and value judgments informing the selection of which indicators to include. As such, the informative content of those 'laundry-lists' is extremely difficult to synthetise in an overall picture of food security on which basis policies can be formulated. Additionally, the proliferation of lists, by providing messages that are often difficult to synthetise and communicate (or even contradictory, in the worst cases), enhanced the confusion of policy-makers and general public on the magnitude, trends and nature of the phenomenon, and triggered a general sense of dissatisfaction with food security measurement (CFS 2011a).

The methodology proposed in this Chapter aims at tackling these difficulties by grounding the measurement exercise in the theoretical framework of the CA, with insights from the literature on social indicators. The methodology has then been adopted, with slight changes in the indicators selected, by FAO in October 2012[146] in order to provide a multidimensional metrics for food security at the global level. Additionally, at the country level, it can support evidence-based policy-making by providing information on the levels and trends of national food security and by identifying progress and weaknesses in the different dimensions.

5.2. A Methodological Proposal to Guide Indicators Selection

"There is no best indicator, best measure of an indicator, or best analysis of an indicator in a generic sense. The definition of "best" depends ultimately on what is most appropriate for the decision that must be made."

(Habicht and Pelletier, p.1519, 1990)

[145] An exception is Feed the Future (2010), which, nonetheless, aims at measuring food security in the specific context of USAID development assistance programs.
[146] http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/.

As discussed in the first chapter, the adoption of the theoretical framework of the CA serves many purposes in the measurement of well-being outcomes: first, the many normative choices involved in the evaluative exercises (and hence the results) are transparent and this enhances the overall justifiability and acceptability of the metrics by its relevant stakeholders. Secondly, the CA focus on the ultimate outcomes of well-being has the advantage of providing a strong criterion for indicators selection, which has the practical implication of avoiding the umpteenth "laundry list". This principle is at the basis of our methodology, which rests on three, deeply interconnected, elements: first, available indicators should fulfil a basic set of quality requirements; then, the purposes of the evaluative exercises should be clearly and transparently specified; and finally, the selection of the available indicators that "passed" the quality check should be based on the *role* the indicator plays in relation to the purposes of the evaluative exercise.

First, candidate indicators should pass a formal "quality" control. The social indicators literature has defined a set of normative standards that define the "goodness" of a headline indicator in the field of development (Jannuzzi 2001, 2005; UN 2003; Darcy & Hofmann 2003; OECD-JRC 2008; Hall *et al.* 2010; Trewin & Hall 2010), and, more specifically, for food security analysis (Frankenbergen 1992; FAO/FSAU 2009; CFS 2011a). These desirable properties relate to: (i) relevance to the policy objective; (ii) validity in the conceptual representation of the underlying phenomenon; (iii) sensitivity to change; (iv) unambiguity and easiness of interpretation; (v) robustness of the resulting measures; (vi) methodological transparency in the construction of the indicator; (vii) timeliness in its production and updated on a regular basis; (viii) being representative of the population in the sample; (ix) being comparable across countries and over time; (x) being accessible to the general public; (xi) being based to the greatest extent possible on international standards, recommendations and best practices; (xii) being constructed from well-established and reliable data sources; (xiii) being consistent with similar indicators.

However, the adherence to a set of desirable properties is only a necessary, but not sufficient, condition for choosing indicators for policy design, monitoring and evaluation. Frankerbergen (1992) and Jannuzzi (2001) noted that indicators selection should be also critically guided by the overall purpose of the evaluative exercise, which leads us to the second element of our taxonomy. As noted by Frankerbergen (1992):

> *"Whether the goal is to evaluate a project, set up a monitoring system or to develop a household food security strategy for the country will to a large extent dictate the choice of the indicator. The user of the information on indicators also will drive the choice of the indicator" (Frankerbergen 1992, p. 83).*

In particular, the choice of the indicator will depend on whether the evaluative exercise is to *monitor* and *assess* the performances of some give metric over time and/or across space, or to *model* the performance in the measurement variables in order to understand underlying causal nexuses, different indicators will be chosen. This is due to the fact that, in the two cases, indicator selection attempts to answer to two different questions: "how much?" on the one hand, and "why?" on the other. Also, Frankerbergen (1992) emphasises that this choice is inextricably linked to *who* will receive the information: in other words, the users of evaluative exercise also exert a strong weight in determining the choice of the indicators.

Finally, once candidate indicators have been checked to satisfy some basic quality requirements and the purposes of the analysis are clarified, the choice will ultimately depend upon the specific role indicators play in the determination of the phenomenon they are trying to measure. As noted above, many of the available lists boil down to include all the available indicators, without linking the objectives of the evaluative exercise with the category to which the indicator belong. Again, the distinction between monitoring and modelling evaluative exercises is critical: for instance, if the purpose is to measure students' educational performances in different countries, cognitive achievement indicators (i.e. standardised test scores) would suit the purpose well. Conversely, if the goal is to understand which factors drive the students' cognitive achievements, indicators capturing the inputs of a hypothetical "education production function" (i.e. books, infrastructures, teachers per student, etc.) would be more appropriate (OECD-JRC 2008; Stiglitz et al. 2009). In the literature of social indicators, this dichotomy, which ultimately relates to the distinction between "means" and "ends" of development (Sen 1999a), is operationally translated into judgments on the *nature* of the indicators (Booysen 2002; Burchi & De Muro 2012a), i.e. of whether they are input, process, and outcome indicators[147]. Specifically, *input indicators* relate to human, physical, or financial resources allocated to a process or a program that affects some social phenomena. *Output* or *process indicators* are intermediate indicators, which translate in quantitative terms a process of allocation of human, physical, and financial resources (*inputs indicators*) that aims at affecting an ultimate policy objective. They describe the dynamics that lead to the outcome, and represent actionable policy leverages to affect the final goal of the policy. Finally, *outcome indicators* are the ones that are more linked to the final goals of public action, or to policy objectives. For instance, in the case of a policy aimed at increasing rice availability through higher yields varieties, higher-yield seeds are an example of input indicator, while rice yields and the quantity of rice available per capita are process and outcome indicators respectively[148].

Most of the available lists overlook this aspect and include all the available indicators in the same analytical category, hence mixing the inputs with the outcomes in the determination of a given well-being outcomes. In turn, this methodological confusion renders very difficult to interpret and synthetise the informative content provided by the evaluative exercise in order to formulate evidence-based policy-making. Conversely, the CA circumvents these difficulties by providing a very clear-cut distinction between means and ends in the process of achievement of well-being outcomes. For this reason, the reliance on the CA as

[147] There is an additional category of indicators, i.e impact indicators, which refer to the general impacts of programs on the policy dimension (Jannuzzi 2005).

[148] Unfortunately, the distinction according to the nature of the indicator is not always as straightforward, in particular when policy objectives are either very specific or extremely general. Nonetheless, as Jannuzzi (2005) recognized, it is always possible to distinguish between indicators more related to policy efforts, and those who refer to the effects (or the lack of them) of such policies.

overarching theoretical framework for the evaluative exercise provides a powerful criterion to discriminate among indicators, which links the nature of the indicator itself and the overall purposes of the analysis. As such, the choice of the indicators for a specific purpose will depend on their specific characteristics in order to represent the phenomenon under scrutiny. The following section will provide an application of this methodology to the choice of a suite of indicators of food security.

5.3. Application of the proposed methodology to define a list of indicators to measure food security

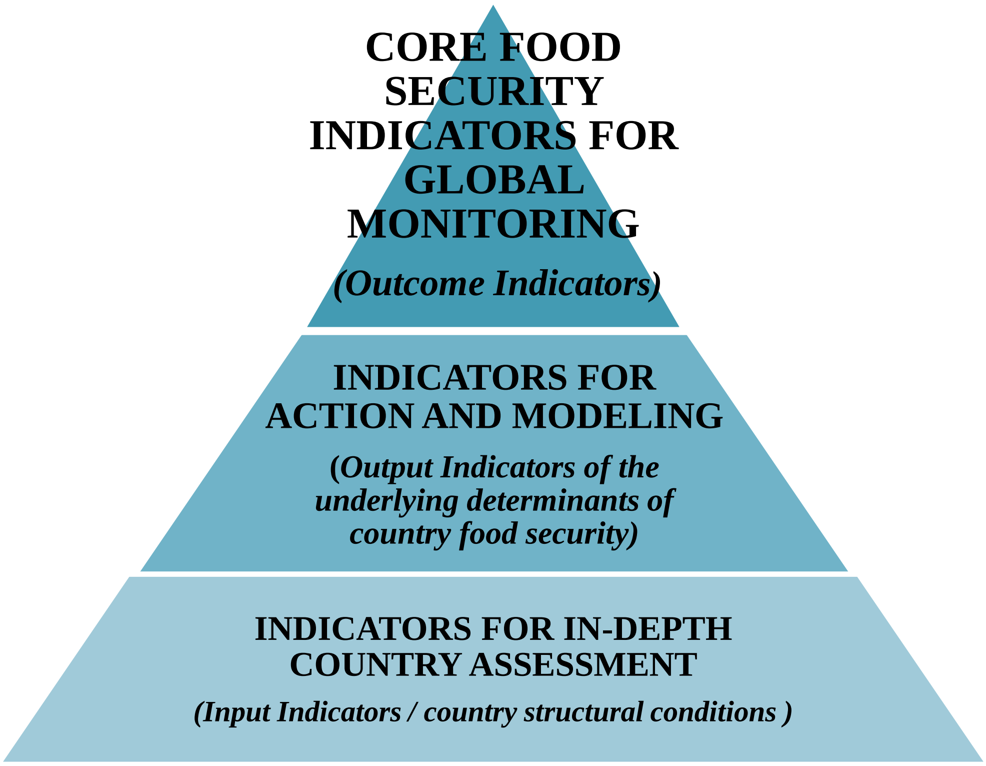
The aim of this section is to apply the insights exposed in the former section in order to select a core suite of indicators for the monitoring of food security. A useful starting point is to distinguish among three distinct focuses of analysis, which in turn correspond to as many categories of indicators. Graphically, these can be represented as a "pyramid" [149] (Figure 6). The top of the pyramid relates to the evaluative exercise demanded by CFS, i.e. the set of core food security indicators that measure the outcomes of different dimensions of food security in a given country. The aims of the suite of indicators are multiple: assessing countries' performances in the many dimensions of food security; identifying the countries that are facing food insecurity situations; and finally, comparing countries across space, in order to prioritize the allocation of resources, and over time, in order to understand the evolution of food security and the effectiveness of policies.

In turn, the second and third levels of the pyramid respectively represent the underlying and structural determinants of those food security outcomes. These two levels of analysis provide, on the one hand, information on the most immediate factors that contribute to countries' food security, and, on the other, on more structural and country-specific conditions. The use of these two additional level is complementary to the core set of indicators: depending on the purpose of

[149] This follows the suggestion provided by Jannuzzi at the CFS Roundtable in September 2011 (Jannuzzi 2011).

the evaluation and on the level of detail required, both provide a broader perspective to understand levels and variation in the set of core indicators across countries and over time.

Figure 6 Different conceptual levels for the analysis of food security and corresponding categories of indicators



In particular, the purpose of the first analytical layer or suite of core indicators is to provide a general and objective assessment of the state of national food insecurity, while at the same time to ensure analytical simplicity. At this level, the fewest possible number of indicators should be selected, in order to avoid the development lengthy and confusing "shopping lists". Given these purposes, indicator selection should focus on measures of outcomes in the distinct dimensions of food insecurity. This criterion, which is implied by the CA's emphasis on the ends of development (Sen 1999a), is also coherent with the recommendations stemming from both the literature on social indicators (Jannuzzi 2001, 2005; UN 2003; Darcy & Hofmann 2003; OECD-JRC 2008; Stiglitz *et al.* 2009; Hall *et al.* 2010; Trewin & Hall 2010) and the one on food security assessments (e.g. Frankerbergen 1992; FAO/FSAU 2009; Feed the

Future 2010). The focus on outcomes, rather than on process or input indicators, is essential to ensure comparability over space and time as well as accountability of policy-making. It is indeed easier to monitor progress upon a limited set of goals agreed by the international community, irrespectively of the uniqueness of each country's background (FAO/FSAU 2009).

Then, the second analytical layer, which we called "*indicators for modelling and action"*, aims at identifying a set of direct and proximate factors that are associated to the performances of the measures belonging to the suite of indicators. It provides a conceptual framework for understanding levels and variations in the core set of food security indicators, and, as such, it is particularly useful for policy-making, as they provide a list of actionable policy leverages that can be used to promote food security. Also, in a regression setup such as the one presented in the next Chapter, they can be used as exogenous variables in explaining variation in food security outcomes[150]. Output or process indicators, which measure the dynamic process of conversion of inputs into policy outcomes, are the ideal candidate indicators for conceptual level. With respect to the analysis of food security, this category includes a wide range of indicators such as performances in production (crops and livestock), market prices, socio-economic conditions, and many other factors that determine, but *are not*, food security outcomes *per se*. This theoretical distinction is particularly important, as in many lists process indicators (such as market prices) are included as direct outcomes of food security[151].

Finally, the third layer of analysis, the one related to *indicators for in-depth country assessments*, provides a a broad set of indicators to contextualize and diagnose the country environment *latu sensu*, in order to allow for detailed check-up of country's structural conditions in relation to food security (i.e. availability and of factors of production, market factors, cultural and socioeconomic conditions, climate, etc.). As opposed to the former level, these factors are more

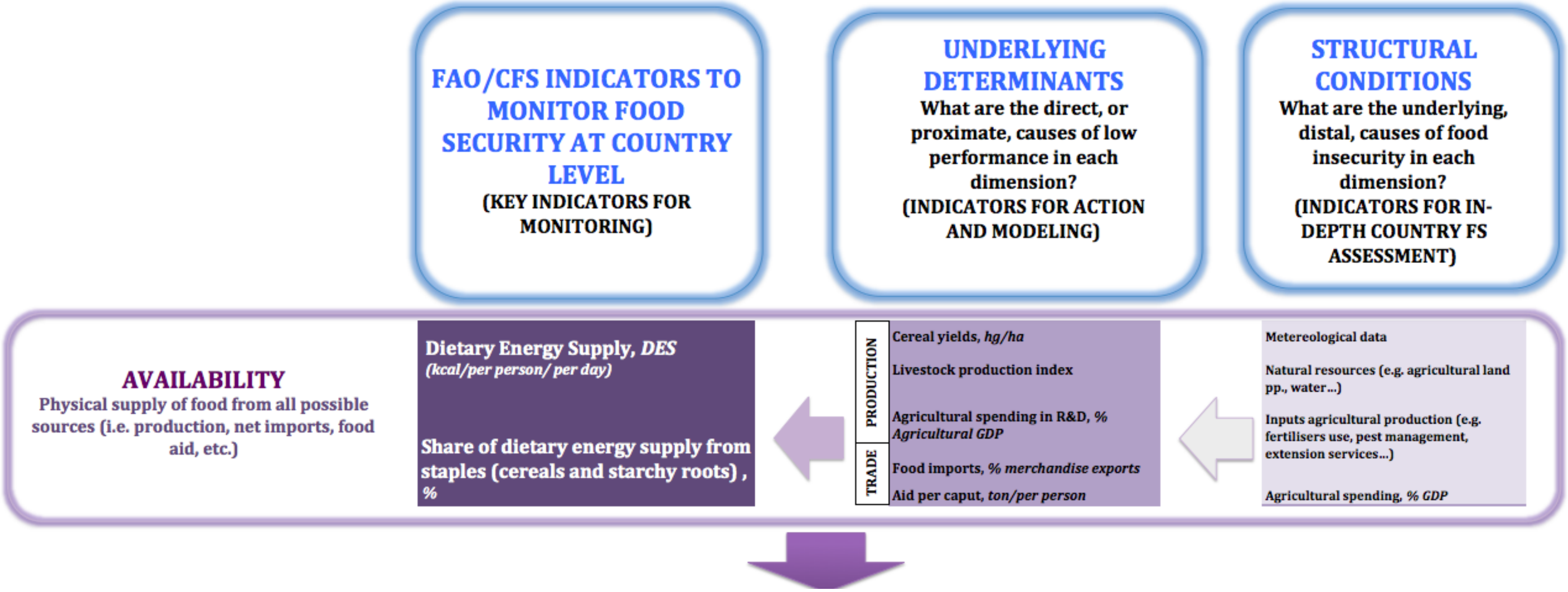
[150] Note that many of the indicators selected in this layer will then be used in the regression part of the structural equation model to measure food security in the next chapter.

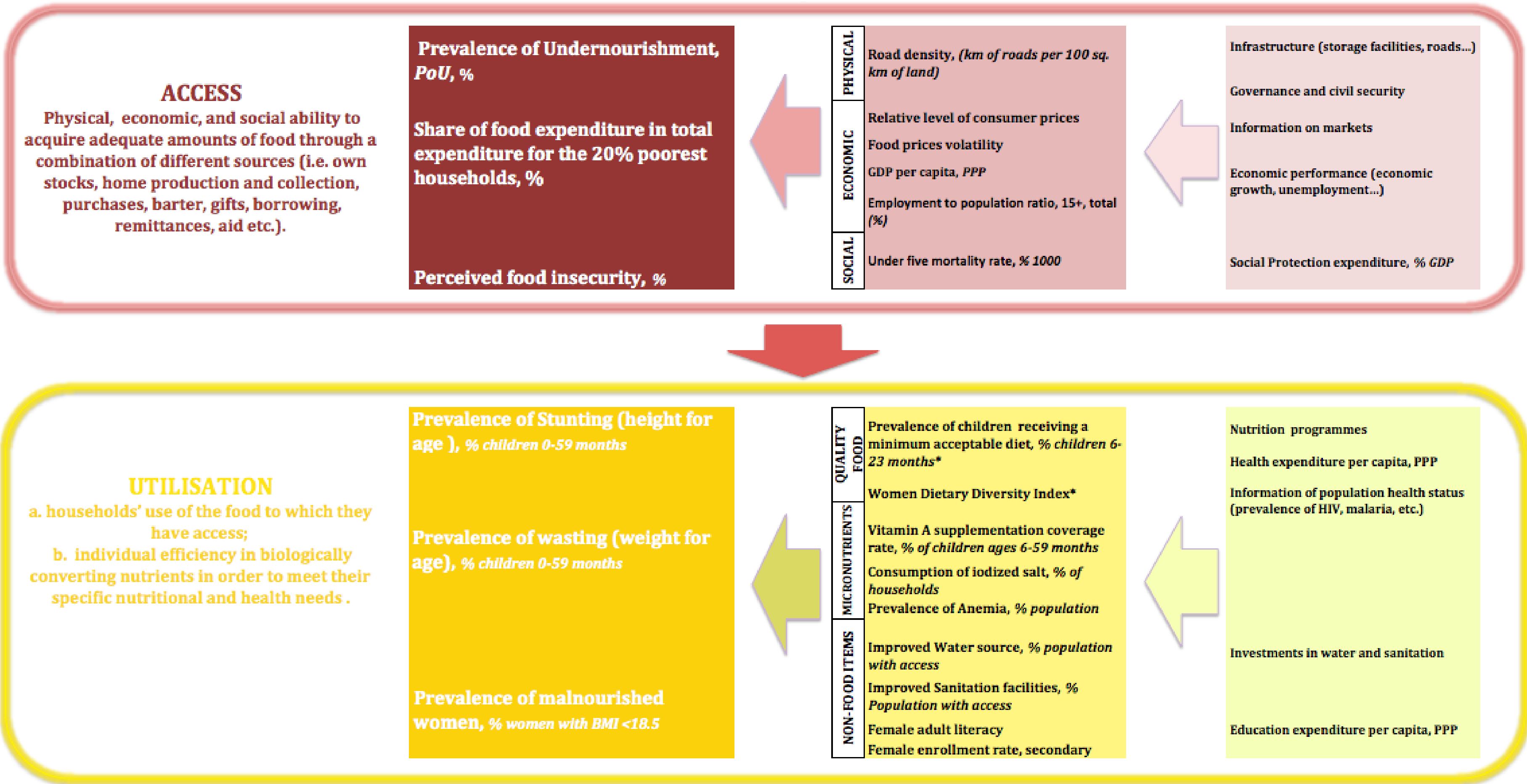
[151] For instance, as the FAO/FSAU (2009) noted: *"A 50 percent increase in the market price of milk (a process indicator) has a completely different outcome in a livelihood system that produces milk than in a livelihood system that is a net purchaser of milk, potentially being beneficial for the former and detrimental for the latter"* (p. 27).

systemic to the country of reference, and hence can be changed with more long-term policies. Ideally, this level of analysis should also provide disaggregated information in order to provide in-depth analysis on the structural vulnerability to food insecurity of different population groups and regions (as discussed in Chapter 3).

Figure 7 provides the three-layer representation. With respect to the third level of analysis, only the areas of focus (instead of a whole list of indicators pertaining to that topic) have been listed. This is because at this level the analysis is very country-specific, and, based on the goals of the analysis and on the country-specificities, different indicators may be selected. Note also that, as discussed in Chapter 3, the different dimensions of food security are sequential to each others: availability is a necessary condition for access, which is in turn necessary for utilisation.

Figure 7 Outcome, process and input indicators of food security




ACCESS
Physical, economic, and social ability to acquire adequate amounts of food through a combination of different sources (i.e. own stocks, home production and collection, purchases, barter, gifts, borrowing, remittances, aid etc.).
Prevalence of Undernourishment, PoU, %
Share of food expenditure in total expenditure for the 20% poorest households, %
Perceived food insecurity, %
PHYSICAL
ECONOMIC
SOCIAL
Road density, (km of roads per 100 sq. km of land)
Relative level of consumer prices
Food prices volatility
GDP per capita, PPP
Employment to population ratio, 15+, total (%)
Under five mortality rate, % 1000
Infrastructure (storage facilities, roads...)
Governance and civil security
Information on markets
Economic performance (economic growth, unemployment...)
Social Protection expenditure, % GDP
UTILISATION
a. households' use of the food to which they have access;
b. individual efficiency in biologically converting nutrients in order to meet their specific nutritional and health needs .
Prevalence of Stunting (height for age), % children 0-59 months
Prevalence of wasting (weight for age), % children 0-59 months
Prevalence of malnourished women, % women with BMI <18.5
FOOD QUALITY
MICRONUTRIENTS
NON-FOOD ITEMS
Prevalence of children receiving a minimum acceptable diet, % children 6-23 months*
Women Dietary Diversity Index*
Vitamin A supplementation coverage rate, % of children ages 6-59 months
Consumption of iodized salt, % of households
Prevalence of Anemia, % population
Improved Water source, % population with access
Improved Sanitation facilities, % Population with access
Female adult literacy
Female enrollment rate, secondary
Nutrition programmes
Health expenditure per capita, PPP
Information of population health status (prevalence of HIV, malaria, etc.)
Investments in water and sanitation
Education expenditure per capita, PPP

5.4. List of first and second level indicators

As outlined in the former section, the indicators in the core set are all outcomes of different dimensions of food insecurity. This fosters comparability over space and time as well as accountability of countries' progress towards food security. Outcomes indicators are sub-divided in three main groups: (i) food availability; (ii) food access; (iii) food utilization[152]. The great majority of these indicators is already collected by United Nations organizations, except for the ones incuded in the "*desiderata*", which are either not collected at all (such as the experienced severity of food insecurity), or their collection is sporadic or linked to specific programs and for which increased collection is advocated here[153]. Finally, the proposed indicators have been selected with the aim of striking the balance between theoretical relevance and issues of overall data quality, availability, and comparability over space and time. These measure are neither ideal nor comprehensive of all the complexity of food security, but they are the best available for the purposes of international comparisons. Figure 8 provides a list of these indicators, while Appendix A-1 presents a detailed description.

As mentioned above, the second level of indicators aims at selecting indicators that can contribute in explaining levels and dynamics in the core set. As in the case of the core set of food security indicators, the indicators selected represent the best compromise between relevance to the concept to be measured, and practical issues of data quality, availability, and comparability over space and time. Figure 9 provides a list of these indicators, while Appendix A-2 their description. Note that the relevance of these indicators in the promotion of food security varies depending each specific country. If this was not the case, this level of analysis would provide a sort of "magic bullet" for which food security outcomes will be function of the same underlying determinants, irrespectively of the country background. It is hence clear that, if this methodological framework is

[152] We do not consider the dimension of stability because indicators are all considered in a given point in time here

[153] In this respect, FAO has started in March 2013 the pilot project "Voices of the Hungry" in order to measure food insecurity through a perception-based indicator (http://www.fao.org/news/story/en/item/171728/).

adopted for assessments based on a single country, this list (as well as the one of core indicators) may change based on country-specificites, policy priorities and data availability.

Figure 8 Proposal for a core set of indicators to monitor national food security

		Indicator Unit of measurement
CORE SUITE OF INDICATORS FOR MONITORING COUNTRY FOOD SECURITY	AV	**Dietary energy supply** ***(kcal/per person/day)***
	AV	**Calories from staples (cereals and starchy roots)** ***(% Dietary energy supply)***
	AV	**Prevalence of Undernourishment** ***(%)***
	AV	**Depth of hunger (intensity of deprivation)** ***(kcal/per person/ day)***
	AV	**Food expenditure for the 20% poorest households (% total consumption expenditure)** **(*Engel coefficient*)**
	AV	**Prevalence of wasting (weight for height)** ***(% children 0-59 months)***
	AV	**Prevalence of stunting (height for age)** ***(% children 0-59 months)***
	D	**Experienced severity of food insecurity** ***(%)***
	D	**Prevalence of children receiving a minimum acceptable diet** **(*% children 6-23 months)***
	D	**Prevalence of underweight women** ***(% of non-pregnant women 15-49 years)***

Note: AV refers to an indicator that is available in a freely accessible database, while D to those "desiderata" indicators for which the collection should be increased at a global level.

Figure 9 Proposal for a set of second-level indicators for modeling food security outcomes

		Indicator Unit of measurement
2nd LEVEL INDICATORS FOR MONITORING AND ACTION	AV	Cereal yields *(hg/ha)*
	AV	Livestock production index
	AV	Public agricultural R&D expenditures *(% agriculture GDP)*
	AV	Roads, density *(km of roads per hundred sq. km)*
	AV	Level of relative food consumer prices *(0-1)*
	AV	Cereal imports *(% merchandise exports)*
	AV	Gdp per capita, ppp 2005 *(international dollars)*
	AV	Employment to population ratio, *(% population older than 15 years)*
	AV	Under five mortality rate *(% 1000)*
	AV	Improved water source *(% population with access)*
	AV	Improved sanitation facilities *(% population with access)*
	AV	Female secondary enrollment rate, *gross (%)*
	AV	Female literacy rates, *%*
	D	Prevalence of Vitamin A deficiency *(% population)*
	D	Prevalence of anaemia *(% population)*
	D	Prevalence of iodine deficiency *(% population)*
	D	Women dietary diversity index

Note: AV refers to an indicator that is available in a freely accessible database, while D to those "desiderata" indicators for which the collection should be increased at a global level.

5.5. Conclusions

By grounding the assessment in the theoretical framework of the CA, this Chapter presents a methodology to select food security indicators that can avoid the typical problem of "laundry lists", i.e. the assembling of tens of indicators without distinguishing between the different role each measure play in the process of food security. The methodology proposed, by exploiting the distinction among outcomes, process and input indicators and by distinguishing among different conceptual levels in the analysis of food security, links each different indicator to a distinct conceptual level. These features distinguish our suite of food security indicators from many others lists, in which the conceptual distinction between outcomes, process, and input indicators in the determination of food insecurity is often neglected.

In particular, indicators are classified in three analytical categories that serve different purposes. The first level aims at providing a synthetic, yet comprehensive, snapshot of food insecurity at the country level through the selection of a suite of core indicators. By focusing on outcomes, the suite is expressly designed to enhance comparability over countries and over time. By contrast, the other two levels are more linked to policy analysis and action: on the one hand, the second level of analysis aims at providing a list of factors that are directly associated to variation in the core measures. Process indicators are particularly apt to this aim, and this group provides a set of actionable policy leverages to influence core measures. On the other hand, the third conceptual level aims at capturing the structural conditions of food insecurity of each country through the use of input indicators.

Finally, this methodology can be used for the analysis of other multidimensional phenomena, or can be adapted to different purposes of analysis and to the exigencies of different users.

Chapter 6

Measuring Food Security: A Structural Equation Approach

6.1. Introduction

In previous chapters, we argued that multidimensional measures suffer from three additional and interrelated shortcomings (Burchi & De Muro 2012a): first, they are not always based on sound theoretical foundations; secondly, they do not provide a rigorous definition of the concept under investigation; and finally, they fail to distinguish between the "inputs" and the "outcomes" of the phenomenon they are aiming at capturing. On the methodological side, Kuklys (2005) noted that the lack of a "natural" aggregation function to combine different dimensions into a summary measure raises the question of devising appropriate aggregation and weighting schemes (Kuklys 2005; CFS 2011), as well as to transparently convey the tradeoffs involved in the index (Ravallion 2010). As a result, available composite measures reflect more data availability and "conventional wisdom" (Galbraith, 1958) than rigorous theoretical and methodological foundations (Burchi & De Muro 2012a).

Taking stock of these relevant contributions, the aim of this Chapter is to combine the theoretical insights on the concept of food security and the operational definition presented in Chapter 3, the methodology proposed in Chapter 5 on indicators selection, and the SEM methodology (Chapter 2) in order to provide a multidimensional measure of food security and to analyse its main covariates at the country level.

Specifically, in order to address the concerns raised by Burchi and De Muro (2012a), we explicitly frame the evaluative exercise in the theoretical framework of the CA to food security delineated in Chapter 3, and adopt as a basis for measurement the operational definition of food security sketched in Section 3.4. Methodologically, we argue that Structural Equation Modelling (SEM, Jöreskog

1973; Jöreskog & Goldberger 1975) offers an appealing methodological framework for the measurement of countries' food security. As discussed in Chapter 2, in general terms SEM models a set of observed indicators as linear expression of unobservable variables and exogenous factor. By the same token, countries' food security can be thought as a latent construct, which in turn is measured through a set of indicators and associated to a set of exogenous factors. We argue that SEM is particularly suitable to tackle the multiple methodological weaknesses that characterise available composite indicators: measurement error and lack of a natural aggregator function to synthetise different indicators into a summary measure. Finally, the use of this methodology allows for estimating the empirical associations between estimated food security outcomes and a set of economic, social, and institutional factors for a set of low and middle-income countries. Compared to other cross-country studies on developmental drivers of food insecurity (as measured by a single metrics) (Smith & Haddad 2000; Klasen 2008; Headey 2013), our model has the advantage of simultaneously addressing both the measurement of multidimensional food security *and* the modelling of its main covariates. Additionally, by combining indicators independently measured, the resulting composite index has the advantage of minimizing measurement error in single indicators. Note that, by building on the methodology presented in Chapter 4, the measurement of food security relies on outome indicators which can be interpreted as "functionings" in distinct dimensions of food security, while process indicators will be then used in the regression part of the model.

The remainder of this Chapter is organized as follows. Section 2 explains why SEM models are particularly suited to deal with the measurement of multidimensional phenomena such as food security. This in turn leads to the presentation of the econometric model in Section 3, while Section 4 introduces the data and reviews the results of our model empirical application. Section 5 then presents the Multidimensional Index of Food Insecurity (MIFI) and further robustness checks. Finally, Section 7 concludes by pointing to strands for further research. In the appendix further statistics are provided.

6.2. Measuring Food Security through SEM

As introduced in Chapter 2, under the general tag of SEM there is a variety of distinct methodologies that differ in both the statistical tools employed and on the assumptions they make regarding the nature of the associations between the variables and their causal links. Different methods share the assumption that a latent construct can be estimated through a set of observable indicators, which represent linear and noisy representations of the phenomenon (Bollen 1989; Kline 2011).

This structure allows for simultaneously tackling the two key methodological issues that arises in the context of multidimensional measurement: lack of an aggregation function and measurement error (Kuklys 2005). With respect to the former, the latent variable is estimated as single, synthetic measure capturing the common variance across the many observed indicators. In virtue of such distinction between latent construct and between observable indicators, it is in turn possible to test a wide variety of hypotheses regarding construct validity (Kline 2011). The issue of measurement error is addressed through the introduction of a residual term that represents the variance left unexplained by the factor and the corresponding indicators[154] (Jöreskog & Goldberger 1978; Jöreskog 1981). By modelling explicitly random measurement error, the latter can be isolated and controlled for in a way that it is not possible with other techniques (i.e. aggregation through equal weights or exploratory factor analysis, EFA).

Additionally, Multiple Indicators and Multiple Causes (MIMIC, Jöreskog 1973; Jöreskog and Goldberger 1975) and full SEM models also aim at explaining what causes the latent variables to change by introducing some exogenous variables that are believed to have a causal influence on the latent factors (Khrishnakumar & Nagar 2008). In this framework, observed variables are function of the latent factors, which, in turn, depend on some exogenous variables that can be interpreted in the same way as standard regression analysis. As discussed in Chapter 3, this setup is particularly relevant in the case of food security analysis

[154] More precisely, MIMIC models allow measurement error only in the endogenous variables (measurement part), while full SEM models allow for measurement error in both endogenous and exogenous variables.

and measurement, as institutional, economic, social, and political elements all concur in influencing food security outcomes (Sen 1981; Drèze & Sen 1989a, 1989b; De Muro & Burchi 2012b; UNDP 2012). Additionally, the explicit inclusion of those factors in a modelling exercise can also shed light on cross-country variations and disentangle some puzzling evidence on distinct countries' or regions performances in food security indicators (Klasen 2008; Headey 2010).

6.3. The econometric model

This Chapter adopts a MIMIC model to measure food security. We argue that this latent variable methodology is particularly suitable in the case of measuring food security: first, food security can be conceptualised as a latent (multidimensional) phenomenon proxied by observable indicators describing different facets of the latent construct; second, a number of institutional, economic, social, and political elements that are thought to be associated with food security can be included in the model and their linkages with food security outcomes empirically tested. The role of these factors in driving food security can also shed light on why countries sharing similar levels of resources vary in their food security outcomes (Klasen 2008).

MIMIC models are characterized by two types of equations: "measurement equations", which model the relationship between the latent phenomenon and its observed indicators, and "structural equations", which link the latent variable to a set of exogenous variables. This general theoretical model is characterised in the following way:

(i) Food security or countries' "capability to be food secure" is considered as a latent and endogenous factor in the structural model;

(ii) Observable outcome indicators or "food security functionings" are modelled as noisy manifestations of the latent construct in the set of measurement equations.

(iii) The latent "capability to be food secure", and in turn, food security functionings, are influenced by a set of social, institutional, and economic

elements. These are linked to the endogenous construct through a structural equation.

Following Khrishnakumar (2007) and Kline (2011), we now introduce some basic notation:

y* a scalar of latent country 's food security, or 'capability to be food secure';

y a (p x 1) vector of observed indicators representing the manifested functionings associated with the capability vector;

λ a (p x 1) vector of factor loadings. These estimate the direct effects of the latent construct on the indicators and are interpreted as regression coefficients. In the case of standardised factor loading, these represent the estimated correlation between the indicator and the factor;

x a (k x 1) vector of exogenous causes of y^*;

β' a (1 x p) vector of path coefficients. These can be interpreted as regression coefficients for the effects on the latent endogenous factor of those variables that are presumed to directly cause them.

Each typical element in each vector will be denoted using a subscript i, which represents country i (e.g. y_i^*, i=1, …, m).

On this basis of the conceptual framework sketched above, let us introduce the following MIMIC model (Jöreskog and Goldberger 1975):

$$y = \lambda\, y^* + \varepsilon \qquad \text{(i)}$$

$$y^* = \beta' \mathrm{x} + \nu \qquad \text{(ii)}$$

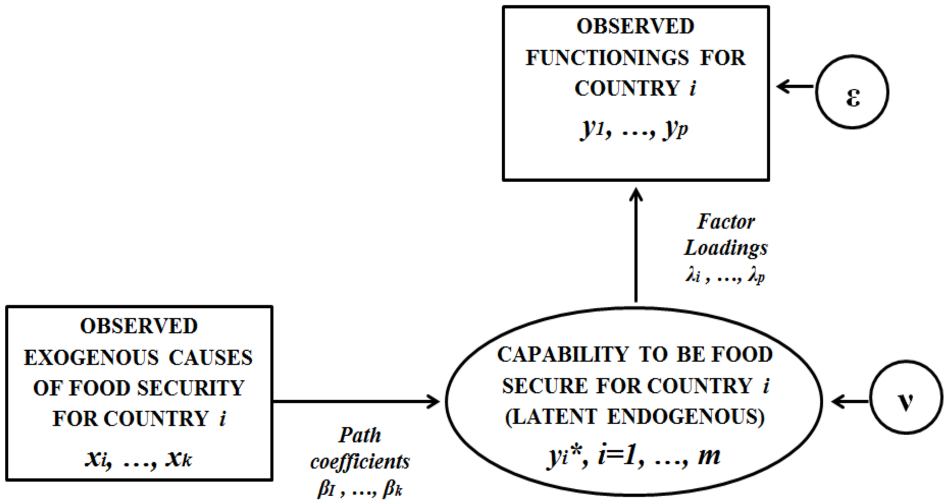
The first set of equations represents the measurement model, which specifies how the observed indicators or "food security functionings" are determined by the latent construct, the "capability to be food secure", while the second equation specifies the structural model, which explains the latent construct of "capability to be food secure" as a function of a set of observed exogenous variables.

Vectors ε and ν are the respective error terms in the measurement and structural equations, with zero expectations, uncorrelated between the two parts. In particular, ε captures uncertainty in the relationship between true food security and the observed indicators. Finally, in MIMIC the exogenous covariates are modelled as error-free (Bollen 1989). The above relations are specified in Figure 10 below. Jöreskog and Goldberg (1975) showed that the latent factor scores can be estimated by:

$$\hat{y}^* = (1-\lambda'\Omega^{-1}\lambda)^{-1}(\alpha' x + \lambda'\Psi^{-1}y) \qquad \text{(iii)}$$

With $\mathbf{V}(\varepsilon) = \mathbf{\Psi}$, $\mathbf{V}(\nu) = \sigma^2\boldsymbol{I}$, and $\mathbf{\Omega} = \lambda\lambda' + \mathbf{\Psi}$. In general $\mathbf{\Psi}$ is assumed to be diagonal in the literature on latent variable models (Khrishnakumar 2007). Figure 10 graphically portrays the model.

Figure 10 A MIMIC model for measuring country food security



6.4. Empirical Application

6.4.1. Data sources and availability

The empirical application of the model described in the previous section aims at simultaneously measuring the latent "capability to be food secure" as proxied by a set of observed indicators and to identify its main covariates at the cross-country level.

The sample relates to a cross-section of middle-income and low-income countries across the world for the year 2008 or the closest point available, with data from the World Bank *World Development Indicators* and United Nations sources Although the sample first included 97 countries, scarce data availability reduced it to 57 countries. Although this is a quite limited sample for SEM, it is akin to the ones of analogous literature that uses the same data for cross-country comparisons[155]. Descriptive statistics are reported in Appendix B.1.

Before turning to examine which indicators have been selected for the estimation, we acknowledge the limits of cross-country analyses. These include (Smith & Haddad 2000; Durlauf et al. 2005): (i) comparability of different indicators; (ii) potential confounding variables; (iii) endogeneity issues. With respect to the first point, particular care has been devoted to use the best data available from international sources, in order to enhance the degree of comparability of different indicators, while in respect to the second one, we tried to minimise the extent of model misspecification by relying on a well-defined conceptual framework, which builds on the literature on the measurement and modelling of food security. Finally, we recognise that endogeneity is an issue that cannot be fully addressed with cross-sectional data, and acknowledge the resulting limitations when drawing statistical inference based on cross-country data.

6.4.2. Indicators in the measurement part

Table 6.1 below presents a list of the measurement indicators selected for the analysis, their definitions, data sources and the range of years they cover. In the light of the discussion of the previous Chapter, the indicators in the measurement part, which together aim to capture the "capability to be food secure", are outcomes indicators of distinct dimensions of food security. This is coherent with the CA's focus on the "ends" of development (Sen 1999) and the recommendations of the statistical literature on social indicators (Jannuzzi 2005, FAO/FSAU 2009; Burchi & De Muro 2012b). These are: (i) FAO's Prevalence of Undernourishment (POU); (ii) dietary diversity index; (iii) prevalence of malnutrition (height for age) in children aged 0-5 years; and (iv) prevalence of malnutrition in women. Note that all these indicators are measures of different

[155] For instance, Khrishnakumar (2007) uses data from 56 countries, while Cracolici *et al.* (2010) from 64.

dimensions of food *insecurity*: hence, we are *de facto* measuring food insecurity or country *incapability* to be food secure.

FAO POU estimates the proportion of population in condition of chronic undernourishment, i.e. people whose dietary energy supply is below a minimum dietary energy requirement for maintaining a healthy life and carrying out light physical activity. The FAO indicator, by summarizing information about dietary energy supply and the distribution of calories in the country, is a measure of both the availability and access dimensions. It is used to monitor global hunger trends in the MDGs (UN 2003).

The share of dietary energy supply from staple food or "dietary diversity index" is an indicator measuring the extent to which the aggregate caloric availability is based on staple foods (cereals and starchy roots). More specifically, it has been constructed from FAO FAOSTAT data as the ratio of aggregate caloric supply provided by staples over total dietary energy supply. A high value indicates a low diet diversification at the macroeconomic level. The indicator is one of the core indicators selected by the Committee on Global Food Security to monitor global progress towards the World Food Summit goals (FIVIMS 2003).

The other two indicators provide information about the nutritional status of two of the most vulnerable population groups - children and women, and hence aim at directly capturing the utilisation dimension. The prevalence of stunting measures the proportion of children aged 0-59 months whose height for age is more than two standard deviations below the median for the international reference population aged 0-59 months, as defined by WHO child growth standards (WHO Multicentre Growth Reference Study Group 2006). This is an indicator of chronic maternal and child malnutrition, manifested in children retarded height growth. The prevalence of stunting is commonly considered as the best indicator of early childhood malnutrition (UN ACC/SCN 2000) and it is a powerful predictor of later life cognitive impairment and poor educational and work-related outcomes (Grantham-McGregor *et al.* 2007). Finally, this indicator is not as significantly affected by the 'nutrition transition bias' as underweight (Misselhorn 2010).

The last indicator selected measures the per cent of non-pregnant women aged 15-49 years who have a Body Mass Index (BMI) below the international reference standard of 18.5 (extreme thinness). Although malnutrition in women is a problem insufficiently recognized (UN ACC/SCN 1992), 60% of the hungry in the world are women (ECOSOC 2007): women are vulnerable to malnutrition throughout their entire life-cycle for both social and biological reasons, and their malnutrition may transmit to children, perpetuating growth and development failure through generations (Walker *et al.* 2011).

Table 6.1: Indicators in the measurement part

Indicator	Definition	Source	Reference years
Prevalence of Undernourishment	% of population in condition of chronic undernourishment.	FAO, Statistics Division	2006-2008
Dietary diversity index	% of total staples supply (cereals plus starchy roots) expressed in calories on total dietary energy supply.	Author's calculations from FAO FAOSTAT data	2008
Malnutrition, height for age (% children 0-5)	% of children aged 0-59 months whose height for age is more than two standard deviations below the median for the international reference population aged 0-59 months, as defined by WHO child growth standards.	World Bank, World Development Indicators	2000-2009
Prevalence of underweight women (% women 15-49 years)	% of non-pregnant women of reproductive age (15-49) who are underweight, as defined by a Body Mass Index below the international reference standard of 18.5 (extreme thinness).	DHS Stat Compiler WHO Global Database on Body Mass Index	2000-2009

6.4.3. Indicators in the Structural Part

As argued earlier, the level of achievement in the capability to be food secure is undoubtedly influenced by the presence of a congenial environment that allows for the capability to be fully realized (Drèze & Sen 1989; Khrishnakumar 2007). This relates to the set of economic, institutional, environmental and technological conversion factors, which, by being to a high extent beyond the individual control, provide potential high windows for policy interventions to promote food security. In turn, differences in the contextual environment can also account for cross-country differences in capability levels and help disentangle interregional paradoxes in different food security levels (e.g. Osmani 1997; Klasen 2008).

The potential exogenous indicators in the structural part were selected on the basis of our theoretical framework, the methodology presented in Chapter 5 and the econometric literature on the modelling of food security outcomes (Drèze & Sen 1989; Osmani 1997; Timmer 2000; Marini & Gragnolati 2003; Klasen 2008; Juma 2011; UNDP 2012; Wiesmann 2004, 2006; Smith and Haddad 2000; Smith *et al.* 2003; Headey 2013). As the indicators in the second layer of the pyramid in Figure 6, these indicators are strongly linked to possible areas of policy interventions and, as such, measure the efforts of the states in providing a congenial environment for the flourishing of food security. Table 6.2 provides a list of the explanatory indicators selected for the structural part, together with their definition, sources and rationale for inclusion.

Table 6.2. Indicators, Definition, Sources and Rationale of the indicators in the Structural Part

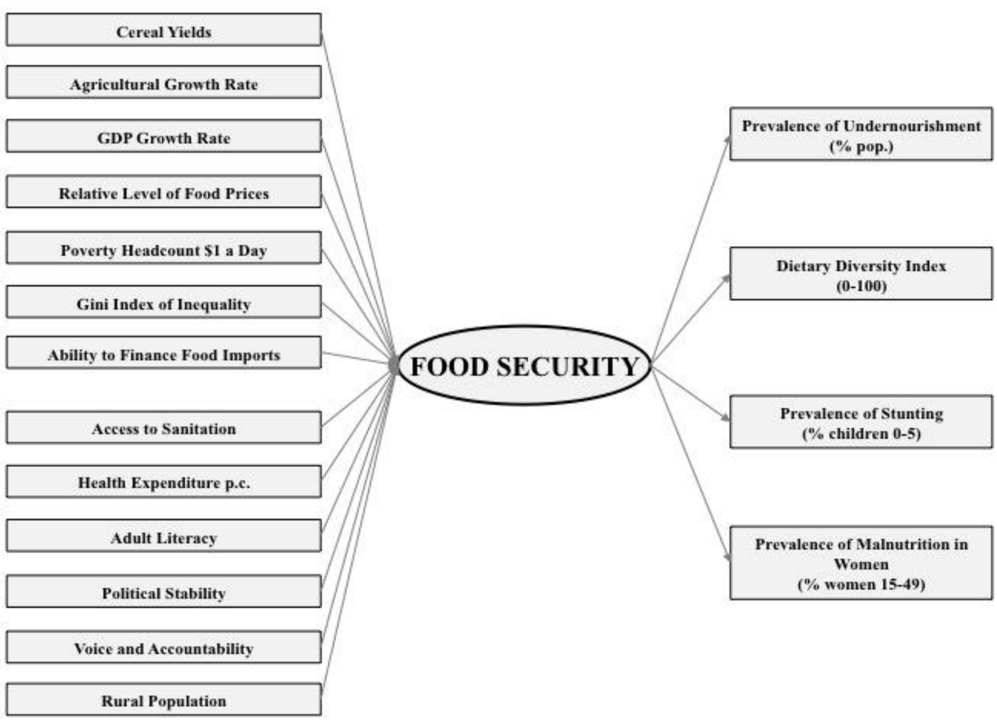
Indicator	Definition	Source	Rationale
Cereal yields	Harvested production per unit of harvested area.	FAO, FAOSTAT	Measure of agricultural productivity. It provides a measure of the "health" of the agricultural sector in the country.
Agricultural spending in R&D, % *Agricultural GDP*	Total agricultural R&D expenditures by the government, higher education, and non-profit sectors as % of agriculture GDP.	ASTI	Proxy for the research intensity in the agricultural sector.
GDP per capita (PPP)	Gross domestic product converted to international dollars using Purchasing Power Parity (PPP) rates.	World Bank WDI	Indicator of the general standard of living in the country.
GDP growth rate	Annual percentage *growth rate* of *GDP* per capita based on constant local currency.	World Bank WDI	Indicator of the dynamism of the economy.
Food imports, % merchandise exports	Ratio of total food imports on total merchandise exports.	World Bank WDI	It measures country's ability to finance its food imports.
Relative level of food prices	Ratio of food consumer prices index and the general consumer prices index.	Author's calculations from FAO FAOSTAT data	The ratio provides a measure of the relative food prices with respect to the prices of goods and services in the economy. Consumer price indexes measure the cost of purchasing a fixed basket of consumer goods and services of constant quality and similar characteristics, with the products in the basket being selected to be representative of households' expenditure.
Poverty headcount ratio, $1.25 a day 2005 PPP	Population below $1.25 a day is the percentage of the population living on less than $1.25 a day at 2005 international prices.	World Bank WDI	Poverty boosts food insecurity by affecting households entitlements to food and increasing their vulnerability to disease (Sen 1981; World Bank 1986; Drèze & Sen 1989).
Gini index	Measure of the inequality of the distribution of income or consumption expenditure among individuals or households within an economy.	World Bank WDI	The inequality in the distribution of resources may affect food security outcomes (Sen 1981).
Road density	Ratio of the length of the country's total road network to the country's land area.	Author's calculations from World Bank data	It is a proxy of the infrastructure stock and connectedness to the markets.

Improved water source, % population with access	% of the population with reasonable access to an adequate amount of water from an improved source.	World Bank WDI	Safe water is an essential component of food and nutritional security. The use of unsafe drinking water is directly related to water-related diseases such as diarrhea, cholera and typhoid. These types of diseases are often found to be a cause of malnutrition in developing countries.
Improved sanitation facilities, % population with access	% of population having access to adequate sanitation facilities.	World Bank WDI	Adequate sanitation is an essential component of food and nutrition security, as it lowers the risks of diarrhea and other diseases that hamper the capability of converting food in good nutritional outcomes.
Literacy rate, adult female	% of females aged 15 and above who can, with understanding, read and write a short, simple statement on their everyday life.	World Bank WDI	The positive relationship between education, female in particular, and food security is well documented in the development literature (Behrman & Wolfe 1987; Kassouf & Senauer 1996; Burchi & De Muro 2007). In particular, literate women provide good nutritional outcomes for their families through their capability to use information related to good health and nutritional practices.
Voice and Accountability Index	The index "captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media"(Kauffman *et al.* 2003, p. 3).	World Bank World Governance Indicators	Related to the "governance" aspect of food security: the work of Sen (1981, 1999) and Drèze & Sen (1989) among the others showed that governance, and in particular accountable forms of governments, play an important role in averting famines. The UNDP (2012) has also recently stressed the role of voice and participation in promoting food security.
Political Stability Index	The index " captures perceptions of the likelihood that the government will be destabilised or overthrown by unconstitutional or violent means, including politically-motivated violence and terrorism" (Kaufmann et al. 2003, p. 3).	World Bank World Governance Indicators	Other index related to the "governance" aspect of-food security:
Rural population (%)	*Rural population* refers to people living in *rural* areas as defined by national statistical offices. It is calculated as the difference between total *population* and urban *population* over total population.	World Bank WDI	Used as a control variable.

6.4.4. *Identification and model fit*

This section presents and analyses estimates of MIMIC model specified according to the path diagram in Figure 11 below.

Figure 11 Path Diagram



As the model is not complex in terms of the latent variable, the 'counting rule' provides a necessary, yet insufficient, condition for model identification (Kaplan 2009). As there are four indicators in the measurement part, the identifying condition is met. The estimation, implemented using Stata Version 12, confirmed identification.

Before turning to the analysis of the estimation results, let examine the model fit. Following Kline (2009), Table 6.3 provides a selection of goodness-of-fit statistics, which seem to point to an overall good model fit to sample data[156]. In particular, the likelihood ratio is not statistically significant at 5% level and the null hypothesis of good model fit cannot be rejected. While the value of 0.046 for the RSMEA and of its 90% confidence interval show good model fit, the relatively high value of the upper bound indicates a reasonable degree of sampling error, which is probably due to the small size of our sample. Both the CFI and the TLI also point to good fit with a value above 0.95 (Hu and Bentler, 1999). Finally, the value of the SMRS of 0.041 is below the upper threshold of 0.05 recommended in the literature for a good-fitting model (Byrne 1998, Diamantopoulos and Siguaw 2000).

Table 6.3. Model fit statistics

Fit statistic	Value	Description
Likelihood ratio		
Chi2_ms(32)	35.8	model vs. saturated
p > chi2	0.295	
RMSEA	0.046	Root mean squared error of approximation
90% CI, lower bound	0	
upper bound	0.113	
CFI	0.976	Comparative fit index
TLI	0.965	Tucker-Lewis index
SRMR	0.041	Standardized root mean squared residual

6.4.5. Estimation results

A “robust” maximum likelihood method was used to derive estimates on standardized data (Bentler 1995; Satorra & Bentler 1994), as the indicators violated the hypothesis of multivariate normality. Table 6.4 below shows the

[156] The likelihood ratio tests the difference in fit between the model and a saturated model with a covariance matrix that perfectly corresponds to the data covariance matrix. The associated p-value tests the null hypothesis that the discrepancy between the observed and model-implied covariance is not statistically significant at 5% level (Kline 2009). However, as the likelihood ratio also depends on the sample size, other fit indices are more appropriate to measure model fit. The RMSEA is a badness of fit index, and a value of 0 indicates the best fit. As a rule of thumb, values below 0.08 indicate a good fit. Finally, the cutoff values for both the CFI and the TLI for good models is 0.95 (Hu and Bentler 1999; Hooper *et al.* 2008).

estimation results for the measurement part of our MIMIC model, reporting both normal and standardised coefficients. While the former can be interpreted as regression coefficients (i.e. they estimate the direct effects of the latent factors on the indicators), standardised factor loadings are estimated correlations between the observed indicators and the food security latent factor. Because they ensure comparability across indicators measured in different units, standardised coefficients can be also interpreted as z-scores (Brown 2009). For instance, in the baseline model, an increase of one unit in the latent variable "food insecurity" will result in an increase in 0.59 standardised units of female malnutrition.
All the coefficients are significant at 1% and of the expected sign[157]. This points to construct validity and the appropriateness of the outcome indicators selected to satisfactorily represent the latent dimension 'food insecurity".

Table 6.4. Parameter estimates for the Measurement Model

	Coefficient	Standardised coefficient
Prev. of Stunting	1.000	0.9 ***
Prev. of Undernourishment	0.71***	0.62 ***
Prev. of Malnutrition in Women	0.67***	0.58 ***
Dietary Diversity Index	0.88***	0.74 ***

*** *denotes significance at 1%.*

The structural part of the model can be interpreted as multivariate regression analysis (Kline 2009). In our case, the latter provides estimates of the influence of exogenous variables selected in explaining countries' achievements in the "capability to be food secure". Table 6.5 shows estimation results from different specifications. The specification that is linked to the parameters estimates for the measurement model in Table 4 is in the first column. Before analysing the results of the structural part of the model, it is important to stress that they are robust to

[157] The loading of the prevalence of undernourishment is fixed to 1 in order to scale the corresponding latent dimension (for further discussion on scaling, see Kline 2009).

the choice of the indicator in the measurement model that is constraint to be equal to 1. Appendix B.3 shows the results for the baseline specification in which the constraint in the measurement part is assigned to different indicators.

With respect to the availability dimension, the yield of cereals, a key measure of agriculture productivity, and the rate of growth in the agricultural sector (col. 7) are not found to be significantly associated with food security at a cross-country level. Given our theoretical framework, this is not surprising: although food availability is a basic prerequisite for food security, it is not a sufficient condition to ensure food security to occur. The “capability to be food secure” ultimately depends on the complex interactions between macroeconomic constraints and opportunities, household entitlements and individual characteristics, as well as on the synergies between food and non-food factors (i.e. basic health and care services, education, access to improved sanitation and water, an unpolluted environment).

These interactions can explain not only the lack of cross-country significance of factors related to the availability of food, but also the heterogeneity of the effects of food production depending on the level of development of the country (as in Headey 2013). As shown in the next section, the link between food availability and food insecurity is strong for very poor countries (in terms of GDP per capita), while as the focus shifts to relatively more advanced developing countries, food availability ceases to be a constraint to food security, which can be caused by other factors related to poor access or utilisation. On the same line, it is not surprising that the rate of food imports to total merchandise exports were found not being statistically significant in our analysis: following Drèze and Sen (1989), a high dependence on food imports is not a cause of food insecurity *per se*, if the country has the capability to finance through its exports and to be resilient to fluctuations in world food prices.

This last point leads us to analyse the factors related to the access dimension. As expected, a key factor affecting food insecurity is income poverty, which, in line with our conceptual framework, can be framed as households’ lack of entitlements to food and basic non-food commodities (Sen 1981). In contrast, we do not find any significant effect related to economic growth. Although the empirical evidence is mixed in this respect[158] (Harttgen et al. 2012; UNDP 2012; Headey 2013), this finding points to the heterogeneity of countries' pathways to food security, which could be either be promoted by rapid economic growth ("growth-mediated"), or through the provision of public goods without sustained economic expansion ("support-led")[159] (Drèze & Sen 1989; Sen 1999; Headey 2013).

Finally, coherently with other empirical contributions (Osmani 1997; Heltberg 2009), the Gini index of income distribution is not statistically associated to food security (col. 6).

At a cross-country level, higher food prices (relative to general consumer prices) are positively and significantly associated with higher levels of food security. This result is coherent with a well-established strand of literature that argues that the aggregate effect of food prices on food security is uncertain, and ultimately depends on the relative terms of trade in terms of trade for food with respect to the goods and services people produce and sell (Sen 1981; Deaton 1989; Barrett & Dorosh 1996; Barrett 2002; Swinnen & Squicciarini 2012). Additionally, this result could also be affected to a certain extent of measurement error due to how the food and consumer prices indexes are constructed. These respectively measure the price of the average basket of food and goods and services consumed by the average individual in the population, and not the prices of a basket of staples consumed by the poorest and more food insecure people. Hence, we may expect different results if a price index based on the consumption patterns of the most deprived segment of the population would be available.

With regards to utilisation, the ratio of female to male adult literacy and the rate of adult female literacy, two common proxy for the status of women in their society (UNDP 1997; Haddad 1999a; Smith *et al.* 2003), are strongly and negatively associated to food insecurity outcomes in all the specifications, while the same does not apply to men's education (col. 3). These results corroborate a well-

158 The case of Sub-Saharan Africa is particularly instructive: while having experienced sustained growth during the 2000s, no corresponding progress in nutrition has been achieved, which led some commentators to refer to this phenomenon as the "paradox of food insecure growth" (UNDP 2012).

159 In a recent contribution, Headey (2013) provides tangible examples of "growth-mediated" or "support-led" food security pathways. While the former includes the case of Thailand or Vietnam during the 1980s and 1990s, Brazil, Mexico or Honduras, without experiencing strong rates of GDP growth, could promote food security through the provision socio-economic improvements in various domains.

acknowledged result in both the cross-country (Osmani 1997; Smith & Haddad 1998; Smith *et al.* 2003; Harttgen *et al.* 2012; Headey 2013) and microeconomic literatures (Thomas *et al*. 1991; Haddad 1999; Webb & Block 2004; Burchi 2010, 2012) on the link between women education (and empowerment) and food security (UNDP 2012). As women get more educated, their ability to shape the allocation of resources within the household increases (i.e. by directly influencing decisions over food, care, and basic services such as water and health care), as well as through their enhanced income-earning ability, and usually this has an impact on food security for all the members of the family (Thomas *et al.* 1991; Haddad 1999b; Webb & Block 2004; Burchi 2010, 2012).

As expected, also health services are found to play a key role in promoting food security, given the strong and significant coefficient of the share of public health expenditure per capita, an indicator that is usually used as a proxy for public provision of social services and public goods (e.g. Anand & Ravallion 1993; Smith & Haddad 2000). It is hence not surprising that the percentage of rural population, which typically enjoys less of these non-food services, is strongly associated with higher food insecurity. This result, together with the one related to food availability, points to the need to overcoming the rather narrow focus on agricultural productivity (World Bank 2008; Hoddinnott *et al.* 2012) in order to devise a comprehensive strategy of broader rural development for food security, including policies for rural non-farm employment, education, health and infrastructure. With respect to the latter, rather interestingly, neither the prevalence of population with access to clean water nor the one with access to improved sanitation facilities turns out being significant in our model. The way in which these indicators are measured for cross-country comparisons (especially in the MDG context) could probably explain this rather counter-intuitive result, which is nonetheless consistent with recent research (Lechtenfeld 2012; Headey 2013). Possible reasons could be imputed to the heterogeneity in the definitions of “access” and in the quality of data, and intrinsic limitations of official statistics in capturing the actual use and quality of these services (Anand 2006; Eurostat 2010; Satterthwaite 2003).

Finally, the lack of statistical association between the governance indicators and food security is coherent with Sen’s theory and empirical evidence (Sen, 1999; Burchi, 2011): while there is robust evidence of the positive effect of democracy on famine prevention, the effect of governance factors on food security is still uncertain.

Table 6.5. Parameter estimates for the Structural Model (selected specifications)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Cereal Yields	0.017	0.01	0.015	0.017	0.005	0.016	0.007
FPI/CPI	-0.157*	-0.171**	-0.178*	-0.157**	-0.158*	-0.158**	-0.170**
Ratio female to male literacy rates	-0.168*			-0.168**	-0.177*	-0.185*	-0.119
Adult literacy, females		-0.171*					
Adult literacy, males			-0.091				
Poverty Headcount $1 a day (% pop.)	0.256**	0.250**	0.222*	0.256**	0.245**	0.243**	0.224
Access to sanitation (% pop.)	-0.079	-0.117	-0.128	-0.079	-0.079	-0.069	-0.103
Health expenditure p.c.	-0.229***	-0.214***	-0.234***	-0.229**	-0.247***	-0.241***	-0.179**
Av. Growth rate (2006-08)	0.017	0.046	0.024		0.013	0.022	-0.002
Growth rate (2008)				0.017			
Av. Agricultural growth rate (2006-08)							0.097
Rural population (% pop.)	0.400***	0.361***	0.420***	0.400***	0.399***	0.404***	0.477***
Voice & Accountability	0.04	0.023	0.03	0.04	0.041	0.035	0.033
Political stability	-0.069	-0.061	-0.064	-0.069	-0.071	-0.059	-0.088
Food imports/merchandise exports					-0.046		
Gini index						0.04	
Chi2	35.8	37.996	38.602	35.8	42.943	51.41	37.705
p > chi2	0.295	0.215	0.196	0.295	0.167	0.036	0.347
RMSEA	0.046	0.057	0.061	0.046	0.064	0.091	0.038

*Note: ***, **, * denote significance at 1%, 5%, and 10% levels, respectively. The estimates were carried out with robust standard errors. Coefficients are standardised.*

6.5. A Multidimensional Index of Countries' Food Insecurity

Based on the results of the above model, we estimated the latent "capability to be food secure" and obtained a Multidimensional Index of Food Insecurity (MIFI) by normalizing the resulting scores on a scale 0-1, where 0 indicates a situation of food security and 1 food insecurity. We argue that this index has three features that renders it appealing for measuring food security: first, by including indicators that provide information on different aspects of the concept, MIFI is more able to capture the complexity of food security than single indicators. The first feature is well shown in Figure 12and Figure 13, which provide a scatterplot of MIFI against the two leading indicators of food insecurity in the MDG context, FAO PoU and the prevalence of underweight in children under 5 years.

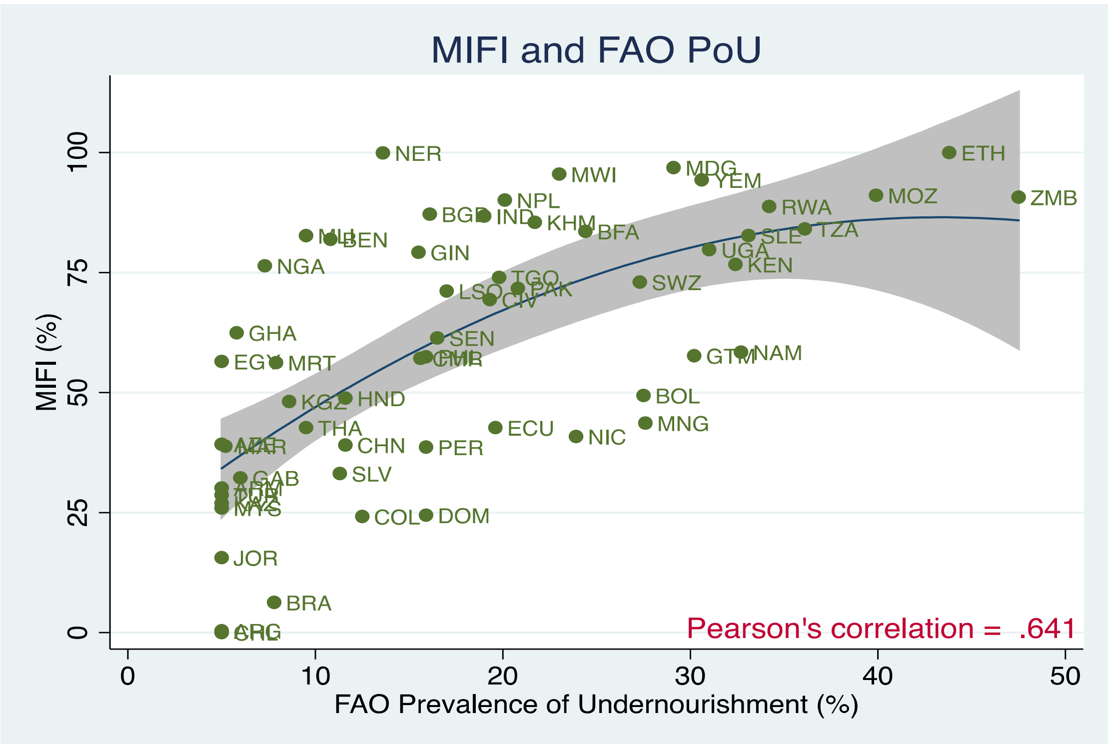
Figure 12 is also a measure on internal validity of MIFI, as PoU is one of its measurement indicators[160]. This figure is extremely interesting as it shows how the inclusion of the other indicators is able to capture more variation in countries' food security performances than the PoU. When the PoU is around a level of 5%, performances in terms of MIFI are extremely varied: these range from the low levels of food insecurity of Argentina, through the relatively poor performances of Azerbaijan, Egypt and Ghana, to the worrisome one of Nigeria. Although the latter country is classified by FAO as characterized by low undernourishment rates (with a PoU of just 7%), a MIFI at 76% provides a very different picture. Such a discrepancy is explained by the high prevalence of children and women malnutrition (at 41% and 12.3% respectively), and the low diet diversification (with a dietary diversification index of 64%) of Nigeria. In contrast to the PoU, which provides information only on availability and access (Chapter 4), MIFI is able to shed light also on the utilization dimension through the two malnutrition indicators and the one on diet diversification.

[160] Another check for internal validity of MIFI was to compute a Principal Component Analysis (PCA), which is presented in Appendix 6.3. Coherently with our theoretical framework, the PCA showed the existence of a single underlying component, which alone captures more 62% of the variance of the dataset and that can be interpreted as the latent "capability to be food secure".

As such, MIFI is able to provide a more nuanced picture of food security than the FAO indicator.

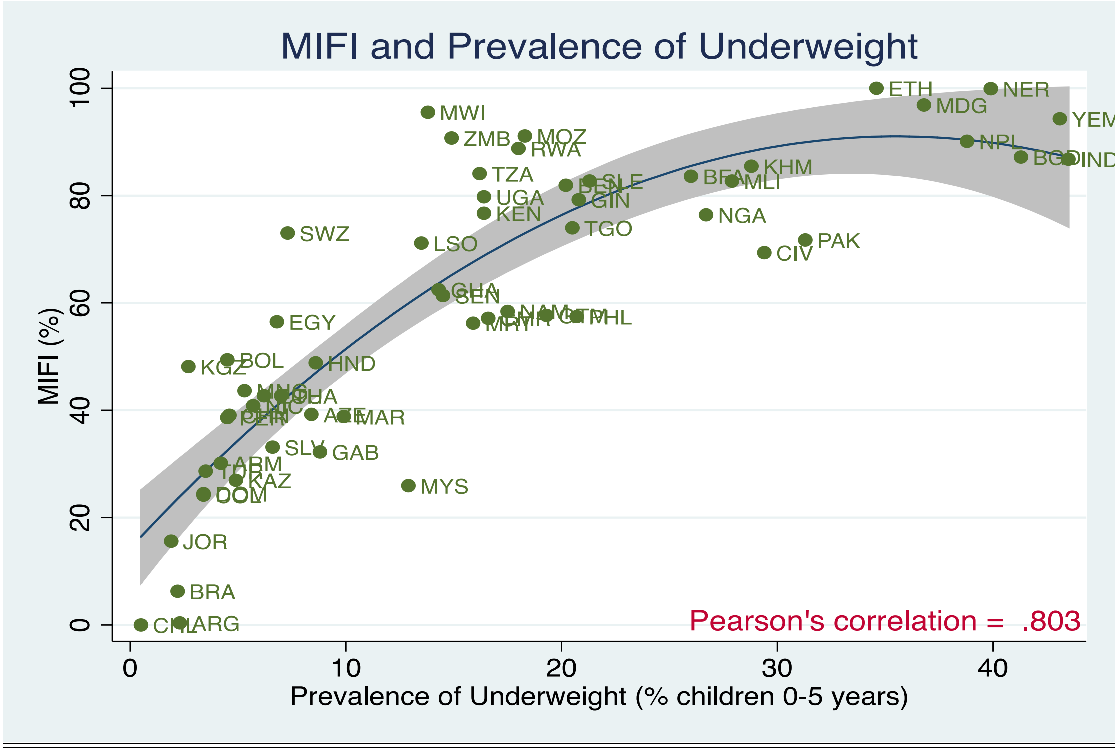
The same conclusion applies when the relationship between MIFI and the prevalence of underweight is analysed. Note that the quite high correlation between the two measures provides a measure of external validity for MIFI, which appears as effectively measuring food security. Nonetheless, despite the good correlation between the two measures, the underweight indicator does not seem as able as MIFI in capturing cross-country heterogeneity in food insecurity outcomes. For instance, while Malaysia and Malawi rank very similarly in terms of prevalence of underweight (12.9% and 13.8% respectively), the analysis of MIFI portrays a very diverse situation: on the one hand, Malaysia, with a MIFI of 31%, is a relatively good performer, while Malawi, on the other hand, with a MIFI score of 95% belongs to the group of the most food insecure countries. Such a divergence between the two metrics stems from the marked differences in the prevalence of stunted children (17.2% and 47.8% respectively) and of diet diversification, as the ratio of staples food to total calories is 70% for Malawi and half of this figure for Malaysia.

Figure 12 Relationship between MIFI and Prevalence of Undernourishment



Note: Pearson’s correlation at 1% significance level.

Figure 13 Relationship between MIFI and Prevalence of Underweight



Note: Pearson's correlation at 1% significance level.

Secondly, through the combination of indicators independently measured, MIFI reduces the impact of random measurement error in single indicators. Moreover, as opposed to other types of composite indexes, such as the Global Hunger Index (Wiesmann 2006), the SEM methodology explicitly models and controls for measurement error by assuming that the latent construct is imperfectly proxied by observed indicators. Finally, as shown by Table 6.6, the strength of association, as measured by rank correlations, of MIFI with other relevant development indicators of health and food security is higher for the composite index than for its components. This feature shows the ability of the MIFI to better capture deprivation in nutrition and health related indicators than its single components, and hence to provide a comprehensive, yet summary, view of the food insecurity performance of the countries. The relatively high correlation with these commonly used measures provides an additional measure of the "external validity" of MIFI's ability to adequately capture food security.

Table 6.6. Rank correlations between MIFI and its components and selected health and nutrition indicators

	MIFI	POU	Prev. of stunting	Prev. of Malnutrition in women	Dietary Diversity Index
Prev. of Wasting	0.68***	0.34*	0.68***	0.89***	0.58***
Prev. of Underweight	0.86***	0.53***	0.85***	0.89***	0.69***
Infant mortality rate	0.77***	0.63***	0.72***	0.56***	0.66***
Under 5 mortality rate	0.79***	0.67***	0.73***	0.55***	0.67***
Depth of hunger	0.74***	0.80***	0.67***	0.49***	0.51***
Engel coefficient	0.64***	0.41***	0.58***	0.45***	0.63***

** and *** denotes significance at 10% and 1% respectively.*

6.5.1. Different informational basis: how do they fare in capturing cross-country variation in food security outcomes?

As noted in the third Chapter, the evolution of the concept of food security over time reflected the paradigm shifts from a supply-based approach based exclusively on food availability (UN 1974) to a multidimensional one that graduallty included the dimension of access first (Sen 1981; World Bank 1986) and utilisation and stability later (WFS 1996). The aim of this section is to assess the extent to which different metrics are able to capture cross-country heterogeneity in food security outcomes.

We start from the typical measure of resources in the analysis of food security, caloric availability. Figure 14 presents the relationship between MIFI and calories available per day per capita, as measured by FAO Dietary Energy Supply (DES). As mentioned in Section 4.2, DES is one of the key “ingredients” in the construction of FAO PoU. From the analysis of the figure, it is possible to observe that, at the bottom of the distribution of caloric supply, the relationship between food availability and food insecurity is extremely strong. This finding points to availability as a necessary condition for food security to occur[161]: when the first link in the food security chain is

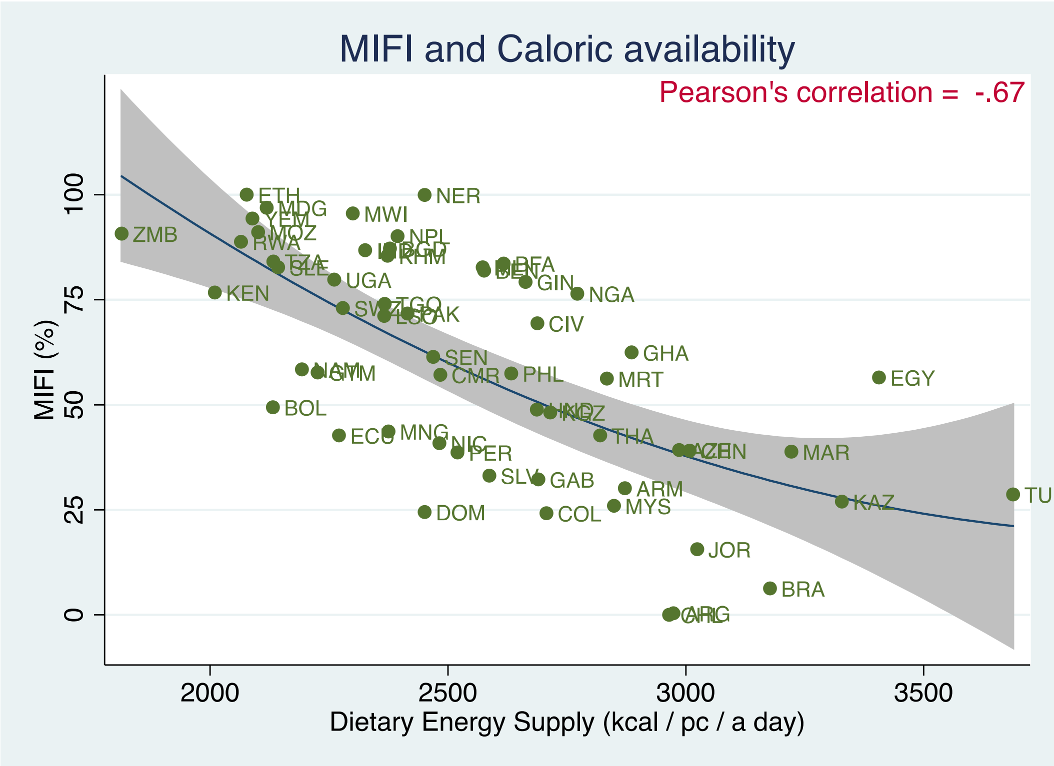
[161] As discussed in Chapter 4.

lacking, it is very likely that the performances of other dimensions will be dismal too. The crucial questions, however, relates to whether availability is also a *sufficient* condition fod food security to occur and whether the unidimensional space of calories can adequately capture variations in food security outcomes. The analysis of Figure 14 shows that, as soon as the focus shifts from low to average or high levels of food availability (i.e. respectively around 2500 and 3000 calories or more), the discrepancy between the two metrics increases and the relationship between food availability and food security becomes progressively weaker. According to the metrics of calories, for instance, the Dominican Republic and Niger would be considered as characterized by the same level of food security, given that they both share the same level of 2500 calories per capita per day. The analysis of MIFI, however, provides an opposite picture: on the one hand, the Dominican Republic, with a MIFI of 25%, is among the top quintile performers, while Niger, with a score of 100%, is classified as the most food insecure country in the sample. The discrepancy between the two metrics applies is evident also for countries that are characterized by very high levels of caloric availability. In this respect, the case of Egypt is particularly instructive. Although the levels of food availability in the country are among the highest in the sample[162], a value of 57% of MIFI indicates relatively high levels of food insecurity. This is mostly driven by the pervasive malnutrition in children (29% are stunted), which, according to a recent study by the World Bank (2011), is also widespread among the households in the top wealth quintile. The Bank stressed that food insecurity in Egypt is neither due to inadequate availability or access, but of umproper utilization of food, as it is driven by dire health and care practices. Intuitevely, this simple analysis shows that the unidimensional space of resources is inadequate to capture the complexity of food security: first, it does not consider the inherent multidimensionality of the concept, and secondly, it neglects the heterogeneity of conversion of resources into actual food security outcomes, which is at the core of Sen's critique to resourcist approaches (Chapter 1). Although such heterogeneity is mainly individual, the country environment *latu sensu,* through socio-economic, cultural, and institutional

[162] In turn, the very high levels of food availability drive Egypt's performance in the PoU, which is at the same 5% level of the best performing countries in our sample (according to both the PoU and MIFI), Chile and Argentina.

factors, plays also a fundamental role in the process of well-being achievement, as also found in the structural part of the MIMIC model presented earlier.

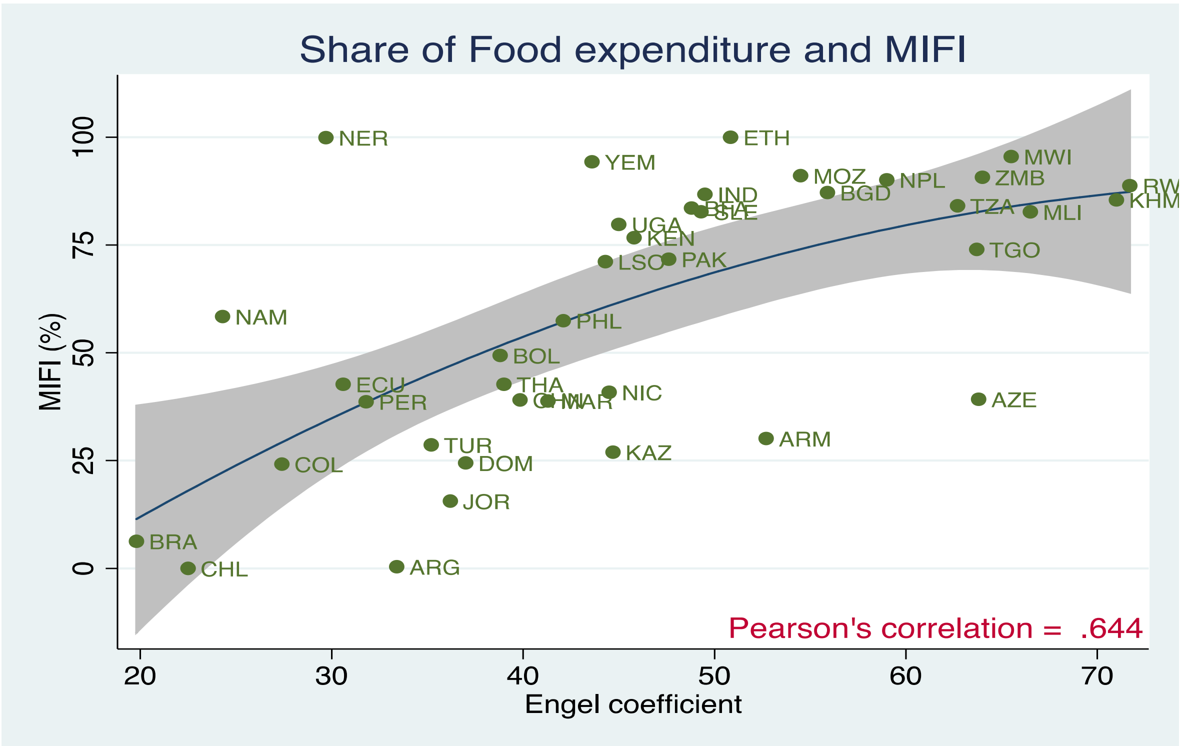
Figure 14 Relationship between MIFI and food availability



Note: Pearson's correlation at 1% significance level.

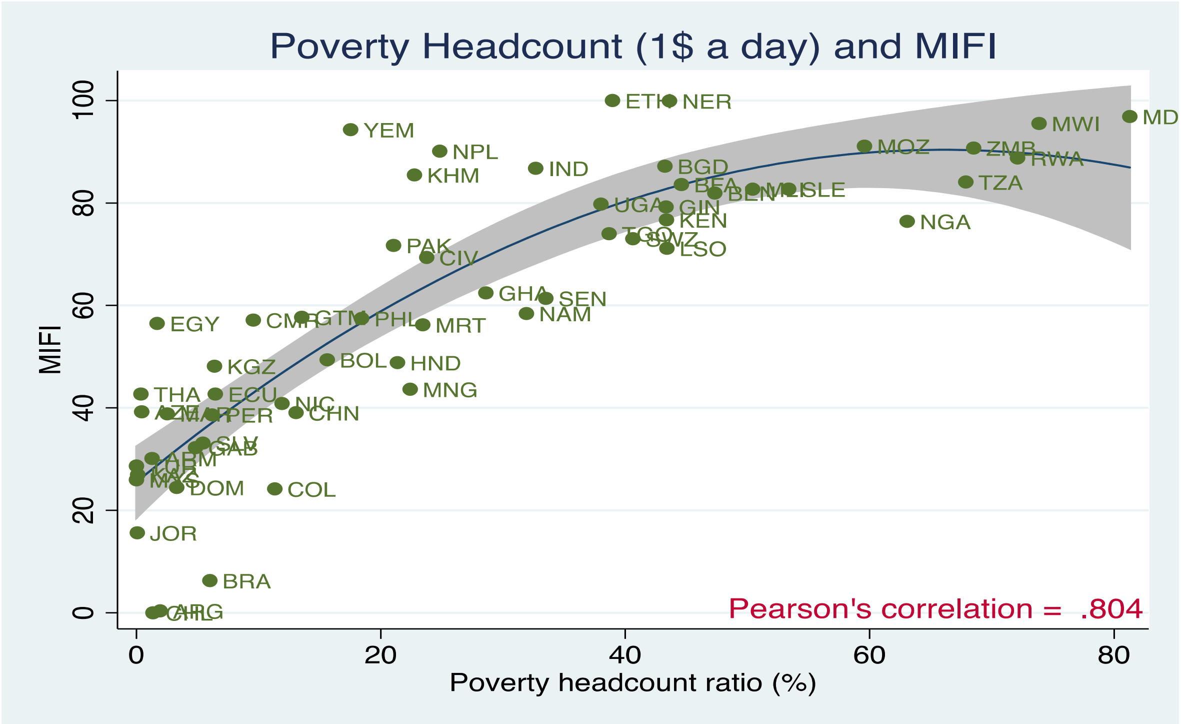
Now we turn to the analysis of the relationship between "food entitlements" and the latent "capability to be food secure", as measured by MIFI. In 1981 Sen (1981) replaced the informational basis of resources with the one of entitlements, i.e. people's effective command over food. In this view, poverty, and hence the failure in securing adequate access, is the main driver of food security (World Bank 1986). Figure 15 provides a scatterplot of the relationship between MIFI and a commonly used measure of poverty, the Engel coefficient. The latter measures the proportion of households' expenditure (or income) spent on food on total expenditure (income). The higher the Engel coefficient, the higher the proportion of the household's budget devoted to food acquisitions, and the lower the availability of additional resources to access non-food commodities. Hence, higher shares indicates lower standards of living. Although there is a fair amount of correlation between the two measures, the analysis of entitlements alone is not able to discriminate across countries that are characterised by very distinct food security situations, such as Argentina and Niger, respectively the best and worst performing countries in terms of MIFI, which share similar levels of the Engel coefficient (around 30%). The comparison with another indicator of poverty, the one-a-day headcount ratio of the World Bank (World Bank 2012), provides similar conclusions as shown in Figure 16.

Figure 15 Relationship between MIFI and food entitlements



Note: Pearson's correlation at 1% significance level.

Figure 16 Relationship between MIFI and Poverty Headcount at $1 a day (PPP)

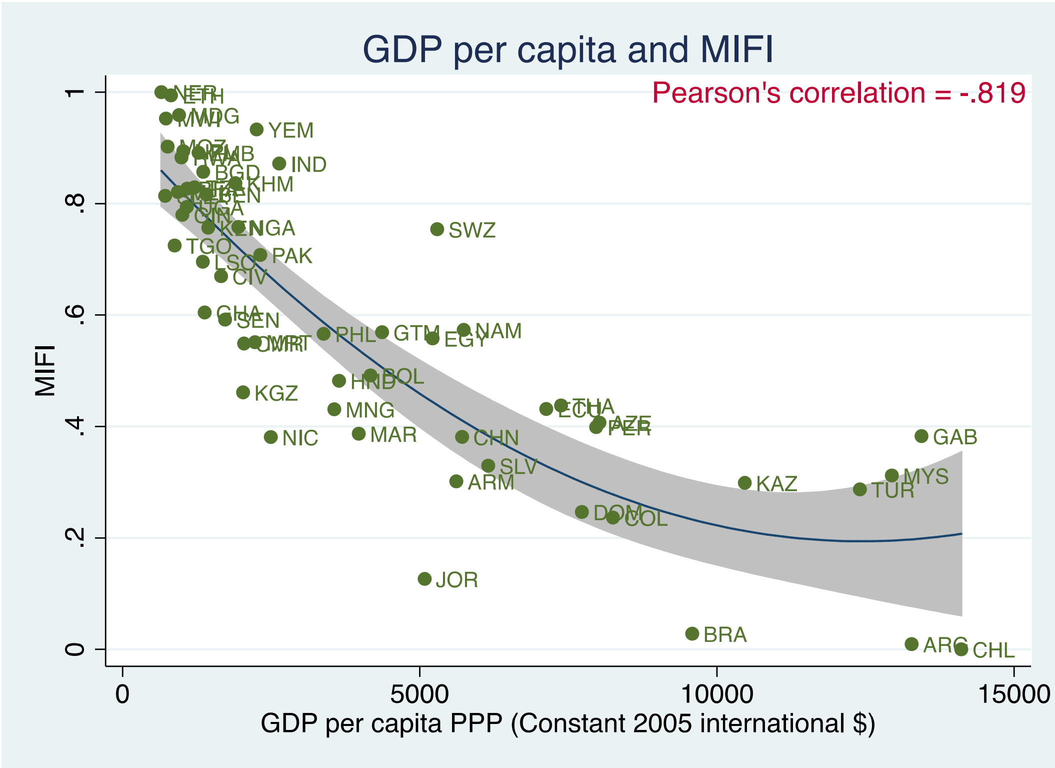


Note: Pearson's correlation at 1% significance level.

Finally, Figure 17 compares MIFI with the quintessential resource-based indicator of development, GDP per capita. Although the correlation between the two indicators is high, assessments based on GDP are not able to satisfactorily capture variation in food security outcomes as well as MIFI. For instance, even if the per capita income in Gabon is four times higher than in Nicaragua (even after correcting for differences in the cost of living), the level of food security in the two countries is the same. A different comparison is provided by the analysis of MIFI scores at a fixed level of GDP: for instance, a great deal of variation in food security outcomes exists for countries that share an income per capita of $5000 PPP.

In line with our theoretical framework (Chapter 3), these examples show that the complexity of food security is best captured through the "capability to be food secure", which we assume to be measured, with all its imperfections, by MIFI than through the use of resources-based indicators. Also, the empirical analysis presented in this Sections underscores the positive evolution over time of the concept of food security in capturing the complexity of the concept.

Figure 17 Relationship between MIFI and GDP per capita



Note: Pearson's correlation at 1% significance level.

6.6. Conclusions, policy implications and issues for further research

Starting from the theoretical and methodological frameworks for the analysis and measurement of food security proposed in earlier chapters, the aim of this one is to measure food security and model its main covariates at the country level through a SEM model.

Methodologically, the paper argued that the latent variable methodology could offer a appropriate framework for the measurement of food security. The MIMIC setup was shown to be able to capture the multidimensional nature of food insecurity and at the same time to minimize the burden of measurement error in single indicators. With respect to the former objective, the empirical evidence presented showed that MIFI provides a more balanced view regarding food insecurity than single indicators, which can be only imperfect proxies of the complexity of the concept, and captures effectively cross-country variation in food insecurity outcomes. Moreover, MIFI is highly correlated to a number of other key health and nutrition indicators, which, while on the one hand supports the external validity of the measure, on the other it is shown to provide a comprehensive, yet summary, view of the food insecurity performance of the countries.

With respect to the second goal, MIFI, by combining indicators that are measured independently from each other and by explicitly modeling the error, reduces and controls for the impact of random measurement error in each single indicators.

In the structural part of the model we empirically tested the relevance of some economic, social, and institutional factors that the cross-country literature usually identifies as drivers of food insecurity outcomes. The empirical results show that economic growth alone is not a sufficient condition to ensure food security, while there is extensive space for public action in promoting food security through, for instance, expenditure on women's education, health, and expansion of households' entitlements to food. This result is particularly relevant as it empirically tests the hyphotesis advanced by Burchi & De Muro (2012b) on the "capability to be food secure" as the result of the interaction between the capability of "being free from hunger" obtained through the access to food, and the ones of being in "good health" and "being educated". Also, the statistical significance of the coefficients associated to prices and rurality points to the relevance of the environment *latu sensu* in the conversion of available resources into food security outcomes. Coherently with the theoretical model outlined in Section XXXX, the "capability to be food secure" not only results from the complex interaction among various human development dimensions, but is also influenced by the environment understood as institutional, social and economic factors.

In particular, with respect to the latter, the empirical evidence on prices and agricultural productivity contributes to a more nuanced policy debate on their role for food security. In particular, the estimates show that at the cross-country level prices are positively associated to food security, which contrasts with the recent messages on the negative impact of soaring food prices on hunger levels launched by United Nations and non-governmental organizations (FAO 2008b; OXFAM 2011). This result, which is coherent with a well-known strand of literature that argues that the impact of food prices will ultimately depend on the distribution of agricultural producers and consumers in the population (Deaton 1989; Barrett & Dorosh 1996; Barrett 2002; Swinnen & Squicciarini 2012), By the same token, despite agricultural productivity is often seen as a *panacea* for food security (Hoddinnott *et al.* 2012; Fan & Pandya-Lorch), our empirical evidence shows a lack of statistical significance of a key measure of agricultural efficiency, i.e. cereal yields. Although further research to validate this result is certainly needed, it is nonetheless coherent with the our theoretical framework: indeed, getting the prices and quantities right is not enough to ensure food security to automatically follow, and, as such, a broader approach, combining investments in rural and human development is much needed.

The last section of the Chapter analyses the relationship between the "capability to be food secure" as measured by MIFI, and two different metrics of food security, the one of caloric availability and the one of entitlements. Both comparisons show that the enlargement of the informational basis for the analysis of food security in order to encompass its multidimensionality is able to capture more cross-country variation in food security outcomes than former metrics based on more restricted informational spaces.

Finally, we acknowledge that one of the main limitations of the present analysis relies on being based on a cross-country sample, for two main reasons: first, food security is an inherently dynamic concept, and, by analysing it at a given point in time, the dimension of stability is left out. Secondly, cross-country estimates suffer from many shortcomings (Smith & Haddad 2000; Durlauf *et al.* 2005), the most prominent of those relates to some unobserved country-specific factors that may lead to endogeneity in the estimates. We leave the investigation of this factors, especially the ones linked to why any variable related to the governance of food security, has been found significant

Part C – Measuring Poverty

Chapter 7

Multidimensional Poverty and its Life-Course Effects: Evidence from Four Developing Countries

7.1. Introduction: "Poverty reduction begins with children"[163]

There are both intrinsic and instrumental reasons to put children at the centre of the development agenda. On the one hand, the reduction of childhood poverty has an intrinsic relevance *per se*, as a matter of promotion of basic human rights and global justice (Sen 1999b, 2007; Vandermorteele 2012; Woodhead *et al.* 2012). On the other, a child-focused approach to poverty reduction is also a mean to sustainable and equitable development outcomes. First, because of the young demographic structure of most developing countries, poor children make a disproportionate share out of the total poor. As such, reducing childhood poverty directly translates into poverty reduction at the population level (White *et al.* 2003; Gordon *et al.* 2004; Barrientos & Dejong 2009; Jones & Sumner 2011; Biggeri & Mehrotra 2011). Second, poverty and inequalities experienced during childhood have negative long-term impacts on a variety of outcomes in later life, such as, *inter alia*, education, health, social skills, and productivity (Grantham Mc-Gregor *et al.* 2007; Glewwe & Miguel 2008; Almond & Currie 2010). Finally, impoverished children can, in turn, be transmitters of poverty to their own children, leading to persistent poverty and widened inequalities between generations (Mehrotra & Jolly 2000; Yaqub 2000; 2002, 2008; Harper *et al.*

163 Vandermoortele (2000).

2003; Harper 2004). As such, policies that invest in children to give them a good start in life are a long-term investment with substantial economic and social returns (Cunha *et al.* 2005, 2008; Commission on Growth and Development 2008; Alderman 2010; Yaqub 2011; Vandermoortele 2012; Outes & Porter 2012).

The recognition of childhood poverty reduction as both intrinsic policy goal and instrument to sustainable development strived an unprecedented blossoming of multidisciplinary research on childhood (Boyden & Dercon 2012). In economics, two major areas of research can be identified: the literature on childhood poverty measurement (Gordon *et al.* 2003; Roche 2010; Biggeri & Mehrotra 2011; Alkire & Roche 2012; Minujin & Delamonica 2012) and the one on Early Child Development (ECD) (Behrman 1996; Glewwe & Jacoby 1995; Glewwe *et al.* 2001; Alderman *et al.* 2006, 2009; Maluccio *et al.* 2006; Grantham-McGregor *et al.* 2007; Glewwe & Miguel 2008; Alderman 2010; Almond & Currie 2010; Sanchez 2009: Dercon & Sanchez 2011). While the former is concerned with providing measures of childhood poverty, understood as a multidimensional phenomenon, in a given point in time, the ECD literature focuses on the analysis of the long-run repercussions of poor health experienced *in utero* and during the first three years of life on a wide range of life course attainments, such as education, productivity and wages and, recently, non-cognitive abilities[164]. Given scarce availability, in the context of developing countries child health is typically proxied by the height-for-age indicator[165].

In turn, these two strands of investigation reflect profound differences in the conceptualisation of children's well-being: on the one hand, the childhood poverty literature combines theoretical insights from the 'new sociology of childhood' (Qvortup 1990; James & Prout 1997; Ben Arieh 2000, 2008) and methodological tools from the broader literature on multidimensional poverty

[164] This literature has been recently expanded by the contributions of Cunha & Heckman (2006, 2008) that pointed to the dynamic interactions of cognitive and non-cognitive skills in child development.

165The increasing amount of data available on morbidity is gradually leading to an expansion of this literature through new research that looks at the effect of early infectious diseases on long-term outcomes in developing countries (i.e. Balhotra & Venkataramani 2012). As of yet, this strand of research, nonetheless, has mostly been limited to advanced economies, and in the US in particular (i.e. Costa 2000; Holding & Snow 2001; Bleakley 2007; Guyer et al. 2000; Case & Paxton 2009).

measurement (Kolm 1977; Sen 1976, 1985; Anand & Sen 1997; Alkire & Foster 2011a). On the other, ECD contributions are firmly grounded in the human capital framework (Becker & Tomes 1986).

Despite the profound differences in theoretical backgrounds and analytical purposes, these approaches appear to be complementary in both theoretical and methodological respects: with respect to the former, we argue that the adoption of the CA as overarching theoretical framework for the analysis of children well-being and its deprivations (Biggeri *et al.* 2011), can overcome the narrow focus of the ECD approach by providing a more complex conceptualisation of childhood and by explicitly recognising the multidimensional nature of poverty and well-being (Sen 1999).

Methodologically, the complementarity between these two literatures arises from their different research foci: on the one hand, the literature on multidimensional poverty measurement focuses only on providing snapshots of children's poverty, in a given point in time or through comparative statics[166], without addressing the crucial question of its potential effects on human development outcomes through the life course. For instance, it may be plausible that the experience of joint deprivations in a given point in time, through their self-reinforcing and dynamic interactions, bears cumulative effects on children's long-term human development. By contrast, the ECD literature, whilst being inherently dynamic, does not fully take account of the multidimensionality of childhood poverty by exclusively focusing on a specific indicator of children's early years well-being, which, in the context of developing countries, is typically retarded growth due to malnutrition. One relevant question is whether a single indicator can capture the complexity of children's well-being, or, in narrower terms, whether a unidimensional metrics can provide a comprehensive measure of health in early childhood. This question arises from two main issues: first, the same health dimension is a multidimensional phenomenon (Strauss & Thomas 2008), and, secondly, most of the diseases that affect children in developing countries are unlikely to affect linear growth (Glewwe & Miguel 2008).

[166] As for instance, in Apablaza & Yalotnesky (2011) or Alkire & Roche (2011).

This Chapter is a first attempt to bridge the gap between these two literatures by combining the *measurement* of multidimensional poverty in dimensions that matter in early childhood with the *modelling* of their potential long-term effects on cognitive outcomes in both the preschool and school periods. Using data on the younger cohort of the Young Lives dataset for four developing countries (Ethiopia, India, Peru and Vietnam), this Chapter attempts to empirically test whether a multidimensional approach to the analysis of early childhood deprivation is a more powerful predictor of children's human development attainments in the medium-term. Specifically, it tries to uncover whether deprivations in the health and nutrition dimensions work in concert in hindering children's cognitive development over distinct development stages and across the very distinct contexts of the four study countries.

The results of the empirical analysis also show that poverty experienced in the early year is persistent over time, and that other inequalities, related to child background characteristics (i.e. gender, locality, access to services, care-giver and household head education, antenatal care), to their educational path (i.e. whether the child attended preschool or entered late in school) and to children's time use work in concert to amplify initial disadvantage. This evidence underlines that a truly multidimensional approach to the analysis of children's cognitive development is strongly required.

This Chapter proceeds in the following way: while Sections 7.2 and 7.3 provide the theoretical and methodological frameworks, Section 7.4 presents the data. Section 7.5 presents the results and 7.6 the robustness checks. Finally, Section 7.7 concludes and presents issues for further research.

7.2. Conceptual Framework

7.2.1. Main limitations of the distinct theoretical approaches to childhood poverty

Although the two literatures on child poverty and on ECD are complementary in providing an overall picture of the multidimensionality of childhood poverty and of its dynamic reflections on lifecourse capabilities, disciplinary barriers have so far prevented cross-fertilization. In this section we argue that the adoption of Sen's Capability Approach (Sen 1985, 1992, 1993, 1999) as theoretical framework of the analysis can bridge the gap between the two strands of research. This gap is ascribable to the different disciplinary and methodological traditions in which the two literatures are rooted.

On the one hand, the literature on childhood poverty, being theoretically grounded in the new sociology of childhood (Qvortup 1990; James & Prout 1997; Ben Arieh 2000, 2008), conceptualizes childhood as an autonomous and independent group that, as such, deserves specific child-focused policies (Ben-Arieh 2008). This has relevant implications for the analysis and measurement of childhood poverty: firstly, because children's exigencies are different from the ones of adults, metrics of children's well-being (and the lack of it) should accordingly take a child-specific focus, as they need to capture children's age-specific material, psychological, emotional and social needs, as well as their agency (White *et al.* 2003; Ben-Arieh 2008). This also entails that the unit of observation must shift from the household to the children themself[167] (Ben-Arieh 2000, 2008; Dercon 2012). Secondly, as children's well-being is multidimensional, evaluations of childhood poverty should be conducted in multidimensional spaces (Ben-Arieh 2000, 2008; Harper *et al.* 2003; Bourdillon 2012; Dercon 2012). As of yet, however, the literature on child poverty measurement has insufficiently analysed the dynamics of childhood poverty and its eventual repercussions on lifecourse capabilities, and has mostly provided static snapshots of multiple deprivations experienced by children in a given point in time[168] (Gordon *et al.* 2003; Di Tommaso 2006; Biggeri *et al.* 2006; Roche 2009; Rotten & Noelen 2010; Ballet *et al.* 2011; UNICEF 2011; Apablaza & Yalotneski 2011). In doing so, this body of work neglects to explore the

[167] Until the early 1990s, in fact, child poverty was mainly conceptualised as a reflection on their households' (monetary) deprivation. This view echoed the broader sociological characterisation of children as passive objects, "who were acted on by the adult world" (Ben-Arieh 2008, p. 7), without recognizing them any type of subjectivity or agency.

168 Notable exceptions are Roelen *et al.* (2010) and Apablaza & Yalotnesky (2011), which, however, are limited to conduct a comparative statics exercise by decomposing changes in multidimensional poverty over time.

possibility that dynamic complementarities across deprivations may arise and affect in a negative way long-term achievements.

By contrast, the literature on ECD is inherently dynamic [169], as it focuses specifically on the long-run impacts of early health deprivation on lifecourse attainments. However, economic models of child well-being suffer from other types of limitations, which mostly stem from being grounded in the broader literature on human capital accumulation. In particular, they adopt an "investment perspective" to the analysis of childhood, which turns out providing an impoverished view of children and of their well-being. Firstly, deprivations in critical dimensions such as nutrition, health, or education are valued in virtue of their reflections on future economic outcomes, such as economic growth, wages, productivity or educational attainments, and not as constitutive dimensions of human well-being (Sen 1999). Recent influential contributions in this domain have gone as far as evaluating children's subjective well-being (i.e. agency, self-esteem) in virtue of their associations with increased returns in education and labour markets (Bowles *et al.* 2001; Cunha *et al.* 2006). Further, such a narrow 'investment perspective' fails to recognise the role of children as agents of their own well-being. Economic models do not include children's own perceptions and responses to poverty, which instead can be key drivers of their future life chances (Bandura *et al.* 2001), but also a channel of transmission of poverty by forging aspirations (Woodhead *et al.* 2012). Together, these two points suggest that in a human capital framework children's present well-being and agency are mostly neglected, as children are conceptualised as "human becomings" (Qvortup 1990) or economic agents *in fieri* (Phipps 2002). Finally, these models assume that children's well-being outcomes are the result of deliberate investment decisions adopted by the household. The 'investment assumption' is a very strong one in the context of developing countries, as it implicitly neglects that: (i) households have imperfect knowledge; (ii) poverty is not only lack of income or resources, but also 'lack of freedom' to choose the best combination of resources to invest in

[169] The idea of child development is by definition dynamic. As defined by Fernald *et al.* (2009), child development is "the psychological and biological changes that occur as a child transitions from dependent infant to an autonomous teenager" (Fernald et al. 2009, p. 1).

children's well-being due to broader environmental, social, and institutional conditions (Sen 1999a).

7.2.2. Bridging the Gap: why Adopting the Capability Approach as Theoretical Framework for the Analysis of Childhood Poverty?

This Chapter argues that there are four features of the CA that renders it a natural fit for bridging the gap between these two literatures and providing a conceptual framework for the analysis of the multidimensionality and dynamics of childhood poverty. In his path breaking contributions, Sen criticised the focus on resources of traditional economic approaches in two main respects: first, as discussed in the first Chapter, unidimensional informational bases (i.e. income, assets, or calories) are inadequate in capturing the complexity of human well-being, and, as such, a plurality of evaluative spaces is needed, the ones of functionings and capabilities. By result, the CA is inherently multidimensional, and as such, it can accommodate well the analysis of the many dimensions of children's well-being. Secondly, Sen argued that the end of development is not resources accumulation, but the expansion of people's real freedoms "to *lead the lives they value – and have reason to value"* (Sen 1999a, p. xii). Symmetrically, poverty is the most elementary form of un-freedom conceivable, as it relates to the incapability to escape hunger, avoidable diseases, premature mortality and the daily burden of other deprivations (Sen 1980; Foster & Sen 1997; Sen 1999). As such, deprivations in critical dimensions for child well-being such as health, nutrition, and education are not only valued as factors of production of future economic welfare, but are as considered as intrinsically valuable in themselves as forms of elementary unfreedoms. Third, the idea of a "people-centered" development (Sen 1999a) also entails that people themselves are active agents of change of their lives and communities. Hence, the approach emphasises individual and collective agency (Ibrahim 2006; Alkire 2008). In the context of child poverty analysis, the focus on agency is translated into the recognition of children as an autonomous group, characterised by different levels of agency over different stages of

maturation (Biggeri *et al.* 2010; Ballet *et al.* 2011; Biggeri & Delamonica 2011). Additionally, the CA emphasis on people entails that the measurement of child poverty should be focused at the child level, in order to reveal achieved well-being outcomes as well as intra-household and gender inequalities in the distribution of resources (Sen 1985, 1992, 1999b; White *et al.* 2003; Klasen 2007; Biggeri & Mehrotra 2011). Given the heterogeneity of human beings, the focus on achieved well-being outcomes is particularly relevant for the analysis of child poverty, as children of different ages, gender, health status, or socioeconomic backgrounds may have unequal conversion rates of resources into actual well-being achievements. Fourth, the CA is also a dynamic approach – time is inherent in it - which can accommodate well the analysis of lifecourse capabilities (Yaqub 2008) and 'well-becoming', i.e. the evolution of capabilities enjoyed in childhood in human development (Comim 2004; Ballet *et al.* 2011).
For these features, we argue that the CA provides a theoretical framework that overcomes the limitations of the human capital approach by taking into account of all the complexities of child development and at the same time provides a suitable theoretical framework in order to ground the empirical analysis of this Chapter.

7.3. Methodology

7.3.1. Measuring multidimensional early childhood poverty

Given its complexity, no single metrics can meaningfully capture childhood poverty: a multidimensional exercise is needed. As discussed in Part A of this Thesis, these questions point to the three main steps characterizing any evaluative exercise: choice of the space of the analysis, identification and aggregation. With respect to the former, coherently with the adoption of the CA as overarching theoretical framework for this analysis, the selected space for conceptualising and measuring poverty in early childhood is the one of achieved functionings. The other two steps, identification and aggregation, will be discussed thoroughly in the next sections.

7.3.1.1. Identification: conceptualizing early childhood poverty

From a normative perspective, a measure of child poverty should aim, on the one hand, at capturing dimensions 'that matters most to children' at different phases of childhood, and at selecting a set of actionable policy leverages that can promote children well-being on the other (White *et al.* 2003; Biggeri *et al.* 2010; Biggeri & Mehrotra 2011). For both purposes the choice of dimensions informing the measure should be oriented to: (i) being tailored to the distinct exigencies that stem from the various stages of childhood (i.e. the early years, preschool and school periods, and adolescence); (ii) being relevant to the context of reference, in order to capture the context-specificity of deprivations; (iii) orienting public policy in an effective way; and, finally, (iv) stimulating public debate and advocacy. As for the inherent complexity of the concept, the literature on the measurement of childhood poverty is unsurprisingly heterogeneous, in terms of theoretical framework adopted and dimensions and indicators selected [170]. Regarding the choice of dimensions, many authors have proposed lists of critical aspects of children's well-being, reflecting in this way the multidimensionality of the concept[171] (Ben-Arieh 2000; Nussbaum 2000; Phipps 2002; Robeyns 2003, Di Tommaso 2006, UNICEF 2007, Biggeri & Mehrotra 2011, Minujin & Delamonica 2012). Nonetheless, as the aim of the present analysis is to measure poverty in the early childhood by looking at children's achieved outcomes, this Chapter identifies poverty as deprivation in the bodily health dimension only. In particular, we conceptualize and measure poverty as children's multiple deprivations in the nutritional and health domains for two main reasons. First, nutrition and health are intrinsically and instrumentally relevant dimensions of children's well-being in the early years. Second, deprivation in these dimensions has been demonstrated to lead to enormous loss of human potential in the developing

[170] See Minujin (2005) and Roetten & Noelen (2008) for a review.

171 A review of the literature on dimensions of children's well-being pointed to some recurrent and interrelated dimensions, such as bodily health and integrity, psychological health, social interactions and life skills, imagination, emotions and play, care, and, last but not least, material well-being.

countries. As reported by Glewwe & Miguel (2008), about 15% per cent of "healthy years of life" among children aged 0-4 in less developed countries is lost due to mortality and morbidity. Half of the burden of disease is due to communicable diseases such as, in order of importance: respiratory infections, diarrhoea, malaria and measles. Nutritional problems (other than diarrhoea) account for 4% of the total burden of disease (Glewwe & Miguel 2008).

7.3.1.2. Identification: choice of the indicators

In order to operationalize the rather abstract concept of early childhood health we selected two indicators for nutrition and two for infectious diseases. Regarding the former, both the wasting (weight for height) and stunting (height for age) indicators were included in order to capture both contemporaneous and chronic malnutrition, as the two phenomena are caused by different factors (Frongillo et al. 1997). With respect to the infection sub-dimension, on the other hand, the indicators chosen measure the occurrence of life-threatening illnesses or injuries, and the presence of acute infection in the previous 24 hours. Both indicators are reported by the main caregiver of the child. As subjective or self-reported indicators of health are often criticised as they may report *perception* of illness rather than actual morbidity (Murray et al. 1992), a more extensive discussion of the two indicators is required. The Young Lives study asks the child caregiver if the child has had a list of symptoms in the previous 24 hours, or if the child has experienced another list of symptoms for which the caregiver thought it might have died. The two lists encompass the symptoms for the major drivers of diseases in those countries, such as high fever or malaria, pneumonia, sever cough or very fast or difficult breathing; diarrhoea or blood in the stools; vomit; unconsciousness, convulsion, epilepsy. The inclusion of this list increases the objectivity of the assessment, as "*symptoms have the characteristic of observability, even if they are not actually observed*" (Idler 1992, p. 42, quoted in Ruggeri Laderchi 2008, p. 214). Nonetheless, the interpretation of these indicators for cross-country comparisons is still difficult, because a variety of factors (income, education, availability and cost of health facilities, and public information on illness and remedy) may all affect self-reported information beyond the actual experience of sickness (Murray et al. 1992; Sen 2002). For instance, Murray *et al.* (1992) suggest that, the lower the opportunity costs due to morbidity, the greater is its recognition. Finally, as discussed in Ruggeri Laderchi (2008), empirical evidence shows that the association between objective and self-reported indicators of health increases as the overall standards of living in a country decreases. For this reason, and for the fact that these types of indicators capture distinct aspects of health whose importance for cannot be dismissed in an evaluation of well-being (Murray et al. 1992), these two indicator provide valuable information on overall child's health that complements the two, more "objective", measures of nutritional status.

The choice of the indicators for the present analysis aimed at reflecting the principles outlined in Chapter 5. In this specific case, they were expressly selected to be: (i) child-focused; (ii) direct measures of distinct facets of deprivations experienced by the child himself; (iii) age-specific; (iv) context-relevant. They all stem from the choice of grounding the analysis in the theoretical framework of the CA: the people-centered perspective of the approach leads to focus directly on the outcomes achieved by the children themselves, rather than on the means to reach them (i.e. their household's income or assets) or other proxies for achievements (i.e. maternal education). Moreover, as already stressed in other chapters of the thesis, the focus on outcome indicators is coherent with the recommendations of the broader literature on the assessment of social phenomena (Jannuzzi 2001, 2005; UN 2003; OECD-JRC 2008; Stiglitz et al. 2009; Hall et al. 2010; Trewin & Hall 2010) and with the empirical studies conducted on child poverty (e.g. Phipps 2002; Di Tommaso 2006; Apablaza & Yalotnesky 2011; Addabbo & Di Tommaso 2011; Dercon 2012). Additionally, as we will aggregate those indicators into a composite index of child early multidimensional poverty, it is methodologically sound to not mix indicators of inputs and outcomes into the same composite index (OECD-JRC 2008). Finally, the last two criteria underscore that the choice of indicators has to anchored to the specificities stemming from the development stage and context in which the child lives, as different things may matter in distinct times of children's lives as well as in different contexts. For instance, if the aim was to measure poverty in a different stage of childhood, other indicators related to other dimensions such as education, subjective well-being or agency could have been used in concert with the ones related to health and nutrition, while in a context of an advanced economy the choice of indicator would have inevitably reflected other types of deprivations (Robeyns 2003; Ruggeri Laderchi 2008).

Far from being perfect, these indicators represent a reasonable mediation across the two distinct exigencies of theoretical soundness and adherence to the concept to be measured and data availability and comparability on the other. Although the Young Lives dataset contains a wealth of information on the major drivers of morbidity and mortality in the developing countries (i.e. respiratory infections, diarrhoea, malaria, measles and nutrition) and has been designed to ensure comparability across countries, difficulties have been encountered in the choice of these indicators (particularly the ones related to morbidity). The selection of the indicators for this work had to strike the difficult balance between three distinct exigencies: the adherence of the indicator to the concept measured; the comparability across four distinct countries; and the necessity to ensure meaningful variation across the sample countries. For instance, a specific indicator related to the care of the child could not be included because only children in Ethiopia and, to a lesser extent, India were experiencing such deprivation while in Peru and Vietnam there were basically no children deprived in such dimension. By the same token, information on breast-feeding was not included because virtually all the children are breast-fed across the whole sample. Data availability was also a constraint for the choice of the indicators: although the Young Lives study was designed to provide the same information in a comparable fashion across all the study countries, differences in the study design for each country inevitably exist in order to capture specific policy issues[172].

7.3.1.3. Aggregation

The second step, *aggregation,* is concerned with the use of the selected information in order to obtain a measure of poverty in the population. As discussed in Chapter 2, in a multidimensional setting aggregation could either take the form of suites of indicators or composite indices. We will exploit both aggregation methods in order to empirically test our research questions.

[172] For instance, although it would have been a useful complement to the data on breast-feeding, we could not include any information on weaning because such information was collected for India only.

In particular, the selection of indicators without aggregating them into a single index entails the development of 'poverty profiles', which show the deprivation embedded in each indicator separately. Conversely, composite indicators collapse all the relevant information in a single figure in order to capture the joint distribution of deprivations experienced by the unit of analysis. The simplest way to aggregate child deprivations into a composite index is to count the number of deprivations and then aggregate them in a single figure. This is the method adopted by UNICEF (Gordon *et al.* 2003), which classified children as poor if they experienced at least one deprivation, and in absolute poverty if they have two or more deprivations. Nonetheless, as in the case of the unidimensional poverty headcount, this method addresses only the issue of poverty *incidence*, while it is insensitive to the breadth and distribution of deprivations. In order to overcome such an important shortfall of the headcount ratio, Alkire & Foster (AF, 2007, 2011b) proposed a multidimensional extension of the Foster-Greer-Thorbecke class of poverty measures, which, depending on the type of data used and on the degree of inequality aversion adopted, can accommodate both the issue of depth and distribution of experienced poverty[173]. The AF family of measures combines the well-known Foster-Greer-Thorbecke poverty indexes (Foster *et al.* 1984), with the counting approach to identification proposed by Atkinson (2003). In particular, the class adopts a two-step process to identify the multidimensionally poor. First, for each individual i, deprivations in dimensions d are detected through the comparison of the individual's achievement x_{id} against a dimension-specific deprivation cutoff, z_d. Then, the weighted sum of all the deprivations experienced by the individual is compared against a cross-dimensional cutoff k, which specifies the number of dimensions required to be considered multidimensional poor. If the weighted sum of the person's deprivations c_i is higher than the dimensional threshold, the person is then counted as multidimensional poor. In this way, the first measure we derive is the (multidimensional) headcount ratio H, which provides the share of population that, once k is set, is identified as multidimensional poor:

[173] For further discussion, see Chapter 2.

$$H = \frac{q_k}{n},$$

with $q_k = \sum_{i=1}^{n} \rho_k(x_i; z) = \sum_{i=1}^{n} w(c_i \geq k) = \begin{cases} 1 & if\ x_{id} < z_d \\ 0 & if\ x_{id} > z_d \end{cases}$.

As in the unidimensional case, the Headcount Ratio is a very crude measure because it is insensitive to both the depth and distribution of poverty. In particular, if a poor person becomes deprived in an additional dimension, the headcount remains unchanged. Let then introduce the *share of possible deprivations* experienced by a poor individual *i*:

$$\frac{c_i(k)}{d},$$

where $c_i(k) = \frac{1}{d}(c_i \rho_k(x_i; z)$.

And A, the average deprivation share among the poor:

$$A = |c(k)|/(qd)$$

It is then possible to define the Adjusted Headcount ratio M_0, which is sensitive to both the frequency and the breadth of multidimensional poverty:

$$M0 = HA$$

A practical advantage of this methodology is that it can be used with discrete and qualitative data, as well as continuous or cardinal ones (Alkire & Foster 2007, 2011b). This property is extremely relevant for our purposes, as two of the indicators that will be used for the present analysis are categorical ones.

Given that all the indicators are complementary in capturing distinct intrinsically valuable facets of the health dimension, equal weights were assigned, so that the multidimensional score is characterised by a nested weighting system. In this Chapter, we are not interested in setting a poverty cutoff to identify the multidimensional poor, because we are only aiming at defining a multidimensional index of child deprivation and then exploit its variation across the sample in order to test its association with later cognitive achievements. Implicitly, this means that we adopted a union approach to identification, i.e. it is sufficient to be deprived in at least one indicator to be considered poor. This approach, while being theoretically justifiable because each attribute is considered an essential attribute of human well-being (Tsui 2002;

Bourguignon & Chakravarty 2003, Atkinson 2003; Duclos *et al.* 2005), also avoids the typical substitutability across attributes that equal weighting systems entail.

Finally, although it would have been desirable, we could not use non-additive poverty measures (i.e. Tsui 2002; Bourguignon & Chakravarty 2003) due limited data availability.

7.3.2. Modeling The Long-Term Effects Of Early Childhood Multidimensional Poverty: Identification Strategy

The aim of the empirical analysis is to test whether the adoption of a multidimensional approach to the measurement of early childhood poverty adds any value (in terms of predictive power) to a model of children's cognitive development. Two questions are empirically tested here: first, which is the best way to deal with the multidimensionality of early childhood poverty in an econometric setup (i.e. through the inclusion of single indicators or through a composite index); and secondly, whether the effect of being deprived in a single point in time is dynamically multiplicative, i.e. if the self-reinforcing interactions across deprivations lead to worse cognitive outcomes over time.

In a standard OLS setup, two major issues may bias parameter estimates: endogeneity due to omitted variables and measurement error[174]. Endogeneity may arise because data on many time-invariant child, household, and school-level characteristics that ultimately influence children's cognitive attainments cannot be observed by the econometrician, and, consequently, are omitted from the model leading to biased

[174] Although we leave the issue of measurement error for further research, let introduce it briefly. In a regression setup, measurement error could be affecting both dependent and independent variable, and arises when available indicators can only imperfectly measure a latent construct, leading to possible bias in the estimates. In our case, we are mostly concerned about the presence of measurement error in the indicators of children's cognitive ability and poverty, as well as in the multidimensional measure of poverty we propose. In the case of cognitive test scores, for instance, the classification of children's cognitive skills may be not accurate, due to intrinsic imperfections in the scale (Cunha & Heckman 2008) and the phenomenon of "regression to the mean" (Jerrim & Vignoles 2011). By the same token, also poverty can be seen as a latent phenomenon, of which we can observe only an imperfect measure. As discussed in Chapter 2, some authors explictly addressed the issue of measurement error in poverty measurement through SEM (Kuklys 2005; Di Tommaso (2006), and Khrishnakumar & Ballon (2009)

parameters estimates[175]. This issue can be explored in more depth from the following decomposition of the error term:

$$\mu_{ij,t} = c_i + h_i + \varepsilon_{ij,t}, \qquad \text{(i)}$$

where c_i and h_i are child and household unobserved and time-invariant characteristics such as child's innate healthiness and ability or household health and stimulation environment, while $\varepsilon_{ij,t}$ is white noise error.

The usual solutions that the literature provides to parameter identification in presence of endogeneity are[176]: (i) instrumental variables (IV), (ii) fixed effects OLS regression with a set of additional controls; (iii) a two-prong strategy that combines the two (e.g. Glewwe *et al.* 2001; Alderman *et al.* 2006; Lopez-Boo 2012). As the identification of convincing IVs is still debated in the literature (Wooldridge 2002, Glewwe & Miguel 2008), we will follow the second route, as in, for instance, Sanchez (2009) and Dercon & Sanchez (2011), by estimating the relationship between lagged early deprivation and cognitive abilities through OLS, including community fixed effects and a large number of child and household controls. In this way, we are able to control for the factors that are common to all the children living in the same community that may affect achievements (i.e. availability and quality of infrastructures, norms and culture, *etc.*). Leaving out contextual factors, our estimation strategy for the first research question only exploits the variance between children and households. In particular, for child *i* born in cluster *j*, our specification is the following[177]:

$$\mathrm{S^{k}_{ij,t} = \beta P^{m}_{ij,t\text{-}1} + X_{ij,t}\Upsilon + \alpha_j + \mu_{ij,t}} \qquad \text{(ii)}$$

where $S^k_{ij,t}$ is the cognitive outcome *k* observed in period *t* for child *i*,; $P^m_{ij,t-1}$ is the

[175] This discussion is similar in structure to the one usually presented to discuss the role of unobservables in the nexus between nutrition and cognitive or non-cognitive abilities, as in Alderman *et al.* (2006), Glewwe & Miguel (2008) and Dercon & Sanchez (2011).

176 For an in-depth literature review and discussion, see Glewwe & Miguel (2008).

[177] In the ECD literature, similar specifications are usually interpreted as demand functions for skill, in which all the inputs except the variable of interest (in this case, the child poverty measure) are replaced by their determinants.

vector of our variables of interest m and β is the associated vector of parameters. Depending on the different empirical specifications of the model, the vector $P^{m}_{ij,t-1}$ can be reduced to be a scalar (i.e. as in the baseline specification, when only height-for-age z-scores are included or in the one in which the multidimensional index is included as unique predictor of later achievements). $X_{ij,t}$ is the vector of household and child exogenous characteristics and Υ is the associated vector of parameters; α_j represents community j predetermined characteristics; and, finally, $\mu_{ij,t}$ is the error term.

In order to test our second research question we adopt a similar specification, which now also includes interactions across the different indicators of early childhood poverty:

$$S^{k}_{ij,t} = \beta P^{m}_{ij,t-1} + X_{ij,t}\Upsilon + \alpha_j + \delta\,(P^{m}_{ij,t-1} * P^{n}_{ij,t-1}) + \zeta_{ij,t} \qquad \text{(iii)}$$

As these two specifications can only imperfectly deal with endogeneity[178], we are only equipped to estimate associations, and not the true causal effects of the impact of early health on cognitive attainment (Behrman1996). The issue of endogeneity can, nonetheless, be limited by exploiting the wealth of information contained in the Young Lives dataset through the inclusion of a very extensive set of child, household, and school controls, which are listed in Appendix C.4.

7.4. Data Characteristics

7.4.1. The Sample

The data come from of the Young Lives study, an innovative and multidisciplinary study that investigates the causes and consequences of childhood poverty. Started in 2002, the study is tracking two cohorts of 12,000 children over a fifteen-year time span in Peru, Ethiopia, Vietnam and India

[178] As Cunha and Heckman (2008) noted, fixed effects methods widely used in the ECD literature imply invoke strong assumptions about the separability of the effects of observables and unobservables on skill formation, and on the way unobservables enter the model (Cunha & Heckman 2008).

(Andhra Pradesh). These countries were chosen to represent the richness and diversity of development experiences and paths. In this paper we will only focus on the younger cohort, which comprises 8,000 children who were born in 2001/2002, during the three rounds of data collection available so far (2002, 2006, and 2009), when index children were approximately 1, 5 and 8 years old. This allows us to focus on three distinct development stages: early childhood, preschool and school years (Glewwe 2005).

The Young Lives study adopted a 'pro-poor' and multi-stage sampling procedure[179] in order to select the sample: first, twenty "sentinel sites" from each country were non-randomly selected with the purpose of excluding rich areas and oversampling poorer ones. Then, children in the right age group in the sentinel sites were randomly sampled[180]. Because this choice left out the top decile households in each country, the sample (with the exception of Peru) is not nationally representative. Nonetheless, comparisons with DHS and other surveys suggest that the Young Lives data are representative of the type of variation that can be found in nationally representative surveys (Dercon & Singh 2011).

Attrition in the Young Lives sample is extraordinarily low, due to a particular effort in tracking children when they move (Outes-Leon & Dercon 2008). Overall, 96.5% per cent of the younger cohort children are present in all the three rounds of the dataset, and, in our sample, the attrition rates for the specific countries are 0.69% for Vietnam, 3.58% for Peru, and 4.03% and 5.8% for Andhra Pradesh and Ethiopia respectively.

7.4.2. Measurement Variables: Cognitive Outcomes

One of the main strengths of the Young Lives dataset relates to the wealth of data collected on children's cognitive abilities in various domains at different developmental stages, instead of the indicators that are commonly employed in similar analyses for developing countries (i.e. enrolment, grade attainment, *etc*.).

179 For each country, the sample is described in detail in the Young Lives sampling reports (Escobal and Flores 2008, Kumra 2008, Nguyen 2008, and Outes-Leon and Sanchez 2008).

180 Only in Peru the sample is representative (Escobal and Flores 2008).

These tests were designed by experts in various disciplines such as child psychology, education, economics and sociology, and adapted to closely relate to the formal school curricula in the four countries[181]. For this reason, test scores are not directly comparable across countries, but only within countries and controlling for the language in which the test was administered. However, given that tests were designed to capture the same underlying construct in each country, comparisons of associations between the abilities measured by the tests and other variables can still be established, as in our analysis (Cueto *et al.* 2009).

In order to assess children's verbal and quantitative ability at preschool age (Round 2), we employ scores in the Peabody Picture Vocabulary Test (PPVT) and the Cognitive Developmental Assessment (CDA) test. The former is a widely used test of age-specific vocabulary acquisition. For each question, the child has to indicate which picture matches a word presented orally by the interviewer. In turn, the CDA measures children's grasp about quantity-related concepts by asking the index child to choose among a series of images that best represent the concept expressed by the examiner (e.g. few, most, nothing, etc.).

Children's cognitive abilities at Round 3 are in turn measured through three tests: PPVT, Early Grade Reading Assessment (EGRA) and Mathematics Achievement Test. In particular, the purpose of the EGRA is to assess the basic skills for literacy acquisition in early grades, including pre-reading skills such as listening comprehension. The instrument comprises three components: familiar word reading, passage reading and comprehension and listening comprehension. Finally, the Mathematics Achievement test aimed at testing basic numeracy of the children. It consisted of twenty simple arithmetical problems (i.e. 2+3=__, or 7x8=__).

7.4.3. Descriptive Statistics

For convenience, table 7.1 below presents the indicators selected for the measurement of multidimensional early childhood poverty, their rationale for inclusion and the relative deprivation threshold for which the child is considered deprived in that

[181] For an extensive discussion of the validity and reliability of these tests, see Cueto et al. (2009).

specific indicator, which is the basis for constructing the composite index using the AF methodology.

Table 7.1. Indicators of early childhood multidimensional poverty

Indicator	Rationale for inclusion	Deprivation threshold
Stunting (height for age z-scores)	Indicator of chronic malnutrition	Children who are more than two standard deviations below the international WHO reference standard (WHO 2006)
Wasting (weight for height z-scores)	Indicator of current malnutrition	Children who are more than two standard deviations below the international WHO reference standard (WHO 2006)
Life threatening illness	Indicator of morbidity that put child's life at risk	If the child has had any of the following illnesses or injuries for which the carer thought he/she might die: high fever/malaria; pneumonia/sever cough; fits/ epilepsy/convulsions; diarrhoea; burns; traffic injuries; nearly drowned; suffocation/asphyxia
Sickness in the past 24 hours	Indicator of acute morbidity	If the child has had one of the following sickness in the past 24 hours: acute diarrhoea; acute respiratory infection (very fast or difficult breathing); blood in the stools; high fever; vomit; convulsions; unconsciousness; extreme lethargy.

Table 7.1 in the Appendix provides the raw headcounts by indicator (i.e. the percentage of children who are deprived in each indicator constituting EMPI), the multidimensional index EMPI for multidimensional child poverty and the percentages of children that are only deprived in only one, two, three, or all indicators (H1-H4) for the pooled sample and each single country.

With respect to the raw headcounts, the analysis of data from Peru on the incidence of reported morbidity by the children's caregivers are particularly striking: as soon as the informational basis is enlarged from nutrition to other dimensions of health, Peruvian children show the highest rates of morbidity across the four study countries. At this descriptive level, it is unclear whether these striking percentages could be attributed to actual morbidity rates or to perceptions of illness, which can be ultimately caused by the other factors discussed in Section 7.3.1.1. As such, the interpretation of cross-country comparisons of this information is really difficult and requires extreme caution (Murray et al. 1992; Ruggeri Laderchi 2008).

Looking at the whole sample, the average EMPI score is of 27%, which means that children are on average deprived in more than one indicator. As expected, Ethiopia appears as the country with the highest percentages of multidimensional poor children, who are on average deprived of one third of the weighted indicators, followed by Peru and India with exactly the same adjusted headcount ratio of 28% (although the India score presents more variation), and then by Vietnam, on which the average child is not deprived in any indicator. By unpacking the index and focusing on the single headcount, it is possible to observe that the equal score of Peru and India is indeed driven by different dimensions: with respect to Peru, as already mentioned, deprivations in health drive the variance of the EMPI, and in particular the indicator related to recent sickness. On the other hand, given the high malnutrition levels of the country (Deaton & Drèze 2009), the nutrition indicators are the ones that most influence the performance of EMPI in India in terms of EMPI.

The correlations across the indicators presented in Appendix C.2 show that the indicators are not strongly correlated with each other, which points to the usefulness of adopting a multidimensional approach for the analysis of early childhood poverty.

Finally, based on multidimensional poverty status, we examine whether children perform differently in cognitive tests. We use a simple t-test for checking whether the means of outcomes variables for the sample of children that are not poor, the ones that are deprived in only one dimension (i.e. with an EMPI==0.25 or a multidimensional headcount ratio equal to 1) and the ones that are multidimensional poor (EMPI>= 0.26) are significantly different from each other. Table 7.3 in the Appendix shows that on average, children that are poor in only one dimension are performing worst than their non-deprived counterparts, although the different is not always statistical significant. Conversely, the difference in mean cognitive outcomes across non-poor children and children that are multidimensional poor is larger than the one between children deprived in only one dimension and is always statistically significant across outcomes, developmental stages and countries. On a purely descriptive basis, it seems that multidimensional poverty exerts a large toll on children's cognitive development.

7.5. Results

In order to empirically assess the relationship between early deprivation and later cognitive attainments we use equations (ii) and (iii) presented in section 7.3.2, which we report here for convenience:

$$S^{k}_{ij,t} = \beta P^{m}_{ij,t\text{-}1} + X_{ij,t}\Upsilon + \alpha_{j} + \mu_{ij,t} \qquad \text{(ii)}$$

$$S^{k}_{ij,t} = \beta P^{m}_{ij,t-1} + X_{ij,t}\Upsilon + \alpha_{j} + \delta\,(P^{m}_{ij,t-1} * P^{n}_{ij,t-1}) + \zeta_{ij,t} \qquad \text{(iii)}$$

Note that the five cognitive outcome variables are raw test scores standardized with mean 0 and standard deviation 1. In order to wipe out community heterogeneity, we used OLS regression with community fixed effects. Because Young Lives data are highly clustered, we use clustered standard errors as suggested in Deaton (1997). Additionally, we control for the following set of child, caregiver, and household characteristics: (a) child's gender; age (in months); whether child's mother tongue is the official one of the country; whether he/she belongs to ethnic minorities (or backwards castes in India); disability status; first-born; antenatal care (i.e. born in a health facility, and birth attended by a doctor, nurse or midwife); vaccinations; whether she attended crèche and preschool; body mass index (z-scores) in the round in which the cognitive outcomes are measured; (b) caregiver's sex, age, education; mother or father or both present in the household; (c) household's location; size; sex, age and education of the head of the household; access to services; and housing quality. The latter are two composite indicators that respectively average the number of rooms per person, floor type, roof and wall type, and the household's access to safe drinking water, electricity, toilet facilities and cooking fuel, all of which are dummy variables. For round 3 only, we also included child' current grade in school; time to reach the school; time devoted to study and work, and whether the child is attending a private or government school[182]. Finally, in the case of PPVT test scores, the model was only estimated for those children that took the test in the main language/s of the

[182] Only in the cases of Peru and India, as in Vietnam all the sample children were attending governmental schools and in Ethiopia the question on the type of school is not available.

country[183]. The full list of controls is included in Appendix C.4.

7.5.1. Results I: Does the adoption of a multidimensional approach to early childhood poverty add any value to a model of children's cognitive development?

We start by addressing our first research question, i.e. whether the adoption of a multidimensional approach to the analysis of early childhood deprivations adds any value to the analysis of children's cognitive development over time and across a range of cognitive outcomes and distinct countries. This means that we are empirically testing the hypothesis of whether the enlargement of the informational basis from stunting to other indicators of health and nutrition contributes to a better comprehension of the poverty-cognition nexus in a developing countries setting. We use the model's predictive power (as measured by the adjusted R-square) to assess the baseline model, in which height-for-age z-scores are included as unique variable of interest, *viz*. the multidimensional specifications, which contains either the four indicators taken separately, or their aggregation into the composite index EMPI. By testing the predictive power of these two types of multidimensional specifications, we are implicitly asking which aggregation strategy, in this econometric setup, is best equipped to explain variation in medium-term cognitive scores. Columns 1-4 in Appendix C.5 report the results of the baseline model with only stunting and the ones obtained by gradually including the indicators constituting the EMPI, while column 5 provides the results of the model in which only the multidimensional index is included. Note that the two health indicators and the composite index, which change from 0 to 1, have been standardised with mean 0 and standard deviation 1 in order to avoid that the related coefficients merely provide the effect of an abrupt jump from not being deprived at all to being deprived either in the indicator or in all the four of EMPI. Also, this enhances the comparability with the two nutrition indicators, which are measured through z-scores. Consequently,

[183] Specifically, in Ethiopia the main languages are Amarigna, Tigrigna and Afarigna, while for Vietnam, Peru and Andhra Pradesh Vietnamese, Spanish and Telugu respectively.

as both the outcomes and the five independent variables are standardised, the associated coefficients can be interpreted as the share of the standard deviation of the cognitive scores that is explained by the independent variables themselves[184].

Coherently with a large body of previous literature (Glewwe & Miguel 2008), we find that the effect of the height-for-age indicator, which summarises child's history of nutrition, is, in most cases, strongly and significantly associated with later cognitive attainments in both rounds (col. 1). Comparatively, the stronger effects due to stunting are found in India especially for Round 2 outcomes, in which an increase in one standard deviation in height-for-age z-scores can explain respectively 8.3% and 10.2% of the standard deviations in PPVT and CDA achievements. Conversely, in Peru, the association between early nutrition and later achievements is stronger for Round 3 outcomes, where an increase in the height-for-age indicator consistently explains around 6% of the variation in Maths, PPVT and EGRA. Finally, in Vietnam and Ethiopia the magnitudes of the coefficients are not as strong as in the former countries: while in Vietnam this finding echoes previous literature on the fairly weak relationship between early nutrition and cognitive outcomes (Le Thuc 2009), in Ethiopia early stunting can only explain around 4% of round 2 outcomes, and even less in the case of Maths and PPVT test scores (2% and 3.2% respectively). Our evidence for Ethiopia shows that other axes of inequalities, linked to carer's education levels, household wealth, rurality, and having attended a preschool since the age of three are more powerful covariates in the nutrition-cognition nexus.

Starting from this baseline specification, we start to gradually include the other indicators selected as metrics of early childhood poverty and to analyse the changes in predictive power of the model after the adoption of such a multidimensional approach. Columns 2-4 present the results stemming from the "suite of indicators approach". In terms of proportion of variation explained, the inclusion of additional indicators related to child early health and nutrition is able to increase the predictive power of the model as compared to the baseline specification. Although the increase in model fit is consistent across all countries

[184] A similar strategy has been adopted by Sanchez (2009) and Dercon & Sanchez (2011).

and outcomes, the improvement in adjusted R-square is not huge. This may be due to the fact that the two health indicators are dummy variables (although standardised) and hence do not carry the same amount of variation than the nutrition ones, which can exploit the whole distribution of standardised scores across the sample.

Although great heterogeneity exists in relation to which type of initial deprivation matters for cognitive achievement, in which country, and in which stage of children's development, the full "suite of indicators" specification is valuable as it shows that, beyond stunting, other indicators of health and nutrition are strongly and significantly associated to children's medium-term cognitive outcomes. For instance, the inclusion of both indicators of children's history and current nutritional status proves to be useful in capturing the complexity of early nutrition and its potential effects on cognitive development. The wasting and stunting indicators seem to play a positive role in the vocabulary development of the child at preschool age in Ethiopia and India, while in Peru and Vietnam it is only the wasting indicator that is significantly associated to PPVT scores in Round 2 and EGRA in Round 3 respectively. In India, a country in which the nutritional status of the population is among the worst in the world (Deaton & Drèze 2009), the coefficients associated to the weight-for-age z-scores are significant for both Round 2 outcomes and Maths scores, and in those cases, are also particularly strong: an increase in one standard deviation of weight-for-height z-scores leads to an increase of 3.4% in Maths, 6% in PPVT and 8.4% in CDA scores. The same applies to the case of Peru, in which the wasting indicator is strongly and significantly associated to medium-term cognitive outcomes, except for CDA scores. Strikingly, in Vietnam the same indicator is negatively associated to the PPVT scores, a finding that necessitates more in-depth analysis.

The fact that in many cases the weight-for-height z-scores shows a strong and significant association with cognitive achievements in both preschool and school age suggests that both forms of malnutrition, which are rooted in distinct causes (Frongillo *et al.* 1997), work in concert to hinder children's cognitive development. As such, the inclusion of weight-for-height z-scores in a model of cognitive development enriches the model without additional informative costs, as usually the two anthropometric indicators are collected jointly.

In the case of Ethiopia and India, it does not seem that the two indicators of infections are statistically associated to later outcomes, while this relationship is fairly strong and significant in the cases of Vietnam and Peru. In the former country, the occurrence of a life-threatening morbidity in the early years can explain 4.2% of variation in Round 2 PPVT and CDA scores (compared to the 4.8% and 3.1% of height-for-age scores), but it disappears once children transition into school. On the other hand, in Peru both the indicators of life-threatening morbidity and recent sickness are negatively and significantly associated to Round 3 outcomes (except in PPVT scores for recent sickness), although with heterogeneous magnitudes. In particular, the coefficient associated to the presence of life threatening morbidity in the early years is relatively important compared to the marginal contribution of other covariates of cognitive achievement. In sum, this relevant information would have been lost if a unidimensional approach to the measurement of early childhood poverty (and health) would have been adopted.

Column 5 then presents the results of the specification in which the multidimensionality of early childhood poverty is captured through the composite index EMPI. For convenience, Table 7.2 below provides a summary of the OLS standardised coefficients obtained from including EMPI as unique variable of interest in the model and shows that the coefficients associated to EMPI are negative, strongly and significantly associated to children's medium-term cognitive outcomes across the whole sample and developmental stages. As explained already, given that both the outcome variables and EMPI are standardised, the associated coefficient for the latter can be interpreted as the share of the standard deviation of the outcomes that can be explained by EMPI. This means, for instance, that an increase of one standard deviation in EMPI leads to a decrease in the standardised maths score in the range of around 4% in Ethiopia and Vietnam, 6% in Peru and 8.2% in Andhra Pradesh. In particular, in India the relationship between EMPI and later outcomes is particularly strong for all the outcomes considered, as well as persistent across rounds. It is also interesting to note that, in the case of PPVT Round 3 scores, the specification with EMPI is the only one that is able to show a strong and significant association between early deprivation indicators and later cognitive outcomes, probably capturing an interaction effect across the four indicators. In the case of Ethiopia, EMPI is significantly associated to PPVT scores in both rounds and Mathematics. The comparison of Vietnam and Peru also provides interesting insights: on the one hand, in Vietnam the association between EMPI and later achievements is particularly strong and significant for Round 2 outcomes, and to a lesser extent to Maths scores in Round 3, while in Peru it is the opposite, as EMPI seems to work as a good predictor of Round 3 cognitive scores in particular. This contrast could be explained by the analysis of the different features of the school systems in the two countries, and to the extent that the overall education quality is successful in mitigating early childhood inequalities[185] (Woodhead *et al.* 2013; Krutikova *et al.* 2013).

Table 7.2. OLS marginal effects of EMPI z-scores on cognitive outcomes at preschool (Round 2) and school age (Round 3)

	ROUND 2		ROUND 3		
	PPVT	**CDA**	**MATHS**	**PPVT**	**EGRA**
ETHIOPIA	-0.054* (-2.05)	-0.023 (-1.02)	-0.038* (-2.02)	-0.054** (-2.19)	-0.026 (-1.27)
INDIA	-0.076*** (-3.28)	-0.103*** (-4.14)	-0.082*** (-4.04)	-0.056*** (-2.7)	-0.06*** (-2.61)
PERU	-0.022 (-1.01)	-0.043* (-1.75)	-0.064*** (-17.31)	-0.047*** (-11.11)	-0.056*** (-10.273)
VIETNAM	-0.054** (-2.49)	-0.053** (-2.29)	-0.04* (-1.772)	-0.027 (-1.1)	-0.043 (-1.41)

Despite the wide strong and significant association of EMPI with later outcomes,

[185] For instance, by focusing on minimum quality standards through specific government programs (World Bank 2004), the Vietnamese educational system is able to some extent to mitigate disadvantage in initial conditions (Krutikova *et al.* 2013).

the "composite index" specification does not seem to be more powerful than the "suite of indicators" approach in predicting children's cognitive outcomes over time in terms of Adjusted R-square. Additionally, beyond its success in explaining a larger share of variation in cognitive achievements than the composite indicator, the "suite of indicators" approach is also valuable as it provides detailed information on which dimensions of early deprivations are persistently associated to medium-term cognitive achievements, and in which contexts and different stages of childhood such association exists.

Finally, it is interesting to note that the predictive power of both models increases as children transition into school. Across all countries, the proportion of the variance in cognitive achievements explained by the model more than doubles when it is applied to Round 3 outcomes (particularly in Mathematics), compared to its explanatory power for pre-school achievements. The case of Peru is particularly striking, as our model can explain 40% and almost half of the variance for Maths and PPVT respectively. The fact that the predictive power of the model increases over time not only shows that early childhood deprivation has persistent effects over children's lifecourse, but that this association is also amplified as children begin their educational path. As already suggested by other commentators (Pollitt 2005; Woodhead *et al.* 2012; Banerjee & Duflo 2011), it may be the case that initial disadvantage is compounded by additional socioeconomic and educational inequalities leading to persistently lower cognitive outcomes. Following this line of reasoning, it is not surprising that in Peru, in which the educational system is highly unequal (Duarte *et al.* 2009), children background characteristics are so powerful in explaining variation in their cognitive attainments.

7.5.2. Results II: Are there dynamic complementarities across deprivations?

This section tests the hypothesis of whether dynamic complementarities across deprivations exist, i.e. whether being jointly deprived in different dimensions of poverty in the early years is associated to worse cognitive outcomes at preschool and school ages. In other words, we are testing the hypothesis of whether the simultaneous presence of two or more deprivations hinders children's cognitive development through their self-reinforcing interactions. Being constructed through the AF methodology, EMPI is not able to capture any multiplicative effect as it merely provides a linear combination of indicators and weights. As mentioned before, we could not explore other types of aggregations that can capture complementarities, such as in Tsui (2002) or Bourguignon & Chakravarty (2003)(Chapter 2), because the two indicators of infection are dichotomic. For this reason, in order to test the hypothesis of dynamic non-additivity, we use model (iii), in which the interaction terms across the four indicators of early childhood poverty are included. In this case, all the indicators have been censored at their deprivation threshold, so that they are all 0-1 variables. This means that the indicator takes the value of 1 when the child is deprived, and 0 otherwise. Consequently, an interaction is equal to 1 when the child is simultaneously deprived in two or three indicators. In our empirical specification we do not include the interaction term across four indicators as basically no child was simultaneously deprived in all of them. Note that, as before, we standardised all the indicators in order to have mean 0 and standard deviation 1, in order to ease interpretation. Again, the coefficients associated to the indicators and the interaction terms can be interpreted as the share of the standard deviation of the outcomes that can be explained by the indicators or the interactions themselves.

Appendix C.7 provides the results for the model with the interactions. For each country, we only include the interaction terms for which there was for which there was enough variation. As a rule of thumb, we used the interactions for which at least 5% of the children were deprived, as reported by the descriptive statistics of the interaction terms in Appendix C.6. Despite the fact that all the indicators included in this model are dummy variables (and hence exploiting less the information conveyed by the nutrition variables in their continuous form), the share of variation explained by this specification and measured through the adjusted R-squares is basically the same or in some cases higher than the ones presented in the "suite of indicators" approach in Appendix C.5. This suggests that the non-linear specification is somehow picking up some multiplicative effects in the process of children's cognitive development.

Evidence in this direction is also given by the statistical significance and relatively strong magnitude of some interaction terms. Although great heterogeneity inevitably exists across the countries, this finding suggests that, once the assumption of a linear relationship between early multidimensional poverty and later attainments is relaxed, there are dynamic multiplicative effects stemming from being jointly deprived in multiple dimensions. In Ethiopia, the simultaneous deprivation in the stunting and the two health indicators for 9% of the sample (roughly 155 children) is associated to a decrease of 8% and 14% of standard deviations in children's Maths and EGRA scores, while being simultaneously stunted and wasted leads to a fall of about 6% in PPVT achievements in Round 3. In India, the interactions that are strongly and significantly associated to children's medium-term cognitive development are the ones between wasting and having experienced a recent sickness (-6.5% s.d. in CDA scores) and being simultaneous deprived in both nutritional indicators (-6.3% and -7.3% standard deviations for PPVT and EGRA in Round 3). It is also interesting to note that in the previous model presented in Appendix C5 no indicator of early deprivation, except EMPI, was associated to children's PPVT scores in Round 3. This suggests that in this case it is the joint distribution of deprivations, whether picked up by the interaction term itself or by the composite index, which is associated to lower scores in vocabulary development. Probably, the interaction across deprivations in both nutritional indicators is picking the "poorest of the poor" children. While in Vietnam, where already the nutrition-cognition link was weaker than in the other countries, no interactions are associated to later cognitive outcomes, in Peru this specification provides rather interesting results. As for the model presented in the previous section, the association of the early childhood poverty indicators and the interaction terms is particularly evident for outcomes in Round 3, when all the children in the sample are already in school. As suggested previously, in Peru the impact of early poverty seems to be magnified by other types of inequalities related to gender, location, ethnicity, and educational paths, which seem to become particularly marked as children grow older. Being a boy, whose mother tongue is Spanish and that lives in urban areas is strongly and positively associated to better cognitive outcomes, while going to a government school and being in a grade that is not age-appropriate is negatively linked to test scores at Round 3. Then, the analysis of the interaction terms that are statistically significant in Peru show that being sick and wasted at the same time can explain -3.4%, -4.9% and -4.5% in Round 3 Maths, PPVT and EGRA scores respectively. Also being jointly stunted and deprived in both health indicators significantly explains a share of -8.3% of standard deviation in the Maths scores.

Remarkably, the coefficients associated to the interactions between being stunted and having experienced a life-threatening morbidity, as well as the ones between being sick and the life-threatening morbidity are both positive and significant. Probably, this result is due to the indicator related to the occurrence of life-threatening morbidity, which, in Peru, has the highest incidence in the whole sample of countries. Given that this indicator is reported by the child's caregiver, a plausible explanation for the high frequency of reported morbidity may be attributed to the phenomenon of adaptive preferences: it may be the case in which the relatively higher levels of education, availability of health facilities, and public information on illness and remedy in Peru than the other study countries, particularly than Ethiopia and Andhra Pradesh, may induce caregivers to report levels of sickness that reflect internalised expectations on health and treatment[186], as suggested Murray et al. (1992) and Sen (2002). Another plausible explanation relates to the ambiguous impact of lagged children's health status on parental education inputs (Glewwe 2005). The positive values associated to those interactions associated may suggest that the parents are trying to compensate children for the negative impacts of early poor health (especially if they felt that the morbidity was leading to the child's death) by increasing their educational and care inputs. Finally, another possible interpretation relates to the reliability and validity of the indicator itself, and to what it is actually measuring in the context of Peru. Unfortunately, the literature on subjective indicators of health in

[186]Simple cross-tabulations of reported percentages of life-threatening illnesses with wealth and carer's education levels seem to rule out this hypothesis, as the rates of reported morbidity seem to be evenly spread across distinct wealth quintiles and education levels. Other factors are probably affecting the indicator more than income and education (i.e. availability and opportunity cost of health remedies and treatment).

Peru or in general in Latin America is rather underdeveloped, and we could not explore this possibility further by looking at other studies. All these considerations also apply to the positive coefficient associated to the interaction between the wasting and recent sickness indicators in the case of Ethiopia for EGRA scores.

7.6. Robustness checks

Appendixes C.8 and C.9 provide the results for the models presented in equations (ii) and (iii) for the Round 3 outcomes by adding both lagged test scores of PPVT and CDA at age 5, in order to control for heterogeneity in preschool ability that may explain variation in school learning outcomes across children. In this way, we are presenting a sort of hybrid "value added specification"[187] (Todd & Wolpin 2003) in our model of children's cognitive development, which, by controlling for one of the main channels via the prediction of school-age cognitive scores occurs, can ensure that all the predictions related to age 8 outcomes come solely from early childhood poverty. Additionally, Appendixes C.8 and C.9 also include a selected list of covariates related to other drivers of inequalities in children's cognitive achievements, so that we are able to understand which other factors, beyond initial deprivations in nutrition and health, are associated to children's cognitive development.

In order to ease the comparison across the different specifications and countries, Table 7.3 provides a summary overview of the changes in coefficients from the multidimensional baseline specifications (cols. 4 and 5 of Appendix C.5) to the new model in which lagged cognitive scores are included (cols. 1 and 2 of Appendix C.8). Children's performance in the CDA and PPVT tests at age 5 is strongly and positively associated with performance on Maths, PPVT and EGRA tests three years later[188]. Although unsurprising, this is of particular interest as it is consistent with the lagged test scores being a valid control for cognitive skills

[187] It is "hybrid" in the sense that, in the case of Maths scores and EGRA, the preschool outcomes are not the same as the one measured at age 8.

[188] The only exception is the absence of statistical significance of both the scores of cognitive abilities in Round 2 in the case of EGRA in Ethiopia.

at five, which is a key feature of the empirical strategy adopted to test the robustness of our results.

The inclusion of the lagged cognitive scores increases the overall fit of the model, although not dramatically for most outcomes, and tends to decrease the coefficients associated to the indicators of early childhood poverty, though not in all the cases. As a general trend across all countries and outcomes, the inclusion of lagged test scores does not hinder the statistical significance of the coefficients for our key measurement variables, which suggests that the association between early childhood poverty and later cognitive attainments is robust.

Table 7.3. Comparison between baseline and hybrid value added model. Only statistical significant coefficients are reported.

Ethiopia						
	Maths		**PPVT**		**EGRA**	
	Baseline	Robustness	Baseline	Robustness	Baseline	Robustness
Height-for_age	0.019*	0.016*	0.033**	0.028**	/	/
Weight-for-age	/	/	/	/	/	/
Life-threatening morbidity	/	/	/	/	/	/
Recent sickness	/	/	/	-0.035*	/	/
Adjusted R-square	0.299	0.301	0.197	0.23	0.134	0.132
EMPI	-0.038*	/	-0.054**	- 0.047*	/	/
Adjusted R-square	0.299	0.302	0.195	0.0228	0.135	0.134

India						
	Maths		**PPVT**		**EGRA**	
	Baseline	Robustness	Baseline	Robustness	Baseline	Robustness
Height-for_age	0.059***	0.048***	/	/	0.038**	/
Weight-for-age	0.034*	/	/	/	/	/
Life-threatening morbidity	/	/	/	/	/	/
Recent sickness	/	/	/	/	/	/
Adjusted R-square	0.299	0.322	0.112	0.136	0.175	0.191
EMPI	-0.0802***	-0.067***	-0.056***	-0.041*	-0.060**	-0.044*
Adjusted R-square	0.298	0.322	0.114	0.138	0.176	0.193

Peru

	Maths		PPVT		EGRA	
	Baseline	Robustness	Baseline	Robustness	Baseline	Robustness
Height-for_age	0.061***	0.063***	0.065***	0.057***	0.060***	0.064***
Weight-for-age	0.031***	0.028***	0.022***	/	0.053***	0.036***
Life-threatening morbidity	- 0.013***	- 0.017***	- 0.015***	-0.020***	-0.020***	-0.023***
Recent sickness	- 0.023***	- 0.025***	/	/	-0.009***	/
Adjusted R-square	0.411	0.417	0.45	0.474	0.291	0.310
EMPI	- 0.064***	-0.067***	0.047***	- 0.043***	-0.056***	-0.54***
Adjusted R-square	0.408	0.414	0.447	0.472	0.287	0.307

Vietnam

	Maths		PPVT		EGRA	
	Baseline	Robustness	Baseline	Robustness	Baseline	Robustness
Height-for_age	0.043***	0.048***	/	/	0.036**	/
Weight-for-age	/	/	/	/	0.057**	0.052*
Life-threatening morbidity	/	/	/	/	/	/
Recent sickness	/	/	/	/	/	/
Adjusted R-square	0.359	0.374	0.126	0.167	0.144	0.162
EMPI	-0.04*	/	/	/	/	/
Adjusted R-square	0.358	0.371	0.126	0.167	0.141	0.160

Similar considerations apply when children's cognitive outcomes at age 5 are included in the specification with the interactions, which tests whether non-linearities in the relationship between early multidimensional poverty and medium-term outcomes exist. Appendix C.10 provides a synoptic table of the comparison in coefficients and predictive power of the model similar to Table 3 above. Again, the inclusion of lagged cognitive scores increases the overall predictive power of the model for all the countries. In Ethiopia, lagged cognitive outcomes slightly increase the magnitude of the coefficients that in the baseline were already significant. With regards to Maths scores, the rather puzzling positive coefficient related to the interaction between wasting and stunting, already highlighted in the case of EGRA scores in the baseline specification, emerges, while the effect of the one between being stunted and having experienced a life-threatening morbidity for PPVT scores disappears. In India, the strong and significant effect of the interaction between wasting and stunting now is also evident in the case of Maths scores, while for Peru the inclusion of the additional controls removes the effect of wasting and of the triple interaction term in the case of PPVT and the one of the interaction between wasting and recent sickness for Maths and EGRA scores. The counterintuitive association between the interactions constructed through the indicator of life-threatening morbidity still remains.

7.6.1. A tale of interlocking inequalities

The estimates of the empirical relation between children's initial deprivation and their medium-term cognitive achievements show that other axes of inequalities are also strongly associated to such outcomes. Appendix C.8 and C.9 present regression results with selected covariates of children's learning outcomes.

While in India and Peru being a boy and first-born has a positive statistical association with medium-term attainments, in Vietnam girls perform better in the reading test, while in Ethiopia there is no evidence of gender bias in learning outcomes. In the latter country, however, unequal learning trajectories even before the child is born: the one-fifth of the sample that is born in medical facilities is consistently performing better than their counterparts in Maths and

PPVT. Later, these initial inequalities are further compounded by not being able to attend preschool, which has .

Rurality is a key factor being associated with lower cognitive outcomes in Peru and Ethiopia, as well as access to services, particularly for Ethiopia in the case of Maths scores, in India for Maths and PPVT, and for all the Round 3 outcomes in Peru[189]. Lower levels of education of the child caregiver are negatively related to children's cognitive development in Peru, Vietnam and India, a finding that is amply documented in the literature (Woodhead et al. 2013). We interpret these three results as evidence that the overall environment in which the child lives has complementary impacts on her cognitive development.

Beyond gender, caste is key dimension of inequality in attainments in Andhra Pradesh, where children from backward castes, scheduled tribes or non-Hindu backgrounds seem to perform less well than their upper-caste counterparts. Rather surprisingly, in Peru ethnic minority is positively associated to Round 3 cognitive outcomes, although it is likely that this result is driven by the very low percentage of children from ethnic minorities in the sample (around 2%). As already stressed, in Peru the model seems to work particularly well in identifying factors that are statistically associated to children's cognitive achievements, which also relate to having a disability and attending a public school. As in the case of Peru, our empirical findings show that attending a private school in Andhra Pradesh is strongly and significantly associated to better Maths scores. This corroborates a widespread finding in the growing literature on the "private school premium" in India (Kremer & Muralidharan 2008). A channel in which poverty seems to work in hindering education achievements is related to not being enrolled or enrolled late into school: across all the countries in our sample, these factors are all negatively affecting achievement (Rolleston & James 2012).

An interesting feature that is common to all the countries and outcomes is the strong and positive coefficient associated to the hours dedicated to school and study. By the same token, the hours dedicated to work in the household or in external economic activities are generally negatively correlated to children's

189 Similar results were found in Outes & Porter (2013), where the access to services in rural Ethiopia is strongly associated to the possibility of catching-up from early stunting.

cognitive outcomes, but in contrast to hours of study, they are not always significantly and in two cases they present an unexpected positive sign. This finding echoes a key result recent research conducted in a context of a developed country, according to which cognitive skills are significantly affected by the way children's time is allocated (Fiorini & Keane 2012). In particular, the effect of time devoted to study and school is particularly large compared to other background characteristics of the child such as parental education or early poverty.

7.7. Conclusions and issues for further research

This Chapter is a preliminary attempt of linking the literature on the measurement of children's poverty and the one on ECD by linking them though the overarching theoretical framework of the CA. In particular, the Chapter addressed the critical question of whether the experience of multiple deprivations is dynamically associated to worse human development attainments over time. In doing so, it aimed at taking a step beyond the measurement of multidimensional poverty by scrutinising its potential effects on children's cognitive development at age 5 and 8. The other goal of the Chapter is to complement the ECD literature in the context of developing countries by enlarging the informational basis from stunting to other indicators of early childhood health and nutrition. By exploiting the wealth of information contained in the Young Lives study, for the first time we included information on to the major drivers of morbidity and mortality in a model of children's cognitive development, across a wide range of cognitive outcomes, different development stages and four distinct country contexts. As such, the Chapter contributes to the ECD literature by explicitly incorporating the multidimensionality of health in a model of cognitive development.

Specifically, we empirically tested two main hypotheses: first, whether a multidimensional approach to the measurement of early childhood poverty is able to capture more variation in children's medium-term cognitive scores than a baseline specification in which only height-for-age scores are included. If this is the case, we also test which is the best empirical way to deal with the multidimensionality of childhood poverty in an econometric model of children's cognitive development, i.e. through a suite of indicators or a composite index. Second, we scrutinise whether non-linearities in the relation between early poverty and medium-term cognitive outcomes exist, through, for instance, the dynamic and multiplicative effects of interlocking dimensions of deprivations experienced in the early years.

Even when controlling for a large number of child, caregiver and household characteristics, as well as children's cognitive scores at age five, the adoption of a multidimensional approach to the measurement of early childhood poverty enriches a standard ECD model by increasing the predictive power of the model itself. The comparison between the two different aggregation strategies also shows that, in terms of adjusted R-square, the "suite of indicators" approach is able to explain more variation in medium-term cognitive outcomes than the alternative specification in which the multidimensional index is included. A possible explanation for this finding could be due to the fact that the indicators composing the index are constructed to be dichotomous, and hence may not exploit fully the variation of their continuous form.

Nonetheless, despite the relative superiority of the suite of indicators approach in terms of explaining a larger share of variation in cognitive achievements, this approach is also valuable as it provides detailed information on which dimensions of early deprivations are persistently associated to medium-term cognitive achievements, and in which contexts and different stages of childhood such association exists. While the height-for-age remains the key indicator to measure early childhood deprivation, given that it summarises multiple dimensions of children's well-being (access to food, health status, health and care environment), we find that the enlargement of the model to the other indicators of health and nutrition is able to provide policy-relevant information that otherwise would have been lost if the stunting indicator had to be adopted as unique metrics for early childhood poverty (and health). This expansion of the informational basis does not necessarily imply additional costs of data collection: for instance, the indicator of wasting, which is usually never included in similar models, was found to explain fair shares of variation in medium-term cognitive scores, suggesting that both the history and the current nutritional status of the child, which are caused by distinct factors, work in concert in determining the nutrition-cognition nexus. As the two anthropometric indicators are usually collected jointly, the inclusion of weight-for-height scores in similar models increases the predictive power of the model with no additional cost of data collection.

The relationship between the indicators of infection and later cognitive scores, on the other hand, is more heterogeneous across countries, cognitive outcomes, and children's development stages. Further research is needed to understand the quality, validity, reliability and cross-comparability of the two indicators, as they are subjectively reported by the children's caregivers. Nonetheless, their inclusion in an ECD model is able, for the first time in this literature in a developing country context, to shed light on the relation between early infection and later cognition. Undoubtedly, this represents a step further in understanding this relationship, especially given that the major drivers of morbidity in the developing countries unlikely affect the height indicator (Glewwe & Miguel 2008), and the extent to which subjective indicators of health have a predictive power on later outcomes[190].

The second research question relates to whether there are dynamic interactions across deprivations. Regarding the predictive power of the model in which the interaction terms are included, the share of variation explained by this specification and measured through the adjusted R-squares is basically the same or in some cases higher than the ones presented in the "suite of indicators" approach in Appendix C.5. This suggests that the non-linear specification is somehow capturing the occurrence of some non-linear processes in children's cognitive development. Evidence in this direction is also given by the statistical significance and relatively strong magnitude of some interaction terms. Although great heterogeneity inevitably exists across the countries, this finding suggests that, once the assumption of a linear relationship between early multidimensional poverty and later attainments is relaxed, there are dynamic multiplicative effects stemming from being jointly deprived in multiple dimensions.

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[190] As of yet, the literature has mostly focus on the predictive power of self-reported health on survival. For a review, see Knauper & Turner (2000).

An interesting feature in all the specifications discussed above is that the predictive power of the model increases in the case of the cognitive outcomes measured as children are already at school. This finding not only shows that early childhood deprivation is persistent over children's lifecourse, but also that its effects are amplified by unequal educational trajectories. As already suggested by other commentators (Pollitt 2005; Woodhead *et al.* 2012; Banerjee & Duflo 2011), initial disadvantage is compounded by additional socioeconomic and educational inequalities leading to persistently lower cognitive outcomes. For instance, it is interesting to note that in Peru the model predicts between one third and half of the variation in achievements when children are aged eight, the highest shares across the four countries. The strong influence of children's initial poverty and background characteristics on their cognitive scores points to the high inequality of the Peruvian educational system, which seems to amplify early childhood deprivations, instead of mitigating them through the provision of quality education.

Beyond school, the empirical estimates show that inequalities in children's cognitive development stem from the interlocking relationship across many other dimensions of disadvantage at the child, caregiver and household levels (i.e. gender, locality, access to services, carer and household head education, antenatal care, time devoted to study and work). This evidence underlines that a truly multidimensional approach to the analysis of childhood poverty and its life-course repercussions is required. Additionally, the evidence reported in this Chapter also shows that the impact of various disadvantages is highly heterogeneous, depending on the different contexts and stages of children's development, which points to the need of avoid mechanistic interpretations of the early poverty-cognition nexus.

The evidence reported in this paper points to additional strands where further research is needed. The first relates to the assessment of the multidimensional ECD model viz. the standard one from a measurement error perspective. In this Chapter, the evaluation of the models relied on their predictive power and to their value added in terms of informational content. Nonetheless, it may be plausible that the multidimensional model with EMPI can be superior to the baseline one because it attenuates the impact of measurement error in computing poverty estimates. The focus on the impact of measurement error on the inference from any empirical poverty measure is an unexplored, yet promising, field of further research in this literature (Calvo & Fernandez 2012). For instance, Chesher & Schluter (2002) showed that unidimensional poverty measures provide upwards bias in the poverty estimates, while Calvo & Fernandez (2012) pointed out that such a bias is attenuated through the use of a multidimensional index based on the dual cutoff methodology, such as the ones in the AF family. An empirical route to evaluate the baseline and the multidimensional model on the basis of measurement error is given by Filmer & Pritchett (2001): by using two different multivariate regression approaches, the two authors assessed the validity and reliability of a wealth index viz. standard poverty measures based on consumption or expenditure data.

A second strand relates to the modeling of the dynamic relationship between children's early multidimensional poverty and their medium-term outcomes through a longitudinal SEM approach. In this way, it could be not only possible to aggregate different dimensions of early deprivation through the SEM methodology and at the same time to deal with measurement error, but also to test the pathways through which poverty in the early years is associated to later cognition.

Finally, a more general research question is linked to how the distinct axes of inequalities related to gender, location, educational paths, household's wealth, ethnicity etc. interact and reinforce the effect of early disadvantage.

Conclusions

Following the seminal work by Nobel Graduate Amartya Sen (1976, 1981, 1985, 1987, 1992, 1993, 1999; Drèze & Sen 1989) in the domain of the CA, the multidimensionality of poverty and food insecurity as critical deprivations of human well-being is now widely acknowledged by academics and policy-makers alike[191]. While the explicit acknowledgement of the "*constitutive plurality of welfare assessments"* (Sen 1993) represents a relevant theoretical advancement from previous unidimensional frameworks, at the same time the multidimensionality of human well-being and of its deprivations entails additional theoretical and methodological difficulties. The latter are particularly relevant when measuring these phenomena: if, as in the CA framework, well-being is conceptualised as an "index of a person's achieved functionings" (Sen 1993), *how should multidimensionality be dealt with?* In this respect, the CA is certainly more demanding in terms of information required if compared with traditional resource-based approaches (Chiappero-Martinetti 2000).

By acknowledging the additional set of difficulties that the adoption of the CA entails, a very basic question originated the investigation of the present PhD thesis: *Is there any advantage of adopting the CA as overarching theoretical framework for measuring poverty and food insecurity?*

In order to tackle this issue, we proceeded in the following way: while the first two chapters of the dissertation provide the overall theoretical framework for the analysis and make an argument towards the choice of the CA as overarching theoretical framework, Section B and C focus respectively on the conceptualisation and measurement of food insecurity and childhood poverty.

[191] For instance, the OECD (2001) stressed that: *'Poverty encompasses different dimensions of deprivation that relate to human capabilities including consumption and food security, health, education, rights, voice, security, dignity and decent work' (OECD 2001),* whereas the World Food Summit definition of food security - *'A situation when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life'* (WFS 1996) – emphasized the four underlying pillars of availability, access, utilisation, and stability.

Normatively, we justified the adoption of the CA given its explicit recognition of the inherent complexity of human well-being, which is not seen as an "*embarassement to hide*" (Sen 1993). This is a methodological advantage of the approach itself, because it renders explicit the inherent value judgments and ethical implications that any evaluative exercise – whether in unidimensional and multidimensional spaces - entails, from the choices of dimensions and indicators, to the one of weights and aggregation methods. Starting from this premise, the contribute of this dissertation to the CA literature is, at the same time, theoretical, methodological and empirical.

Regarding the former, the main theoretical contribution of the thesis lies in expanding the literatures on food security and childhood poverty by providing two original conceptual frameworks grounded in the CA for the analysis of both phenomena (Ch. 4 and 6). With the latter in particular, we attempted to bridge the gap between two strands of research that, as of yet, have never been combined: the one that aims at measuring childhood poverty in a given point in time (Gordon *et al.* 2003; Roche 2010; Biggeri & Mehrotra 2011; Alkire & Roche 2012; Minujin & Delamonica 2012), and the Early Child Development (ECD) literature, which models the effects of early years nutrition (measured by height for age) on later outcomes (Glewwe & Jacoby 1995; Glewwe *et al.* 2001; Alderman *et al.* 2001, 2006, 2009; Maluccio *et al.* 2006; Grantham-McGregor *et al.* 2007; Glewwe & Miguel 2008; Alderman 2010; Almond & Currie 2010; Sanchez 2009: Dercon & Sanchez 2011). In doing so, the thesis originally addressed one issue emphasised by Thorbecke (2008):

> *"Most of the remaining unresolved issues in poverty analysis are related directly or indirectly to the multidimensional nature and dynamics of poverty (...) We need to identify and understand better the various dimensions of poverty and how the latter interact over time and across space" (p. 3),*

In doing so, the thesis not only expands the flourishing literature on the empical operationalization of the CA (see Kakwani & Silber 2008, for a review), but also combines the *measurement* of multidimensional food insecurity or childhood poverty with the *modelling* of their causes and consequences. This is a strength of the PhD dissertation because, as of yet, only few contributions in the CA domain have addressed this issue (Kuklys 2005; Di Tommaso 2007; Khrishnakumar 2007;Khrishnakumar and Ballon), and, to the best of our knowledge, none has attempted so far to model the *dynamic implications of multidimensional poverty*.

This in turn leads us to the methodological value added of the present work, which is substantiated in many different ways. The key message that emerges from the different contributions contained in present investigation is that *the adoption of the CA indeed entails substantial methodological implications in the two key steps of any measurement exercise: identification and aggregation.*

With respect to the former, the thesis emphasises that the CA, with its focus on the "*ends of development*" (Sen 1999), entails a powerful criterion to choose among indicators. This is particularly relevant in the domain of the food security literature, in which the recent proliferation of laundry-list of indicators to capture the multidimensionality of the concept contributed to a high degree of confusion, if not misleading messages, regarding the magnitude and trend of the phenomenon (CFS 2011). In this respect, Chapter 4 proposes an original methodological framework grounded in previous CA food security works (Dreze & Sen 1989; Burchi & De Muro 2012b) to analyse and select food security, which will be then operationalized for measuring countries food security in Chapter 5. Despite its relevancy in the food security literature, the methodology we propose can be also used to the identificantion of development indicators in general. For instance, we adopted the same methodological framework to select indicators of children's health and education in Chapter 6.

On the other hand, the contribution of the thesis addresses two methodological issues related to aggregation. First, it aimed to tackle the three main flaws that Burchi & De Muro (2012a) identified as the key shortcomings of most multidimensional indicators of well-being: (i) lack of a sound theoretical foundation; (ii) aggregation on merely empirical bases, reflecting data availability and "conventional wisdom"; (iii) failure to distinguish between "means" and "ends" of human development. Additionally, the thesis emphasises that the choice of the CA entails a powerful criterion to choose among indicators. We showed that, by grounding the measurement exercise in the sound theoretical foundations of the CA, it is possible to overcome these issues.

Then, this work tried to answer the question of whether standard econometric techniques such as Structural Equation Model (SEM) can provide additional insights in the empirical implementation of Sen's CA. Chapter 5 in particular shows that the use of SEM combined with the theoretical framework we provided for the analysis of food security is particularly useful to measure the latent "*capability to be food secure*". The SEM methodology is also particularly relevant to address two critical issues in the aggregation of multiple dimensions of well-being (Kuklys 2005): (ii) measurement error; and (iii) lack of a natural aggregator function to synthetize different indicators into a summary measure.

As an additional methodological contribution, Chapter 2 systematises the large body of empirical literature concerned with aggregation methods for multidimensional phenomena, which has been expanding tumultuously in the last years (e.g. Lovell *et al.* 1994; Chakravarty *et al. 1998;* Klasen 2000; Tsui 2002; Bourguignon & Chakravarty 2003; Duclos *et al.* 2005; Lugo & Maasoumi 2008; Betti *et al.* 2008; Alkire & Santos 2010; Alkire & Foster 2011; Rippin 2011; Weismann 2006; Gentilini & Webb 2008; Maplecroft 2011; Troubat 2011; EIU 2012). Although some surveys of the literature already exist[192] (Kuklys 2005b; Deutsche & Silber 2005; Bibi 2005), Chapter 2 fills a gap in this literature by reviewing the entirety of the approaches proposed (i.e. axiomatic and not) and taking into account of the most recent methodological developments. In this way, the Chapter contributes to the literature on multidimensional measures by taking stock of the variety of methodologies proposed, outlining their strengths and weaknesses, and systematising these contributions in a coherent way in order to providing an accessible, yet rigorous, entry point for all those scholars or practitioners interested in the topic.

Finally, as anticipated, our empirical evidence in Chapter 5 and 6 supports Sen's idea of an actual advantage of expanding the focus of analysis from unidimensional to capability-based informational bases in order to better capture the phenomena under scrutiny. Both Chapters show that the concept of development is comprised of many dimensions, and these interact in determining human development outcomes.

[192] For an extensive review of each methodology see Kakwani & Silber (2008).

In particular, with respect to the measurement of food security, we operationalized the theoretical framework proposed in Chapter 4 through Structural Equation Modelling techniques in order to develop a multidimensional index of countries' *capability to be food secure.* By including information on different aspects of food insecurity, we showed that the multidimensional score is able to provide a comprehensive picture of countries' food insecurity, and, at the same time, to discriminate across countries that, according to a single metrics such as FAO Prevalence of Undernourishment, would have similar food security performances. Lastly, the SEM framework also allowed for the inclusion of institutional, social, and economic covariates in the model and to identify the main covariates of food security at the country level. Besides the lagged rate of countries' growth, many of these factors relate to fundamental dimensions of human development (i.e. health, women's education, and poverty), suggesting that a two-prong strategy combining pro-poor growth and public interventions in key human development dimensions is needed to actively promote countries' s food security. Moreover, evidence on the positive role of publicly-provided goods such as education and health services, which are vital to convert food available in actual nutritional outcomes, can also explain puzzling cross-country variations in food security performances (Klasen 2008). Another interesting result we found relates to the role of prices, as, on average, higher food prices seem to lead to higher food security. This result, which counters the recent messages by FAO and NGOs on the harm that high food prices may cause to the poor (FAO 2008; OXFAM 2011), shows that at the cross-country level prices have mixed effects on food security, and that further research is certainly needed.

Regarding our empirical analysis on childhood poverty, after having outlined our original theoretical framework, we used the Young Lives dataset, a highly innovative and longitudinal study of childhood poverty, to first develop a multidimensional measure of early childhood poverty in the health and nutrition dimensions, and then to understand the association between that initial deprivation (experienced at around 6-18 months) on a variety of children's later cognitive attainments at the preschool and school ages (5 and 8 years respectively). We found that childhood poverty experienced in the early years is strongly and significantly associated with later inequalities in children's cognitive attainments across all the four countries included in the Young Lives dataset (Ethiopia, Peru, Vietnam, and India, Andhra Pradesh). This finding holds even after controlling for a wide range of children's background characteristics, including lagged test scores for vocabulary and logic, and for different specifications of the multidimensional early childhood poverty index.

In particular, this chapter contributes to the two literatures of childhood poverty measurement and Early Child Development by addressing two specific knowledge gaps: in the domain of the literature on poverty measurement, it scrutinises whether poverty measured in a multidimensional space is a better predictor of later cognitive attainments than a unidimensional metrics, such as the one of height-for-age scores. In this respect, we show that the interaction of multiple health and nutrition deprivations bears stronger long-term effects on learning outcomes than deprivation in the nutrition dimension alone. On the other hand, our analysis enriches the ECD literature by explicitly incorporating the multidimensionality of health in a model of child development. We exploited the wealth of information contained in the Yound Lives dataset by creating a multidimensional measure of childhood health status that includes information on the major drivers of the burden of disease in developing countries (i.e. respiratory infections, diarrhea, malaria, and nutrition) (Glewwe & Miguel 2008). The evidence provided in this paper implies that a multidimensional approach to child poverty reduction should start at the very beginning of the child's life and should be sustained over different stages of childhood though appropriate policies that focus simultaneously on health, nutrition, and education.

In providing these theoretical, methodological and empirical insights, the thesis is particularly timely to engage in the current debate regarding the post Millennium Development Goal (MDG) framework for three main reasons. First, it addresses two themes that are at the centre of the post-2015 agenda: childhood poverty and inequality in health and education, and food security (Woodhead *et al.* 2012; Zukang 2012). Secondly, it shows that the adoption of the CA has strong normative and methodological implications that are particularly relevant for the identification of the indicators that will inform the post-MDG agenda. Finally, by offering cross-country evidence on the value added of multidimensional measures in the understanding of poverty and food insecurity, it provides evidence-based research to critically inform the post-2015 agenda, as “the goal is not to *measure* poverty – but to *reduce* it” (Alkire and Santos 2009, p.123).

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Appendix A

Measuring Food Security: A Suite Of Indicators Approach

Appendix A.1. Description of the indicators included in the suite

i. *Outcomes indicators of food availability*

- ***Dietary energy supply***: Total food supply (expressed in calories) per person per day. Although it is a rough indicator of individual caloric availability (because it does not represent the specific needs of varying age groups, gender and levels of activity), it provides an overall snapshot of aggregate food availability in the country.
- S***hare of dietary energy supply from staples (cereals and starchy roots)***: Share of total staples supply (cereals plus starchy roots) expressed in calories on total dietary energy supply. A high value indicates a low diversity of aggregate food supply, which is characterized by prevalence of staple foods.

ii. *Outcomes indicators of food access*

- ***Prevalence of undernourishment:*** Proportion of population in condition of chronic undernourishment, i.e. people whose dietary energy supply is continuously below a minimum dietary energy requirement for maintaining a healthy life and carrying out light physical activity.
- ***Depth of Hunger:*** Difference between the minimum dietary energy requirement at the population level and the average dietary energy level of the undernourished population. The greater the mean food deficit, the greater the susceptibility for health risks related to undernutrition.
- ***Share of food expenditure in total expenditure for the 20% poorest households (Engel Coefficient):*** Share of food consumption expenditure in monetary value over total consumption expenditure (%).
- ***Experienced severity of food insecurity:*** Food security scale as obtained from qualitative surveys such as USDA Household Food Insecurity Scale.

iii. Outcomes indicators of food utilization

- ***Prevalence of stunting***: Anthropometric indicators for children under five years of age are the three major nutritional indicators. Stunting is an indicator of chronic maternal and child malnutrition, manifested in children retarded height growth. Linear growth deficit are mostly due to prolonged exposure to an inadequate diet and poor health. Reducing the prevalence of stunting among children (particularly 0-23 months) is important because linear growth deficits accrued early in life are associated with cognitive impairments, poor educational performance and decreased work productivity among adults (Feed the Future 2011).

- ***Prevalence of Wasting***: Anthropometric indicator of acute early childhood malnutrition (usually emergency-related), manifested in low weight for height. Wasted children have much greater risk of dying from infectious diseases than non-wasted children.
- ***Prevalence of children (6-23 months) receiving a minimum acceptable diet:*** Indicators that focus on children under the age of two years are particularly important to have the pulse of the food security situation in the country. This indicator measures the proportion of children 6-23 months of age who receive a minimum acceptable diet (MAD), apart from breast milk. The minimum acceptable diet indicator combines standards of dietary diversity (a proxy for nutrient density) and feeding frequency (a proxy for energy density) by breastfeeding status; and thus provides a useful way to track progress at simultaneously improving the key quality and quantity dimensions of children's diets.
- ***Prevalence of underweight women***: It measures women nutritional status during reproductive age. This indicator provides information about the extent to which women's diets meet their caloric requirements. Women are vulnerable to malnutrition throughout their life-cycle for social and biological reasons. Malnutrition in women is a problem insufficiently recognized and inadequately documented (UN ACC/SCN 1992).

Appendix A.2. Description of the set of selected indicators for modelling and action

i. Process indicators of food availability

- ***Cereal yields:*** Measures agricultural productivity. It provides a measure of the health of the agricultural sector in the country.
- ***Livestock production index***: Measure of productivity in the livestock sector. Livestock are important contributors to total food production and to nutrients supply (primarily proteins and essential amino acids). Animal products not only represent a source of high-quality food, but, equally important, they are a source of livelihoods for many small farmers in developing countries, for purchasing food as well as agricultural inputs, such as seed, fertilizers and pesticides, as well as stabilisers of their incomes, by acting as cash buffer or capital reserve (Sansoucy 1995).
- ***Agricultural spending in R&D, % agricultural GDP:*** Research intensity in the agricultural sector. Although it is not strictly a process indicator (it is more related to inputs), it has been inserted in this list for signaling an actionable policy leverage to increase agricultural productivity because spending on agricultural research and development is the most crucial, among all types of agricultural expenditure, to growth in the agricultural sector (Juma 2011)

ii. Process indicators of food access:

- ***Road density:*** It is usually used as a proxy of physical infrastructure stock of the country and connectedness to markets (e.g. Troubat 2011).
- ***Relative level of consumer prices:*** Ratio between the year averages of food consumer price index and the consumer price index. The ratio provides a measure of the relative cost of a food bundle with respect to the general level of prices in the economy.
- ***Annualised volatility of monthly food price index:*** Annualised measure of variation of monthly food price indexes.
- ***Cereals imports, % merchandise exports:*** It measures country's ability to finance its cereals imports. The food group of cereals was chosen as it is one of the most consumed and most traded food groups worldwide (Troubat 2011). A high dependence on cereals imports, or, more generally, on food imports is not a cause of food insecurity *per se*, if the country has the capability to finance these imports and to be resilient to fluctuations in world food prices. The indicator aims precisely at capturing these last two aspects.
- ***Gross Domestic Product (GDP) per capita, Purchasing Power Parity (PPP):*** PPP GDP is gross domestic product converted to international dollars using purchasing power parity rates. GDP per capita is an indicator of a country's standard of living.
- ***Employment to Population ratio, % population older than 15 years:*** It provides a general overview of the employment structure in the country.
- ***Under five mortality rate:*** The indicator measures child survival. It also reflects the broader social, economic and environmental conditions in which children live, including their health care (UNDG 2003). For this reason, because data on the incidences of poverty are often unavailable or of scarce frequency (including the World Bank's $1 a day poverty headcount), the indicator has been selected in this context as a proxy of multidimensional poverty of the population and their standard of living.

iii. Process indicators of food utilization

The dimension of utilization synthetizes different aspects, which relate to the quality of the diet; the general health status of the population; and 'non-food items', all those items that, although not-strictly related to food, contribute to the efficient conversion of food into nutritional and health status.

With respect to indicators of *diet quality*:

- ***Women dietary diversity index:*** The validated indicators measures the mean number of food groups (out of none food groups) consumed by women of reproductive age (Feed the Future 2010b). T

Non-food items:

- ***Improved water source:*** Proportion of population with reasonable access to an adequate amount of improved drinking water source. Water is an essential component of food and nutritional security. The use of unsafe drinking water is directly related to water-related diseases such as diarrhoea, cholera and typhoid. These types of diseases are often found to be a cause of malnutrition.

- ***Improved sanitation facilities:*** Proportion of population with access to an improved sanitation facilities. Adequate sanitation is an essential component of food and nutrition security, as it lowers the risks of diarrhoea and other diseases that hamper the capability of converting food in good nutritional outcomes.
- ***Female adult literacy:*** Adult literacy rate is the percentage of people ages 15 and above who can, with understanding, read and write a short, simple statement on their everyday life. It is widely acknowledged that education, in particular female, is a key determinant of food security outcomes (Behrman & Wolfe 1987; Kassouf & Senauer 1996; Burchi & De Muro 2007)
- ***Female enrollment rate, secondary gross:*** gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that corresponds to the level of education shown. The positive relationship between education, especially of women, and food security is well documented in the development literature (Behrman & Wolfe 1987; Kassouf & Senauer 1996; Burchi & De Muro 2007). In particular, educated women can provide good nutritional outcomes for their families through the use of information related to good health and nutritional practices. This indicator focuses on enrolment rates at the secondary level of education, instead of primary education, as it has been shown that secondary education levels of the mother are particularly conducive to foster food security outcomes (Smith & Haddad 2000).

Indicators of *health status of the population with respect to nutritional deficiencies:*

- ***Prevalence of vitamin A deficiency:*** Prevalence of vitamin A deficiency in the population. Deficiency of vitamin A is associated with significant morbidity and mortality from common childhood infections and is the world's leading preventable cause of childhood blindness (WHO 2012).
- ***Prevalence of iodine deficiency:*** Prevalence of iodine deficiency in the country. Iodine deficiency is caused by a low dietary supply of iofine. Iodine deficiency leads to increased perinatal mortality and mental retardation, and it is the leading cause of preventable brain damage in childhood (source: WHO).
- ***Prevalence of anemia:*** Proportion of population with anemia. Nutritional deficiencies (including iron, folate, vitamin B12, and vitamin A) can cause anaemia (WHO 2012).

Appendix B

Measuring Food Security: A Structural Equation Approach

Appendix B.1. Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Prev. of stunting (% children 0-5 yrs)	97	28.35	14.00	2.00	57.70
Prev. of malnutrition in adult females	67	10.67	8.91	0.70	39.90
Prev. Of Undernourishment	97	18.54	14.20	5	72.4
Dietary Diversity Index	97	0.56	0.12	0.32	0.82
Cereal Yields	97	2352.64	1535.44	252.20	7894.70
GDP p.c. (PPP)	94	5796.75	6652.37	422.23	49952.16
Gini index	82	43.14	8.33	29.33	63.90
GDP growth rate (2007)	96	6.56	4.37	-3.65	25.05
$1 a day Poverty headcount (% pop.)	88	24.82	23.43	0.00	83.76
Ratio food imports on merchandise exports	90	13.43	6.90	1.86	45.56
Ratio food prices over consumer prices indexes	89	1.05	0.22	0.31	2.18
Road density index	96	28.06	36.62	1.00	201.00
Access to sanitation (% pop.)	96	59.66	30.57	9.00	100.00
Access to water (% pop.)	96	80.32	16.24	42.00	100.00
Health exp. p.c.	95	213.56	236.35	10.66	1116.63
Adult literacy ratio (females)	94	79.24	22.51	17.98	100.00
Female-to-male adult literacy ratio	92	0.86	0.17	0.35	1.15
Rural pop. (%)	97	50.91	22.10	1.78	89.86
Voice & accountability index	97	-0.40	0.86	-2.20	1.56
Political stability index	97	-0.31	0.86	-2.43	1.16

Appendix B.2. Multivariate Exploratory Analysis

Exploratory multivariate analysis has been conducted in order to analyse the structure of the sample data. Table A2 provides correlations between the four functionings indicators selected. All the indicators are statistically significant correlated among each other, which we interpret as reflecting the underlying construct of food security.

Appendix B.3. Pairwise correlations of functionings indicators (N=57)

	PoU	ddi	stunt	bmifem
Prev. of Undernourishment (PoU)	1			
Dietary Diversity Index (ddi)	0.624***	1		
Prev. of stunting (stunt)	0.277*	0.541***	1	
Prev. of Female malnutrition (bmifem)	0.340**	0.655***	0.440***	1

*** p<0.01, ** p<0.05, * p<0.1.

Appendix B.4. Principal Component Analysis of the functioning Indicators and Factor Loadings

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	**2.46399**	**1.71416**	**0.6160**	**0.6160**
Comp2	**.749835**	**.19546**	**0.1875**	**0.8035**
Comp3	**.554375**	**.322579**	**0.1386**	**0.9421**
Comp4	**.231796**	**.**	**0.0579**	**1.0000**

Principal components (eigenvectors)

Variable	Comp1	Comp2	Comp3	Comp4	Unexplained
pouNEW	**0.4510**	**0.7534**	**0.2497**	**0.4083**	**0**
stunt2	**0.5836**	**0.1088**	**-0.0722**	**-0.8014**	**0**
bmifem_dhs~o	**0.4519**	**-0.5875**	**0.6434**	**0.1914**	**0**
diet_staples	**0.5017**	**-0.2746**	**-0.7200**	**0.3929**	**0**

Appendix C
The Dynamic Association Between Early Childhood Multi-dimensional Poverty And Cognitive Development: Evidence From Four Developing Countries

Appendix C.1. Descriptive statistics of indicators of early childhood poverty

VARIABLES	POOLED SAMPLE (N=7550) Mean (sd)	ETHIOPIA (N=1792) Mean (sd)	INDIA (N=1888) Mean (sd)	PERU (N=1889) Mean (sd)	VIETNAM (N=1981) Mean (sd)
Sickness past 24hrs	0.43 (0.49)	0.47 (0.5)	0.38 (0.49)	0.53 (0.5)	0.34 (0.47)
Wasted	0.11 (0.31)	0.15 (0.36)	0.21 (0.41)	0.02 (0.14)	0.05 (0.22)
Stunted	0.3 (0.46)	0.41 (0.49)	0.3 (0.46)	0.28 (0.45)	0.21 (0.41)
Serious illness or injury	0.24 (0.43)	0.3 (0.46)	0.22 (0.42)	0.32 (0.47)	0.13 (0.34)
Early multidimensional poverty index	0.27 (0.24)	0.33 (0.26)	0.28 (0.24)	0.29 (0.22)	0.18 (0.2)
Not deprived	0.32 (0.47)	0.24 (0.43)	0.3 (0.46)	0.25 (0.43)	0.47 (0.5)

% Deprived in one dimension	0.38 (0.49)	0.34 (0.48)	0.38 (0.49)	0.43 (0.5)	0.37 (0.48)
% Deprived in two dimensions	0.22 (0.41)	0.27 (0.45)	0.23 (0.42)	0.25 (0.43)	0.13 (0.34)
% Deprived in three dimensions	0.07 (0.26)	0.11 (0.32)	0.08 (0.27)	0.07 (0.25)	0.03 (0.17)
% Deprived in four dimensions	0.01 (0.09)	0.02 (0.15)	0.01 (0.09)	0 (0.04)	0 (0.05)

Note: N is the number of observations for which EMPI has been calculated.

Appendix C.2. Tetrachoric Correlations Between The Indicators Constituting EMPI

	Sick 24 hrs	Life-threatening morbidity	Stunted
ETHIOPIA (N=1792)			
Sick 24 hrs	1		
Life-threatening morbidity	0.31*	1	
Stunted	0.09*	0.09*	1
Wasted	0.21*	0.25*	0.10*
INDIA (N=1888)			
Sick 24 hrs	1		
Life-threatening morbidity	0.18*	1	
Stunted	0.14*	0.14*	1
Wasted	0.06	0.05	0.01
PERU (N= 1889)			
Sick 24 hrs	1		
Life-threatening morbidity	0.09*	1	
Stunted	0.07*	0.13*	1
Wasted	0.03	-0.02	0.03
VIETNAM (N= 1981)			
Sick 24 hrs	1		
Life-threatening morbidity	0.18*	1	
Stunted	0.12*	0.26*	1
Wasted	0.01	0.09	0.31*

** Denotes statistical significance at at least 10%.*

Appendix C3. Mean test scores by multidimensional poverty status

	Mean not poor	Mean Poor in 1 dimension (EMPI==0.25)	Diff. with not poor	Mean Multidimensional poor (EMPI>=0.26)	Diff. with not poor	
POOLED						
PPVT raw score (R2)	51.07	46.56	4.51***	40.57	10.5	***
CDA raw score	9.47	9.01	0.46***	8.38	1.09	***
Maths raw score	14.90	12.96	1.94***	10.42	4.48	***
PPVT raw score	69.27	63.63	5.64***	56.56	12.71	***
EGRA raw score	7.90	7.12	0.78***	5.92	1.98	***
ETHIOPIA						
PPVT raw score (R2)	50.63	46.51	4.12**	39.97	10.66	***
CDA raw score	8.69	8.46	0.23	7.74	0.95	***
Maths raw score	7.10	6.29	0.81**	4.88	2.22	***
PPVT raw score	77.45	70.43	7.02***	60.55	16.9	***
EGRA raw score	3.88	3.52	0.36**	3.22	0.66	***
INDIA						
PPVT raw score	41.07	39.99	1.08	34.54	6.53	***
CDA raw score	9.77	9.51	0.26*	8.95	0.82	***
Maths raw score	13.27	12.30	0.97***	10.62	2.65	***
PPVT raw score	52.80	51.06	1.74	43.88	8.92	***
EGRA raw score	5.81	5.61	0.20	4.87	0.94	***
PERU						
PPVT raw score (R2)	47.07	44.06	3.01***	41.21	5.86	***
CDA raw score	8.69	8.42	0.27**	8.13	0.56	***
Maths raw score	15.36	14.26	1.10***	13.29	2.07	***
PPVT raw score	62.17	59.40	2.77***	56.06	6.11	***
EGRA raw score	8.94	8.44	0.50***	7.84	1.1	***
VIETNAM						
PPVT raw score (R2)	60.14	56.45	3.69***	52.88	7.26	***
CDA raw score	10.08	9.67	0.41***	9.29	0.79	***
Maths raw score	19.27	17.76	1.51***	17.65	1.62	***
PPVT raw score	79.71	75.41	4.29***	72.81	6.9	***
EGRA raw score	10.34	9.86	0.48***	9.55	0.79	***

*** p<0.01, ** p<0.05, * p<0.1 indicates statistical differences.

Appendix C4. List of controls used in baseline and extended specifications, Round 2 and Round 3

ROUND 2	Baseline controls	Male; age (months), disability status; child is first born; mother received antenatal care; child is born in a health facility; ethnicity or caste; child’s birth attended by doctor, nurse, or midwife; child received no vaccinations; child is in preschool; child attended crèche before 3 years of age; current nutritional status (body mass index, z-scores), child’s mother is in the household; child’s father is in the household; both parents are in the household; caregiver's age, sex, education (none, primary, secondary, post-secondary); household size; head of the household’s sex and education (none, primary, secondary, post-secondary); housing quality index; access to services index; location.
ROUND 3	Baseline controls	Male; age (months), disability status; child is first born; mother received antenatal care; child is born in a health facility; ethnicity or caste; child’s birth attended by doctor, nurse, or midwife; child received no vaccinations; child is in preschool; child attended crèche before 3 years of age; current nutritional status (body mass index, z-scores), child’s mother is in the household; child’s father is in the household; both parents are in the household; caregiver's age, sex, education (none, primary, secondary, post-secondary); household size; head of the household’s sex and education (none, primary, secondary, post-secondary); housing quality index; access to services index; location; time used to study (average daily time devoted to school, study or play); time used to work; child's grade, child missed school for more than one week; child attends government school (only in the case of Peru and India)
	Robustness check	Baseline + lagged CDA and PPVT scores in Round 2

Appendix C5. Research question 1: Baseline viz. Multidimensional specifications

ETHIOPIA ROUND 2

VARIABLES	(1) PPVT	(2) PPVT	(3) PPVT	(4) PPVT	(5) PPVT	(6) PPVT
Height-for-age z-scores	0.034	0.038	0.039	0.039		0.054
	(2.287)**	(2.385)**	(2.398)**	(2.472)**		(2.994)***
Weight-for-height z-scores		0.044	0.042	0.040		0.054
		(2.064)**	(2.018)*	(1.987)*		(2.386)**
Life-threatening morbidity			-0.023	-0.017		-0.051
			(-0.993)	(-0.784)		(-1.475)
Recent sickness				-0.038		-0.076
				(-1.705)		(-2.047)*
EMPI z-scores					-0.054	0.075
					(-2.050)*	(1.644)
Constant	-2.570	-2.620	-2.682	-2.674	-2.472	-2.611
	(-4.042)***	(-3.850)***	(-4.091)***	(-4.015)***	(-3.956)***	(-3.995)***
Observations	1,239	1,193	1,192	1,192	1,238	1,192
R-squared	0.131	0.136	0.137	0.139	0.130	0.140
Number of communities	25	25	25	25	25	25
Adjusted R-square	0.108	0.112	0.112	0.112	0.107	0.113

*Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.*
Standard errors clustered at community level ; community fixed effects included in all regressions

ETHIOPIA ROUND 2

Appendix C

VARIABLES	(1) CDA	(2) CDA	(3) CDA	(4) CDA	(5) CDA	(6) CDA
Height-for-age z-scores	0.039	0.039	0.039	0.039		0.059
	(2.452)**	(2.380)**	(2.366)**	(2.365)**		(2.475)**
Weight-for-height z-scores		0.027	0.026	0.026		0.046
		(1.220)	(1.171)	(1.173)		(1.630)
Life-threatening morbidity			-0.015	-0.015		-0.061
			(-0.677)	(-0.662)		(-1.796)*
Recent sickness				0.001		-0.049
				(0.048)		(-1.108)
EMPI z-scores					-0.023	0.101
					(-1.024)	(1.589)
Constant	-1.980	-1.878	-1.923	-1.923	-1.787	-1.832
	(-4.060)***	(-3.806)***	(-3.904)***	(-3.896)***	(-3.802)***	(-3.763)***
Observations	1,534	1,487	1,486	1,486	1,533	1,486
R-squared	0.072	0.071	0.071	0.071	0.068	0.073
Number of communities	25	25	25	25	25	25
Adjusted R-square	0.0523	0.0494	0.0490	0.0483	0.0480	0.0496

*Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.*
Standard errors clustered at community level ; community fixed effects included in all regressions

ETHIOPIA ROUND 3

VARIABLES	(1) MATHS	(2) MATHS	(3) MATHS	(4) MATHS	(5) MATHS	(6) MATHS
Height-for-age z-scores	0.020	0.018	0.018	0.019		0.013
	(1.878)*	(1.742)*	(1.709)*	(1.759)*		(0.823)
Weight-for-height z-scores		0.017	0.016	0.015		0.010
		(0.963)	(0.948)	(0.868)		(0.411)
Life-threatening morbidity			-0.012	-0.008		0.005
			(-0.537)	(-0.381)		(0.106)
Recent sickness				-0.021		-0.006
				(-0.812)		(-0.155)
EMPI z-scores					-0.038	-0.029
					(-2.016)*	(-0.456)
Constant	-0.752	-0.695	-0.715	-0.716	-0.689	-0.734
	(-1.594)	(-1.413)	(-1.457)	(-1.480)	(-1.558)	(-1.552)
Observations	1,160	1,131	1,131	1,131	1,160	1,131
R-squared	0.322	0.323	0.323	0.324	0.322	0.324
Number of communities	28	26	26	26	28	26
Adjusted R-square	0.299	0.299	0.299	0.299	0.299	0.298

*Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.*
Standard errors clustered at community level ; community fixed effects included in all regressions

ETHIOPIA ROUND 3

VARIABLES	(1) PPVT	(2) PPVT	(3) PPVT	(4) PPVT	(5) PPVT	(6) PPVT
Height-for-age z-scores	0.032	0.033	0.032	0.033		0.035
	(2.593)**	(2.584)**	(2.598)**	(2.694)**		(2.097)**
Weight-for-height z-scores		0.013	0.013	0.011		0.013
		(0.552)	(0.540)	(0.459)		(0.456)
Life-threatening morbidity			-0.010	-0.005		-0.009
			(-0.564)	(-0.257)		(-0.435)
Recent sickness				-0.041		-0.046
				(-1.925)*		(-1.287)
EMPI z-scores					-0.054	0.010
					(-2.192)**	(0.165)
Constant	-2.373	-2.221	-2.236	-2.250	-2.249	-2.245
	(-3.749)***	(-3.513)***	(-3.652)***	(-3.684)***	(-3.690)***	(-3.739)***
Observations	1,025	996	996	996	1,025	996
R-squared	0.225	0.227	0.227	0.230	0.225	0.230
Number of communities	25	23	23	23	25	23
Adjusted R-square	0.196	0.196	0.195	0.197	0.195	0.196

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

ETHIOPIA ROUND 3

VARIABLES	(1) EGRA	(2) EGRA	(3) EGRA	(4) EGRA	(5) EGRA	(6) EGRA
Height-for-age z-scores	0.023	0.022	0.021	0.020		0.021
	(1.674)	(1.574)	(1.522)	(1.487)		(1.026)
Weight-for-height z-scores		-0.015	-0.017	-0.016		-0.015
		(-0.764)	(-0.823)	(-0.775)		(-0.739)
Life-threatening morbidity			-0.039	-0.041		-0.044
			(-1.354)	(-1.469)		(-0.793)
Recent sickness				0.011		0.008
				(0.405)		(0.146)
EMPI z-scores					-0.026	0.006
					(-1.265)	(0.085)
Constant	-0.025	-0.007	-0.067	-0.063	0.095	-0.059
	(-0.037)	(-0.010)	(-0.094)	(-0.087)	(0.139)	(-0.081)
Observations	1,032	1,004	1,004	1,004	1,032	1,004
R-squared	0.168	0.168	0.170	0.170	0.167	0.170
Number of communities	26	24	24	24	26	24
Adjusted R-square	0.136	0.134	0.135	0.134	0.135	0.133

Robust t-statistics in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
Standard errors clustered at community level ; community fixed effects included in all regressions

INDIA ROUND 2

VARIABLES	(1) PPVT	(2) PPVT	(3) PPVT	(4) PPVT	(5) PPVT	(6) PPVT
Height-for-age z-scores	0.083	0.083	0.083	0.083		0.084
	(4.169)***	(4.217)***	(4.245)***	(4.167)***		(3.556)***
Weight-for-height z-scores		0.060	0.059	0.058		0.060
		(1.992)**	(1.974)*	(1.931)*		(1.980)*
Life-threatening morbidity			-0.019	-0.018		-0.021
			(-0.785)	(-0.730)		(-0.666)
Recent sickness				-0.014		-0.017
				(-0.720)		(-0.536)
EMPI z-scores					-0.076	0.007
					(-3.283)***	(0.147)
Constant	-2.723	-2.585	-2.617	-2.591	-2.468	-2.585
	(-4.761)***	(-4.603)***	(-4.609)***	(-4.566)***	(-4.195)***	(-4.574)***
Observations	1,671	1,671	1,671	1,671	1,671	1,671
R-squared	0.162	0.166	0.166	0.166	0.152	0.166
Number of communities	101	101	101	101	101	101
Adjusted R-square	0.145	0.148	0.148	0.147	0.135	0.147

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

INDIA ROUND 2

VARIABLES	(1) CDA	(2) CDA	(3) CDA	(4) CDA	(5) CDA	(6) CDA
Height-for-age z-scores	0.102	0.101	0.101	0.101		0.095
	(5.426)***	(5.526)***	(5.545)***	(5.487)***		(4.095)***
Weight-for-height z-scores		0.084	0.083	0.082		0.076
		(3.132)***	(3.048)***	(3.006)***		(2.420)**
Life-threatening morbidity			-0.027	-0.026		-0.016
			(-1.033)	(-0.986)		(-0.451)
Recent sickness				-0.011		0.000
				(-0.455)		(0.005)
EMPI z-scores					-0.103	-0.022
					(-4.140)***	(-0.427)
Constant	-2.852	-2.658	-2.692	-2.671	-2.558	-2.696
	(-4.417)***	(-4.147)***	(-4.154)***	(-4.136)***	(-3.949)***	(-4.183)***
Observations	1,826	1,826	1,826	1,826	1,826	1,826
R-squared	0.120	0.125	0.126	0.126	0.109	0.126
Number of communities	101	101	101	101	101	101
Adjusted R-square	0.103	0.108	0.108	0.108	0.0921	0.108

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

INDIA ROUND 3

VARIABLES	(1) MATHS	(2) MATHS	(3) MATHS	(4) MATHS	(5) MATHS	(6) MATHS
Height-for-age z-scores	0.058	0.059	0.059	0.059		0.031
	(4.519)***	(4.585)***	(4.586)***	(4.592)***		(1.725)*
Weight-for-height z-scores		0.035	0.034	0.034		-0.001
		(1.946)*	(1.880)*	(1.877)*		(-0.024)
Life-threatening morbidity			-0.020	-0.020		0.033
			(-0.931)	(-0.892)		(1.089)
Recent sickness				-0.006		0.056
				(-0.309)		(1.970)*
EMPI z-scores					-0.082	-0.119
					(-4.039)***	(-2.871)***
Constant	-0.774	-0.745	-0.746	-0.739	-0.644	-0.803
	(-1.524)	(-1.456)	(-1.459)	(-1.446)	(-1.263)	(-1.593)
Observations	1,751	1,751	1,751	1,751	1,751	1,751
R-squared	0.315	0.316	0.317	0.317	0.314	0.320
Number of communities	101	101	101	101	101	101
Adjusted R-square	0.298	0.299	0.300	0.299	0.298	0.302

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

INDIA ROUND 3

VARIABLES	(1) PPVT	(2) PPVT	(3) PPVT	(4) PPVT	(5) PPVT	(6) PPVT
Height-for-age z-scores	0.029	0.029	0.030	0.029		0.014
	(1.561)	(1.573)	(1.582)	(1.511)		(0.593)
Weight-for-height z-scores		0.024	0.023	0.022		0.005
		(0.940)	(0.911)	(0.848)		(0.173)
Life-threatening morbidity			-0.018	-0.016		0.010
			(-0.848)	(-0.773)		(0.291)
Recent sickness				-0.020		0.011
				(-0.705)		(0.259)
EMPI z-scores					-0.056	-0.059
					(-2.702)***	(-1.167)
Constant	-0.615	-0.578	-0.577	-0.559	-0.540	-0.590
	(-0.805)	(-0.757)	(-0.759)	(-0.733)	(-0.722)	(-0.769)
Observations	1,454	1,454	1,454	1,454	1,454	1,454
R-squared	0.137	0.138	0.138	0.139	0.139	0.139
Number of communities	101	101	101	101	101	101
Adjusted R-square	0.112	0.112	0.112	0.112	0.114	0.112

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

INDIA ROUND 3

VARIABLES	(1) EGRA	(2) EGRA	(3) EGRA	(4) EGRA	(5) EGRA	(6) EGRA
Height-for-age z-scores	0.038	0.038	0.038	0.038		0.019
	(2.368)**	(2.401)**	(2.406)**	(2.355)**		(0.796)
Weight-for-height z-scores		0.018	0.017	0.016		-0.006
		(0.701)	(0.674)	(0.649)		(-0.234)
Life-threatening morbidity			-0.014	-0.012		0.022
			(-0.706)	(-0.625)		(0.622)
Recent sickness				-0.017		0.024
				(-0.727)		(0.753)
EMPI z-scores					-0.060	-0.079
					(-2.614)**	(-1.493)
Constant	-0.802	-0.785	-0.785	-0.768	-0.715	-0.807
	(-1.162)	(-1.140)	(-1.140)	(-1.115)	(-1.039)	(-1.167)
Observations	1,719	1,719	1,719	1,719	1,719	1,719
R-squared	0.195	0.196	0.196	0.196	0.196	0.198
Number of communities	101	101	101	101	101	101
Adjusted R-square	0.176	0.176	0.175	0.175	0.176	0.176

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

PERU ROUND 2

VARIABLES	(1) PPVT	(2) PPVT	(3) PPVT	(4) PPVT	(5) PPVT	(6) PPVT
Height-for-age z-scores	0.022	0.023	0.023	0.023		0.024
	(1.428)	(1.523)	(1.478)	(1.418)		(1.147)
Weight-for-height z-scores		0.057	0.057	0.057		0.057
		(3.008)***	(3.007)***	(2.989)***		(2.952)***
Life-threatening morbidity			0.004	0.004		0.001
			(0.162)	(0.172)		(0.017)
Recent sickness				-0.015		-0.019
				(-0.717)		(-0.423)
EMPI z-scores					-0.022	0.006
					(-1.010)	(0.109)
Constant	-1.585	-1.511	-1.504	-1.500	-1.573	-1.500
	(-1.641)	(-1.602)	(-1.565)	(-1.576)	(-1.624)	(-1.576)
Observations	1,569	1,568	1,568	1,568	1,569	1,568
R-squared	0.083	0.087	0.087	0.087	0.083	0.087
Number of communities	114	114	114	114	114	114
Adjusted R-square	0.0641	0.0670	0.0664	0.0661	0.0639	0.0655

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

PERU ROUND 2

VARIABLES	(1) CDA	(2) CDA	(3) CDA	(4) CDA	(5) CDA	(6) CDA
Height-for-age z-scores	0.047	0.048	0.047	0.046		0.038
	(2.510)**	(2.505)**	(2.426)**	(2.381)**		(1.554)
Weight-for-height z-scores		0.025	0.024	0.024		0.021
		(0.676)	(0.664)	(0.655)		(0.613)
Life-threatening morbidity			-0.005	-0.004		0.011
			(-0.219)	(-0.203)		(0.241)
Recent sickness				-0.018		-0.001
				(-0.752)		(-0.034)
EMPI z-scores					-0.043	-0.030
					(-1.752)*	(-0.424)
Constant	-3.335	-3.294	-3.301	-3.291	-3.276	-3.296
	(-4.830)***	(-5.019)***	(-5.135)***	(-5.191)***	(-4.811)***	(-5.162)***
Observations	1,812	1,811	1,811	1,811	1,812	1,811
R-squared	0.125	0.125	0.125	0.126	0.124	0.126
Number of communities	118	118	118	118	118	118
Adjusted R-square	0.109	0.109	0.108	0.108	0.108	0.108

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

PERU ROUND 3

VARIABLES	(1) MATHS	(2) MATHS	(3) MATHS	(4) MATHS	(5) MATHS	(6) MATHS
Height-for-age z-scores	0.063	0.063	0.062	0.061		0.044
	(8.753)***	(8.978)***	(8.706)***	(8.270)***		(5.577)***
Weight-for-height z-scores		0.032	0.032	0.031		0.025
		(5.561)***	(5.339)***	(5.096)***		(4.651)***
Life-threatening morbidity			-0.014	-0.013		0.019
			(-4.013)***	(-3.805)***		(2.034)**
Recent sickness				-0.023		0.011
				(-3.134)***		(0.674)
EMPI z-scores					-0.064	-0.061
					(-17.309)***	(-3.184)***
Constant	-2.843	-2.873	-2.929	-2.927	-2.725	-2.959
	(-8.256)***	(-8.166)***	(-8.187)***	(-8.362)***	(-8.746)***	(-8.323)***
Observations	1,756	1,755	1,755	1,755	1,756	1,755
R-squared	0.421	0.423	0.423	0.424	0.420	0.425
Number of communities	64	64	64	64	64	64
Adjusted R-square	0.409	0.411	0.411	0.411	0.408	0.411

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

PERU ROUND 3

VARIABLES	(1) PPVT	(2) PPVT	(3) PPVT	(4) PPVT	(5) PPVT	(6) PPVT
Height-for-age z-scores	0.065	0.065	0.065	0.065		0.053
	(6.770)***	(6.517)***	(6.353)***	(6.351)***		(2.989)***
Weight-for-height z-scores		0.022	0.021	0.021		0.017
		(3.095)***	(2.970)***	(2.967)***		(3.248)***
Life-threatening morbidity			-0.015	-0.015		0.008
			(-3.460)***	(-3.443)***		(0.485)
Recent sickness				-0.001		0.022
				(-0.408)		(1.351)
EMPI z-scores					-0.047	-0.042
					(-11.108)***	(-1.447)
Constant	-2.810	-2.823	-2.885	-2.885	-2.600	-2.909
	(-6.350)***	(-6.484)***	(-6.687)***	(-6.687)***	(-6.711)***	(-6.897)***
Observations	1,623	1,622	1,622	1,622	1,623	1,622
R-squared	0.462	0.463	0.463	0.463	0.459	0.464
Number of communities	62	62	62	62	62	62
Adjusted R-square	0.450	0.451	0.451	0.450	0.447	0.450

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

PERU ROUND 3

VARIABLES	(1) EGRA	(2) EGRA	(3) EGRA	(4) EGRA	(5) EGRA	(6) EGRA
Height-for-age z-scores	0.062	0.062	0.061	0.060		0.052
	(6.617)***	(5.958)***	(5.699)***	(5.674)***		(3.062)***
Weight-for-height z-scores		0.053	0.053	0.053		0.050
		(7.107)***	(6.843)***	(6.851)***		(8.029)***
Life-threatening morbidity			-0.020	-0.020		-0.004
			(-3.485)***	(-3.442)***		(-0.310)
Recent sickness				-0.009		0.008
				(-2.379)**		(0.634)
EMPI z-scores					-0.056	-0.031
					(-10.273)***	(-1.247)
Constant	-1.983	-2.036	-2.122	-2.121	-1.836	-2.135
	(-9.249)***	(-8.758)***	(-8.673)***	(-8.791)***	(-7.189)***	(-8.659)***
Observations	1,621	1,620	1,620	1,620	1,621	1,620
R-squared	0.304	0.307	0.308	0.308	0.303	0.308
Number of communities	61	61	61	61	61	61
Adjusted R-square	0.289	0.291	0.291	0.291	0.287	0.291

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

VIETNAM ROUND 2

VARIABLES	(1) PPVT	(2) PPVT	(3) PPVT	(4) PPVT	(5) PPVT	(6) PPVT
Height-for-age z-scores	0.048	0.052	0.053	0.053		0.043
	(2.320)**	(2.424)**	(2.472)**	(2.453)**		(1.605)
Weight-for-height z-scores		-0.038	-0.040	-0.041		-0.046
		(-1.820)*	(-1.859)*	(-1.931)*		(-2.352)**
Life-threatening morbidity			-0.042	-0.041		-0.027
			(-2.007)*	(-1.939)*		(-0.783)
Recent sickness				-0.018		0.003
				(-0.672)		(0.062)
EMPI z-scores					-0.054	-0.035
					(-2.486)**	(-0.531)
Constant	-3.001	-3.041	-3.135	-3.140	-2.911	-3.155
	(-5.184)***	(-5.314)***	(-5.552)***	(-5.610)***	(-5.421)***	(-5.623)***
Observations	1,371	1,371	1,371	1,371	1,371	1,371
R-squared	0.145	0.146	0.148	0.149	0.145	0.149
Number of communities	36	36	36	36	36	36
Adjusted R-square	0.125	0.125	0.127	0.127	0.124	0.126

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

VIETNAM ROUND 2

VARIABLES	(1) CDA	(2) CDA	(3) CDA	(4) CDA	(5) CDA	(6) CDA
Height-for-age z-scores	0.031	0.032	0.032	0.032		0.035
	(1.866)*	(1.867)*	(1.868)*	(1.849)*		(1.632)
Weight-for-height z-scores		-0.007	-0.010	-0.011		-0.010
		(-0.383)	(-0.500)	(-0.584)		(-0.516)
Life-threatening morbidity			-0.042	-0.040		-0.044
			(-1.866)*	(-1.811)*		(-1.365)
Recent sickness				-0.036		-0.042
				(-1.591)		(-1.054)
EMPI z-scores					-0.053	0.011
					(-2.293)**	(0.227)
Constant	-3.277	-3.288	-3.371	-3.358	-3.236	-3.353
	(-5.343)***	(-5.343)***	(-5.499)***	(-5.576)***	(-5.475)***	(-5.590)***
Observations	1,534	1,534	1,534	1,534	1,534	1,534
R-squared	0.138	0.138	0.141	0.143	0.140	0.143
Number of communities	36	36	36	36	36	36
Adjusted R-square	0.120	0.120	0.121	0.123	0.122	0.122

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

VIETNAM ROUND 3

VARIABLES	(1) MATHS	(2) MATHS	(3) MATHS	(4) MATHS	(5) MATHS	(6) MATHS
Height-for-age z-scores	0.045	0.043	0.043	0.043		0.022
	(2.821)***	(2.722)**	(2.740)***	(2.744)***		(1.135)
Weight-for-height z-scores		0.020	0.022	0.021		0.011
		(1.007)	(1.103)	(1.060)		(0.493)
Life-threatening morbidity			0.027	0.028		0.061
			(1.576)	(1.602)		(2.288)**
Recent sickness				-0.017		0.030
				(-0.797)		(0.791)
EMPI z-scores					-0.040	-0.079
					(-1.772)*	(-1.528)
Constant	0.458	0.452	0.477	0.460	0.505	0.437
	(0.808)	(0.800)	(0.851)	(0.816)	(0.850)	(0.780)
Observations	1,516	1,516	1,516	1,516	1,516	1,516
R-squared	0.375	0.375	0.376	0.376	0.373	0.378
Number of communities	36	36	36	36	36	36
Adjusted R-square	0.359	0.359	0.360	0.359	0.358	0.361

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

VIETNAM ROUND 3

VARIABLES	(1) PPVT	(2) PPVT	(3) PPVT	(4) PPVT	(5) PPVT	(6) PPVT
Height-for-age z-scores	-0.011	-0.008	-0.008	-0.008		-0.015
	(-0.519)	(-0.356)	(-0.377)	(-0.374)		(-0.468)
Weight-for-height z-scores		-0.033	-0.034	-0.036		-0.039
		(-1.085)	(-1.128)	(-1.198)		(-1.226)
Life-threatening morbidity			-0.016	-0.013		-0.004
			(-0.672)	(-0.575)		(-0.097)
Recent sickness				-0.038		-0.023
				(-1.357)		(-0.607)
EMPI z-scores					-0.027	-0.024
					(-1.104)	(-0.427)
Constant	-0.523	-0.519	-0.531	-0.572	-0.620	-0.575
	(-0.779)	(-0.773)	(-0.793)	(-0.852)	(-0.898)	(-0.854)
Observations	1,422	1,422	1,422	1,422	1,422	1,422
R-squared	0.148	0.149	0.149	0.151	0.149	0.151
Number of communities	36	36	36	36	36	36
Adjusted R-square	0.125	0.125	0.125	0.126	0.126	0.126

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

VIETNAM ROUND 3

VARIABLES	(1) EGRA	(2) EGRA	(3) EGRA	(4) EGRA	(5) EGRA	(6) EGRA
Height-for-age z-scores	0.043	0.036	0.037	0.036		0.037
	(2.338)**	(2.068)**	(2.082)**	(2.075)**		(1.620)
Weight-for-height z-scores		0.058	0.059	0.057		0.057
		(2.161)**	(2.233)**	(2.225)**		(2.123)**
Life-threatening morbidity			0.013	0.015		0.015
			(0.592)	(0.674)		(0.506)
Recent sickness				-0.033		-0.033
				(-1.023)		(-0.771)
EMPI z-scores					-0.043	0.000
					(-1.413)	(0.009)
Constant	0.080	0.069	0.083	0.047	0.103	0.047
	(0.121)	(0.106)	(0.128)	(0.071)	(0.155)	(0.072)
Observations	1,502	1,502	1,502	1,502	1,502	1,502
R-squared	0.163	0.165	0.166	0.167	0.162	0.167
Number of communities	36	36	36	36	36	36
Adjusted R-square	0.141	0.144	0.143	0.144	0.141	0.144

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

Appendix C6. Descriptive statistics of the interaction terms

	Ethiopia (N=1792)		India (N=1888)	
	Mean	Std. Dev.	Mean	Std. Dev.
Stunted*wasted	0.07	0.26	0.06	0.24
Stunted*morbidity	0.14	0.34	0.08	0.28
Stunted*sickness	0.20	0.40	0.13	0.34
Wasted*morbidity	0.07	0.25	0.05	0.22
Wasted*sickness	0.09	0.29	0.09	0.28
Morbidity*sickness	0.19	0.39	0.11	0.31
Stunted*morbidity*sickness	0.09	0.28	0.04	0.20
	Peru (N=1889)		**Vietnam (N=1981)**	
	Mean	**Std. Dev.**	**Mean**	**Std. Dev.**
Stunted*wasted	0.01	0.08	0.02	0.14
Stunted*morbidity	0.10	0.31	0.04	0.21
Stunted*sickness	0.15	0.36	0.08	0.28
Wasted*morbidity	0.01	0.08	0.01	0.09
Wasted*sickness	0.01	0.11	0.02	0.13
Morbidity*sickness	0.18	0.38	0.06	0.24
Stunted*morbidity*sickness	0.06	0.24	0.02	0.14

Appendix C7. Research question 2: Model with the interactions

ETHIOPIA

VARIABLES	(1) PPVT R2	(2) CDA	(3) MATHS	(4) PPVT R3	(5) EGRA
Stunted	0.010	0.026	0.014	-0.045	0.007
	(0.227)	(0.506)	(0.399)	(-1.036)	(0.158)
Wasted	-0.023	-0.050	-0.061	0.049	-0.096
	(-0.486)	(-1.870)*	(-2.319)**	(1.336)	(-1.692)
Life-threatening morbidity	-0.026	0.021	0.016	-0.008	-0.044
	(-0.473)	(0.457)	(0.494)	(-0.163)	(-0.643)
Recent sickness	-0.025	0.047	-0.016	-0.058	0.029
	(-0.632)	(1.592)	(-0.487)	(-2.303)**	(0.907)
Stunted*wasted	-0.007	0.039	-0.021	-0.056	-0.020
	(-0.217)	(1.538)	(-0.870)	(-1.883)*	(-0.798)
Stunted*morbidity	-0.022	-0.046	0.003	0.033	0.092
	(-0.377)	(-0.750)	(0.079)	(0.511)	(1.142)
Stunted*sickness	-0.073	-0.076	0.003	0.039	-0.000
	(-1.391)	(-1.544)	(0.076)	(1.012)	(-0.008)
Wasted*morbidity	-0.014	0.004	-0.005	-0.050	0.020
	(-0.450)	(0.189)	(-0.182)	(-1.230)	(0.649)
Wasted*sickness	0.057	0.018	0.053	0.009	0.119
	(1.533)	(0.652)	(1.615)	(0.266)	(2.106)**
Morbidity*sickness	0.015	-0.042	0.014	0.023	-0.005
	(0.278)	(-1.042)	(0.353)	(0.472)	(-0.082)
Stunted*morbidity*sickness	0.035	0.033	-0.076	-0.054	-0.142
	(0.554)	(0.781)	(-1.726)*	(-0.817)	(-2.044)*
Constant	-2.516	-1.815	-0.694	-2.258	-0.103
	(-3.981)***	(-3.671)***	(-1.551)	(-3.597)***	(-0.150)
Observations	1,238	1,533	1,160	1,025	1,032
R-squared	0.134	0.071	0.328	0.230	0.184
Number of communities	25	25	28	25	26
Adjusted R-square	0.104	0.0452	0.299	0.192	0.144

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

INDIA

VARIABLES	(1) PPVT R2	(2) CDA	(3) MATHS	(4) PPVT R3	(5) EGRA
Stunted	-0.078	-0.089	-0.084	0.023	-0.030
	(-3.095)***	(-2.876)***	(-3.050)***	(0.618)	(-1.057)
Wasted	-0.026	-0.001	-0.000	-0.003	0.036
	(-0.864)	(-0.030)	(-0.018)	(-0.080)	(0.948)
Life-threatening morbidity	0.014	-0.008	-0.012	-0.013	0.007
	(0.345)	(-0.170)	(-0.378)	(-0.359)	(0.188)
Recent sickness	0.007	-0.005	0.003	-0.003	-0.006
	(0.210)	(-0.151)	(0.105)	(-0.076)	(-0.164)
Stunted*wasted	-0.010	-0.050	-0.042	-0.063	-0.073
	(-0.394)	(-1.511)	(-1.570)	(-1.872)*	(-2.474)**
Stunted*morbidity	0.013	0.018	0.010	-0.008	-0.040
	(0.328)	(0.370)	(0.323)	(-0.206)	(-1.112)
Stunted*sickness	0.004	0.050	0.015	-0.052	0.008
	(0.129)	(1.307)	(0.500)	(-1.182)	(0.219)
Wasted*morbidity	-0.018	-0.034	-0.004	-0.014	0.005
	(-0.819)	(-1.091)	(-0.197)	(-0.503)	(0.217)
Wasted*sickness	-0.016	-0.065	-0.026	0.005	-0.036
	(-0.573)	(-1.827)*	(-1.221)	(0.143)	(-1.152)
Morbidity*sickness	-0.055	0.015	0.010	0.016	-0.006
	(-1.301)	(0.351)	(0.299)	(0.326)	(-0.136)
Stunted*morbidity*sickness	0.012	-0.063	-0.048	-0.005	0.003
	(0.324)	(-1.388)	(-1.323)	(-0.107)	(0.081)
Constant	-2.565	-2.771	-0.793	-0.684	-0.843
	(-4.288)***	(-4.222)***	(-1.583)	(-0.906)	(-1.218)
Observations	1,671	1,826	1,751	1,454	1,719
R-squared	0.157	0.120	0.323	0.144	0.203
Number of communities	101	101	101	101	101
Adjusted R-square	0.135	0.0984	0.303	0.113	0.179

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

PERU

VARIABLES	(1) PPVT R2	(2) CDA	(3) MATHS	(4) PPVT R3	(5) EGRA
Stunted	0.004	-0.028	-0.111	-0.083	-0.108
	(0.100)	(-0.625)	(-8.895)***	(-6.150)***	(-10.583)***
Wasted	-0.033	-0.006	-0.015	0.040	0.000
	(-1.698)*	(-0.119)	(-0.929)	(1.932)*	(0.014)
Life-threatening morbidity	-0.013	-0.008	-0.078	-0.052	-0.065
	(-0.304)	(-0.163)	(-9.285)***	(-6.182)***	(-4.421)***
Recent sickness	-0.025	-0.029	-0.023	-0.008	-0.015
	(-0.876)	(-0.911)	(-2.714)***	(-1.687)*	(-2.327)**
Stunted*morbidity	-0.001	-0.047	0.149	0.040	0.090
	(-0.018)	(-0.970)	(26.366)***	(2.778)***	(8.097)***
Stunted*sickness	0.001	-0.001	0.005	-0.011	0.008
	(0.024)	(-0.026)	(0.362)	(-0.784)	(0.582)
Wasted*sickness	-0.002	-0.044	-0.034	-0.049	-0.045
	(-0.098)	(-0.664)	(-2.197)**	(-3.016)***	(-1.745)*
Morbidity*sickness	0.039	0.012	0.036	0.036	0.015
	(0.965)	(0.201)	(4.111)***	(3.474)***	(0.850)
Stunted*morbidity*sickness	-0.043	0.040	-0.083	-0.012	-0.016
	(-0.824)	(0.700)	(-11.507)***	(-0.929)	(-1.359)
Constant	-1.499	-3.193	-2.736	-2.831	-1.920
	(-1.599)	(-4.994)***	(-7.456)***	(-7.087)***	(-6.915)***
Observations	1,569	1,812	1,756	1,623	1,621
R-squared	0.086	0.127	0.428	0.464	0.308
Number of communities	114	118	64	62	61
Adjusted R-square	0.0617	0.107	0.413	0.449	0.289

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

VIETNAM

VARIABLES	(1) PPVT R2	(2) CDA	(3) MATHS	(4) PPVT R3	(5) EGRA
Stunted	-0.027	-0.020	-0.078	-0.003	-0.012
	(-0.811)	(-0.577)	(-2.460)**	(-0.094)	(-0.417)
Wasted	-0.012	0.011	-0.028	0.000	-0.045
	(-0.500)	(0.583)	(-1.567)	(0.017)	(-1.920)*
Life-threatening morbidity	-0.003	-0.044	0.006	0.024	0.002
	(-0.080)	(-1.341)	(0.278)	(0.614)	(0.071)
Recent sickness	0.000	-0.037	-0.035	-0.037	-0.041
	(0.011)	(-1.536)	(-1.560)	(-1.036)	(-1.155)
Stunted*morbidity	-0.025	0.003	0.015		-0.003
	(-0.705)	(0.081)	(0.476)		(-0.080)
Stunted*sickness	-0.009	0.003	0.036	0.029	-0.001
	(-0.233)	(0.092)	(1.398)	(0.712)	(-0.024)
Morbidity*sickness	-0.054	0.019	0.027	-0.042	0.018
	(-1.689)	(0.618)	(0.780)	(-0.867)	(0.414)
Stunted*morbidity*sickness	0.018	-0.028	-0.005	0.002	0.004
	(0.560)	(-0.629)	(-0.126)	(0.045)	(0.079)
Constant	-2.974	-3.245	0.489	-0.597	0.137
	(-5.323)***	(-5.333)***	(0.845)	(-0.901)	(0.213)
Observations	1,371	1,534	1,516	1,422	1,502
R-squared	0.147	0.142	0.379	0.151	0.164
Number of communities	36	36	36	36	36
Adjusted R-square	0.122	0.120	0.360	0.124	0.139

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

Appendix C8. Robustness check, first research question (selected covariates)

ETHIOPIA ROUND 3

VARIABLES	(1) MATHS	(2) MATHS
Male	0.022	0.014
	(0.612)	(0.375)
Long-term illness or health problem	-0.093	-0.066
	(-1.566)	(-1.026)
Amharic is child's mother tongue	0.002	0.008
	(0.026)	(0.096)
First-born	-0.057	-0.055
	(-0.850)	(-0.817)
Child born in health facility (hospital or other)	0.246	0.234
	(2.155)**	(2.120)**
No vaccinations	-0.056	-0.046
	(-0.878)	(-0.743)
Attended pre-school	0.305	0.306
	(3.153)***	(3.201)***
Rural	-0.606	-0.611
	(-5.390)***	(-5.610)***
Carer's education: none	-0.016	-0.023
	(-0.231)	(-0.320)
Carer's education: primary	-0.022	-0.030
	(-0.365)	(-0.486)
Carer's education: secondary	-0.053	-0.057
	(-0.430)	(-0.472)
Housing quality index	0.117	0.138
	(0.832)	(0.971)
Access to services index	0.363	0.348
	(2.511)**	(2.432)**
Hours doing chores, domestic tasks, care	0.013	0.014
	(1.147)	(1.197)
Hours in school or studying	0.089	0.087
	(4.196)***	(4.146)***
PPVT raw z-scores R2	0.071	0.073
	(2.166)**	(2.230)**
CDA raw z-scores R2	0.053	0.053
	(1.913)*	(1.963)*
Height-for-age z-scores	0.016	
	(1.718)*	
Weight-for-height z-scores	0.011	
	(0.650)	
Life-threatening morbidity	-0.003	
	(-0.114)	
Recent sickness	-0.015	
	(-0.554)	
EMPI z-scores		-0.029
		(-1.572)
Constant	-1.120	-1.101
	(-2.591)**	(-2.778)**
Observations	1,112	1,140
R-squared	0.326	0.325
Number of communities	26	27
Adjusted R-square	0.301	0.302

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1
ETHIOPIA ROUND 3

VARIABLES	(1) PPVT	(2) PPVT
Male	-0.004	0.000
	(-0.082)	(0.005)
Long-term illness or health problem	0.134	0.160
	(1.429)	(1.703)
Amharic is child’s mother tongue	0.255	0.298
	(1.204)	(1.518)
First-born	-0.086	-0.071
	(-1.118)	(-0.965)
Child born in health facility (hospital or other)	0.285	0.297
	(1.676)	(1.834)*
No vaccinations	-0.129	-0.119
	(-2.356)**	(-2.336)**
Attended pre-school	0.266	0.273
	(1.802)*	(1.736)*
Rural	-0.437	-0.437
	(-2.257)**	(-2.298)**
Carer’s education: none	-0.130	-0.128
	(-0.924)	(-0.949)
Carer’s education: primary	-0.158	-0.151
	(-1.489)	(-1.508)
Carer’s education: secondary	-0.235	-0.238
	(-1.487)	(-1.582)
Housing quality index	0.138	0.118
	(0.753)	(0.646)
Access to services index	0.170	0.160
	(1.148)	(1.093)
Hours doing chores, domestic tasks, care	0.009	0.014
	(0.747)	(1.068)
Hours in school or studying	0.086	0.084
	(4.180)***	(4.246)***
PPVT raw z-scores R2	0.119	0.122
	(3.765)***	(3.891)***
CDA raw z-scores R2	0.088	0.088
	(3.068)***	(3.086)***
Height-for-age z-scores	0.028	
	(2.431)**	
Weight-for-height z-scores	0.009	
	(0.358)	
Life-threatening morbidity	-0.002	
	(-0.093)	
Recent sickness	-0.035	
	(-1.904)*	
EMPI z-scores		-0.047
		(-1.723)*
Constant	-2.387	-2.386
	(-4.482)***	(-4.487)***
Observations	986	1,014
R-squared	0.261	0.256
Number of communities	23	24
Adjusted R-square	0.230	0.228

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

ETHIOPIA ROUND 3

VARIABLES	(1) EGRA	(2) EGRA
Male	-0.017	-0.016
	(-0.318)	(-0.301)
Long-term illness or health problem	0.109	0.092
	(1.390)	(1.181)
Amharic is child's mother tongue	-0.186	-0.171
	(-2.227)**	(-1.583)
First-born	-0.056	-0.053
	(-0.621)	(-0.602)
Child born in health facility (hospital or other)	0.099	0.101
	(0.537)	(0.552)
No vaccinations	-0.006	0.009
	(-0.085)	(0.140)
Attended pre-school	-0.051	-0.034
	(-0.556)	(-0.366)
Rural	-0.344	-0.356
	(-2.492)**	(-2.719)**
Carer's education: none	-0.051	-0.047
	(-0.544)	(-0.525)
Carer's education: primary	-0.067	-0.059
	(-0.952)	(-0.856)
Carer's education: secondary	-0.049	-0.033
	(-0.541)	(-0.367)
Housing quality index	0.514	0.523
	(1.761)*	(1.772)*
Access to services index	-0.136	-0.135
	(-0.856)	(-0.871)
Hours doing chores, domestic tasks, care	-0.040	-0.038
	(-1.763)*	(-1.694)
Hours in school or studying	0.048	0.047
	(1.746)*	(1.749)*
PPVT raw z-scores R2	0.045	0.045
	(1.071)	(1.078)
CDA raw z-scores R2	0.046	0.045
	(1.104)	(1.123)
Height-for-age z-scores	0.016	
	(1.261)	
Weight-for-height z-scores	-0.015	
	(-0.807)	
Life-threatening morbidity	-0.030	
	(-1.136)	
Recent sickness	0.012	
	(0.419)	
EMPI z-scores		-0.017
		(-0.834)
Constant	-0.332	-0.212
	(-0.478)	(-0.317)
Observations	994	1,021
R-squared	0.167	0.165
Number of communities	24	25
Adjusted R-square	0.132	0.134

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

INDIA ROUND 3

VARIABLES	(1) MATHS	(2) MATHS
Male	0.172	0.175
	(4.158)***	(4.242)***
Long-term illness or health problem	0.095	0.096
	(1.056)	(1.075)
Child from scheduled tribe	-0.144	-0.146
	(-1.986)**	(-1.994)**
Child from backward caste	-0.171	-0.180
	(-2.466)**	(-2.628)***
Child from non-Hindu background	-0.216	-0.225
	(-1.673)*	(-1.782)*
Child's first language is Telugu	0.129	0.124
	(1.734)*	(1.677)*
First-born	-0.017	-0.025
	(-0.373)	(-0.554)
No vaccinations	0.039	0.036
	(0.969)	(0.905)
Attended pre-school	-0.026	-0.012
	(-0.460)	(-0.213)
Rural	0.130	0.120
	(1.220)	(1.108)
Carer's education: none	-0.265	-0.273
	(-2.831)***	(-2.878)***
Carer's education: primary	-0.125	-0.122
	(-1.224)	(-1.183)
Carer's education: secondary	-0.111	-0.117
	(-1.402)	(-1.466)
Housing quality index	0.177	0.166
	(1.759)*	(1.623)
Access to services index	0.431	0.428
	(3.036)***	(3.046)***
Not enrolled	-1.026	-1.046
	(-13.002)***	(-13.527)***
Enrolled in first grade	-0.763	-0.784
	(-11.106)***	(-11.734)***
Enrolled in second grade	-0.318	-0.332
	(-5.565)***	(-5.820)***
Hours doing chores, domestic tasks, care	0.043	0.046
	(1.481)	(1.599)
Hours in school or studying	0.093	0.092
	(4.923)***	(4.848)***
CDA raw z-scores R2	0.142	0.145
	(5.820)***	(5.955)***
PPVT raw z-scores R2	0.072	0.075
	(2.356)**	(2.441)**
Public school	-0.131	-0.134
	(-2.303)**	(-2.358)**
Height-for-age z-scores	0.048	
	(3.423)***	
Weight-for-height z-scores	0.020	
	(1.149)	
Life-threatening morbidity	-0.011	
	(-0.485)	
Recent sickness	-0.001	

	(-0.028)	
EMPI z-scores		-0.065
		(-3.126)***
Constant	-0.848	-0.810
	(-1.788)*	(-1.692)*
Observations	1,671	1,671
R-squared	0.340	0.339
Number of communities	101	101
Adjusted R-square	0.322	0.322

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

INDIA ROUND 3

VARIABLES	(1) PPVT	(2) PPVT
Male	0.260	0.262
	(4.662)***	(4.636)***
Long-term illness or health problem	0.147	0.149
	(0.948)	(0.947)
Child from scheduled tribe	0.005	0.006
	(0.052)	(0.064)
Child from backward caste	-0.027	-0.029
	(-0.276)	(-0.295)
Child from non-Hindu background	0.062	0.066
	(0.280)	(0.295)
Child’s first language is Telugu	0.018	0.014
	(0.192)	(0.152)
First-born	0.060	0.058
	(0.990)	(0.945)
No vaccinations	-0.028	-0.032
	(-0.437)	(-0.504)
Attended pre-school	-0.057	-0.052
	(-0.793)	(-0.729)
Rural	-0.108	-0.111
	(-0.592)	(-0.617)
Carer’s education: none	-0.085	-0.086
	(-0.518)	(-0.525)
Carer’s education: primary	-0.137	-0.133
	(-0.715)	(-0.699)
Carer’s education: secondary	-0.032	-0.031
	(-0.191)	(-0.183)
Housing quality index	0.046	0.042
	(0.450)	(0.419)
Access to services index	0.608	0.603
	(3.175)***	(3.158)***
Not enrolled	-0.369	-0.375
	(-3.642)***	(-3.779)***
Enrolled in first grade	-0.258	-0.266
	(-2.824)***	(-3.032)***
Enrolled in second grade	-0.106	-0.110
	(-1.213)	(-1.265)
Hours doing chores, domestic tasks, care	-0.046	-0.045
	(-1.767)*	(-1.722)*
Hours in school or studying	0.089	0.088
	(2.880)***	(2.870)***
CDA raw z-scores R2	0.084	0.084
	(3.483)***	(3.409)***
PPVT raw z-scores R2	0.144	0.145
	(3.467)***	(3.501)***
Public school	-0.065	-0.065
	(-0.754)	(-0.758)
Height-for-age z-scores	0.017	
	(0.888)	
Weight-for-height z-scores	0.020	
	(0.747)	
Life-threatening morbidity	-0.013	
	(-0.641)	
Recent sickness	-0.009	
	(-0.308)	
EMPI z-scores		-0.041

		(-1.824)*
Constant	-0.488	-0.506
	(-0.733)	(-0.761)
Observations	1,383	1,383
R-squared	0.164	0.164
Number of communities	101	101
Adjusted R-square	0.136	0.138

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

INDIA ROUND 3

VARIABLES	(1) EGRA	(2) EGRA
Male	0.085	0.089
	(2.005)**	(2.069)**
Long-term illness or health problem	0.126	0.128
	(1.220)	(1.241)
Child from scheduled tribe	-0.010	-0.009
	(-0.117)	(-0.100)
Child from backward caste	-0.155	-0.158
	(-1.656)	(-1.684)*
Child from non-Hindu background	0.130	0.127
	(1.187)	(1.156)
Child's first language is Telugu	0.196	0.193
	(2.489)**	(2.464)**
First-born	0.101	0.099
	(2.412)**	(2.382)**
No vaccinations	0.022	0.017
	(0.488)	(0.386)
Attended pre-school	-0.035	-0.031
	(-0.482)	(-0.418)
Rural	0.062	0.058
	(0.505)	(0.477)
Carer's education: none	-0.190	-0.195
	(-1.805)*	(-1.880)*
Carer's education: primary	-0.098	-0.098
	(-0.829)	(-0.833)
Carer's education: secondary	-0.106	-0.111
	(-1.085)	(-1.161)
Housing quality index	0.097	0.093
	(0.984)	(0.950)
Access to services index	0.253	0.248
	(1.689)*	(1.688)*
Not enrolled	-0.887	-0.891
	(-8.582)***	(-8.698)***
Enrolled in first grade	-0.744	-0.751
	(-9.238)***	(-9.500)***
Enrolled in second grade	-0.352	-0.356
	(-4.850)***	(-4.928)***
Hours doing chores, domestic tasks, care	0.068	0.069
	(2.337)**	(2.393)**
Hours in school or studying	0.067	0.067
	(3.170)***	(3.208)***
CDA raw z-scores R2	0.102	0.102
	(3.928)***	(3.945)***
PPVT raw z-scores R2	0.099	0.099
	(4.347)***	(4.287)***
Public school	-0.043	-0.042
	(-0.707)	(-0.693)
Height-for-age z-scores	0.019	
	(1.123)	
Weight-for-height z-scores	0.005	
	(0.187)	
Life-threatening morbidity	-0.007	
	(-0.397)	

Recent sickness	-0.013	
	(-0.528)	
EMPI z-scores		-0.044
		(-1.882)*
Constant	-0.495	-0.495
	(-0.765)	(-0.756)
Observations	1,641	1,641
R-squared	0.213	0.214
Number of communities	101	101
Adjusted R-square	0.191	0.193

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

PERU ROUND 3

VARIABLES	(1) MATHS	(2) MATHS
Male	0.171	0.159
	(16.388)***	(16.441)***
Long-term illness or health problem	-0.075	-0.064
	(-4.057)***	(-3.650)***
Child is either native amazon, black or Asiatic	0.128	0.124
	(4.118)***	(4.027)***
Child first language is Spanish	0.180	0.205
	(8.991)***	(13.777)***
First-born	0.116	0.118
	(5.845)***	(6.299)***
No vaccinations	0.058	0.064
	(5.967)***	(6.464)***
Attended pre-school	-0.045	-0.036
	(-3.376)***	(-2.653)**
Attended crèche before 3yrs of age	-0.036	-0.042
	(-1.696)*	(-2.021)**
Rural	-0.178	-0.190
	(-35.188)***	(-34.505)***
Carer’s education: none	-0.300	-0.331
	(-11.992)***	(-15.273)***
Carer’s education: primary	-0.256	-0.269
	(-5.411)***	(-6.167)***
Carer’s education: secondary	-0.185	-0.186
	(-3.701)***	(-3.755)***
Housing quality index	0.060	0.065
	(1.798)*	(2.222)**
Access to services index	0.485	0.479
	(16.182)***	(15.710)***
Not enrolled	-1.613	-1.536
	(-49.083)***	(-42.750)***
Enrolled in first grade	-1.160	-1.167
	(-30.504)***	(-30.393)***
Enrolled in second grade	-0.459	-0.460
	(-42.433)***	(-46.851)***
Hours doing chores, domestic tasks, care	0.015	0.014
	(1.989)*	(2.011)**
Hours in school or studying	0.059	0.058
	(6.882)***	(6.630)***
PPVT raw z-scores R2	-0.013	-0.012
	(-0.853)	(-0.858)
CDA raw z-scores R2	0.119	0.123
	(10.451)***	(11.034)***
Public school	-0.234	-0.238
	(-14.180)***	(-16.302)***
Height-for-age z-scores	0.063	
	(7.830)***	
Weight-for-height z-scores	0.028	
	(4.131)***	
Life-threatening morbidity	-0.017	
	(-5.255)***	
Recent sickness	-0.025	
	(-3.578)***	
EMPI z-scores		-0.067
		(-16.775)***

Constant	-3.108	-2.901
	(-8.616)***	(-9.067)***
Observations	1,701	1,702
R-squared	0.430	0.426
Number of communities	62	62
Adjusted R-square	0.417	0.414

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

PERU ROUND 3

VARIABLES	(1) PPVT	(2) PPVT
Male	0.132	0.124
	(16.686)***	(13.069)***
Long-term illness or health problem	-0.015	-0.010
	(-1.057)	(-0.705)
Child is either native amazon, black or Asiatic	0.397	0.390
	(14.773)***	(13.969)***
Child first language is Spanish	0.232	0.255
	(19.551)***	(17.961)***
First-born	0.016	0.018
	(1.203)	(1.324)
No vaccinations	-0.049	-0.045
	(-4.443)***	(-3.498)***
Attended pre-school	0.067	0.078
	(5.878)***	(5.968)***
Attended crèche before 3yrs of age	0.063	0.055
	(5.320)***	(4.869)***
Rural	-0.197	-0.202
	(-28.703)***	(-27.309)***
Carer’s education: none	-0.516	-0.545
	(-21.904)***	(-27.210)***
Carer’s education: primary	-0.381	-0.392
	(-35.535)***	(-37.938)***
Carer’s education: secondary	-0.248	-0.250
	(-13.245)***	(-13.715)***
Housing quality index	0.103	0.106
	(4.160)***	(4.314)***
Access to services index	0.627	0.632
	(46.607)***	(44.484)***
Not enrolled	-1.343	-1.488
	(-28.568)***	(-67.695)***
Enrolled in first grade	-0.689	-0.686
	(-23.328)***	(-22.252)***
Enrolled in second grade	-0.094	-0.095
	(-11.705)***	(-11.544)***
Hours doing chores, domestic tasks, care	-0.021	-0.021
	(-4.437)***	(-5.006)***
Hours in school or studying	0.021	0.021
	(7.046)***	(6.705)***
PPVT raw z-scores R2	0.057	0.056
	(10.124)***	(10.555)***
CDA raw z-scores R2	0.161	0.163
	(28.835)***	(29.615)***
Public school	-0.160	-0.162
	(-7.173)***	(-8.113)***
Height-for-age z-scores	0.057	
	(5.301)***	
Weight-for-height z-scores	0.002	
	(0.337)	
Life-threatening morbidity	-0.020	
	(-4.292)***	
Recent sickness	-0.002	
	(-0.632)	
EMPI z-scores		-0.043

		(-10.208)***
Constant	-2.927	-2.673
	(-9.086)***	(-9.714)***
Observations	1,572	1,573
R-squared	0.488	0.484
Number of communities	60	60
Adjusted R-square	0.474	0.472

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

PERU ROUND 3

VARIABLES	(1) EGRA	(2) EGRA
Male	0.035	0.021
	(4.044)***	(2.101)**
Long-term illness or health problem	-0.078	-0.067
	(-2.631)**	(-2.277)**
Child is either native amazon, black or Asiatic	0.156	0.148
	(4.802)***	(4.856)***
Child first language is Spanish	0.444	0.470
	(25.918)***	(30.394)***
First-born	0.010	0.008
	(0.515)	(0.429)
No vaccinations	-0.068	-0.060
	(-4.551)***	(-4.238)***
Attended pre-school	0.088	0.097
	(3.271)***	(3.270)***
Attended crèche before 3yrs of age	0.026	0.019
	(2.112)**	(1.561)
Rural	-0.268	-0.274
	(-35.312)***	(-34.921)***
Carer’s education: none	-0.302	-0.331
	(-11.273)***	(-13.092)***
Carer’s education: primary	-0.225	-0.239
	(-12.212)***	(-14.176)***
Carer’s education: secondary	-0.247	-0.250
	(-12.071)***	(-12.389)***
Housing quality index	0.108	0.114
	(4.445)***	(4.938)***
Access to services index	0.366	0.366
	(11.802)***	(12.718)***
Not enrolled	-1.900	-2.079
	(-58.252)***	(-41.782)***
Enrolled in first grade	-0.982	-0.989
	(-60.881)***	(-61.915)***
Enrolled in second grade	-0.163	-0.167
	(-12.750)***	(-12.428)***
Hours doing chores, domestic tasks, care	-0.013	-0.014
	(-4.288)***	(-3.679)***
Hours in school or studying	0.015	0.015
	(4.114)***	(4.161)***
PPVT raw z-scores R2	0.023	0.026
	(3.709)***	(4.592)***
CDA raw z-scores R2	0.156	0.160
	(8.649)***	(8.950)***
Public school	-0.054	-0.056
	(-4.947)***	(-4.531)***
Height-for-age z-scores	0.064	
	(6.496)***	
Weight-for-height z-scores	0.036	
	(5.236)***	
Life-threatening morbidity	-0.023	
	(-3.718)***	
Recent sickness	-0.004	
	(-1.083)	
EMPI z-scores		-0.054
		(-8.431)***
Constant	-1.262	-0.969

	(-5.682)***	(-4.169)***
Observations	1,569	1,570
R-squared	0.327	0.323
Number of communities	59	59
Adjusted R-square	0.310	0.307

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

VIETNAM ROUND 3		
VARIABLES	(1) MATHS	(2) MATHS
Male	0.006	0.003
	(0.144)	(0.084)
Long-term illness or health problem	-0.079	-0.081
	(-1.521)	(-1.542)
Child does not belong to Kihn group	-0.175	-0.180
	(-1.086)	(-1.133)
	0.265	0.267
	(1.549)	(1.597)
First-born	0.050	0.047
	(1.319)	(1.204)
No vaccinations	-0.049	-0.048
	(-0.853)	(-0.822)
Attended pre-school	-0.169	-0.170
	(-1.499)	(-1.526)
Attended crèche before 3yrs of age	0.066	0.065
	(1.395)	(1.340)
Rural	0.058	0.090
	(0.526)	(0.782)
Carer's education: none	-0.432	-0.434
	(-2.568)**	(-2.577)**
Carer's education: primary	-0.246	-0.244
	(-2.662)**	(-2.581)**
Carer's education: secondary	-0.090	-0.096
	(-1.110)	(-1.195)
Housing quality index	0.062	0.065
	(0.396)	(0.418)
Access to services index	0.188	0.193
	(0.946)	(1.008)
Not enrolled	-1.682	-1.752
	(-4.045)***	(-4.092)***
Enrolled in first grade	-1.154	-1.213
	(-5.674)***	(-5.608)***
Enrolled in second grade	-0.181	-0.233
	(-0.910)	(-1.121)
Hours doing chores, domestic tasks, care	-0.028	-0.031
	(-1.240)	(-1.381)
Hours in school or studying	0.027	0.029
	(1.999)*	(2.114)**
PPVT raw z-scores R2	0.061	0.058
	(2.448)**	(2.416)**
CDA raw z-scores R2	0.109	0.107
	(3.749)***	(3.663)***
Height-for-age z-scores	0.048	
	(2.747)***	
Weight-for-height z-scores	0.024	
	(1.086)	
Life-threatening morbidity	0.031	
	(1.574)	
Recent sickness	-0.010	
	(-0.538)	
EMPI z-scores		-0.036
		(-1.655)

Constant	0.609	0.628
	(1.002)	(0.986)
Observations	1,343	1,343
R-squared	0.393	0.389
Number of communities	36	36
Adjusted R-square	0.374	0.371

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

VIETNAM ROUND 3

VARIABLES	(1) PPVT	(2) PPVT
Male	0.012	0.015
	(0.302)	(0.402)
Long-term illness or health problem	0.055	0.060
	(0.802)	(0.907)
Child does not belong to Kihn group	-0.125	-0.117
	(-0.570)	(-0.548)
Child’s mother tongue is Vietnamese	0.046	0.041
	(0.240)	(0.215)
First-born	0.021	0.020
	(0.426)	(0.411)
No vaccinations	-0.071	-0.077
	(-1.606)	(-1.685)
Attended pre-school	-0.035	-0.029
	(-0.507)	(-0.414)
Attended crèche before 3yrs of age	0.073	0.069
	(0.964)	(0.909)
Rural	-0.183	-0.188
	(-1.623)	(-1.694)*
Carer’s education: none	-0.633	-0.623
	(-5.356)***	(-5.268)***
Carer’s education: primary	-0.274	-0.278
	(-3.421)***	(-3.596)***
Carer’s education: secondary	-0.104	-0.106
	(-1.325)	(-1.360)
Housing quality index	0.027	0.031
	(0.180)	(0.208)
Access to services index	0.036	0.039
	(0.188)	(0.204)
Not enrolled	-0.344	-0.329
	(-0.895)	(-0.837)
Enrolled in first grade	-0.361	-0.344
	(-1.121)	(-1.035)
Enrolled in second grade	-0.167	-0.156
	(-0.534)	(-0.485)
Hours doing chores, domestic tasks, care	-0.027	-0.028
	(-0.954)	(-0.976)
Hours in school or studying	-0.004	-0.005
	(-0.264)	(-0.314)
PPVT raw z-scores R2	0.194	0.195
	(5.413)***	(5.470)***
CDA raw z-scores R2	0.113	0.114
	(4.152)***	(4.180)***
Height-for-age z-scores	-0.013	
	(-0.573)	

Weight-for-height z-scores	-0.033	
	(-1.210)	
Life-threatening morbidity	-0.004	
	(-0.148)	
Recent sickness	-0.021	
	(-0.794)	
EMPI z-scores		-0.011
		(-0.388)
Constant	0.008	-0.027
	(0.010)	(-0.032)
Observations	1,259	1,259
R-squared	0.195	0.193
Number of communities	36	36
Adjusted R-square	0.167	0.167

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

VIETNAM ROUND 3

VARIABLES	(1) EGRA	(2) EGRA
Male	-0.090	-0.093
	(-2.013)*	(-2.122)**
Long-term illness or health problem	0.007	-0.003
	(0.093)	(-0.038)
Child does not belong to Kihn group	0.056	0.043
	(0.734)	(0.567)
Child’s mother tongue is Vietnamese	0.154	0.149
	(1.220)	(1.177)
First-born	0.013	0.014
	(0.296)	(0.316)
No vaccinations	0.017	0.019
	(0.349)	(0.400)
Attended pre-school	0.089	0.088
	(0.834)	(0.831)
Attended crèche before 3yrs of age	-0.010	-0.011
	(-0.218)	(-0.230)
Rural	0.122	0.138
	(0.577)	(0.662)
Carer’s education: none	-0.557	-0.559
	(-4.219)***	(-4.176)***
Carer’s education: primary	-0.191	-0.193
	(-2.083)**	(-2.059)**
Carer’s education: secondary	-0.036	-0.040
	(-0.520)	(-0.577)
Housing quality index	0.274	0.280
	(1.520)	(1.566)
Access to services index	0.119	0.106
	(0.794)	(0.744)
Not enrolled	-1.163	-1.199
	(-2.725)***	(-2.738)***
Enrolled in first grade	-0.555	-0.591
	(-3.134)***	(-3.385)***
Enrolled in second grade	-0.221	-0.244
	(-1.435)	(-1.559)
Hours doing chores, domestic tasks, care	-0.031	-0.032
	(-1.450)	(-1.486)
Hours in school or studying	-0.001	-0.001
	(-0.088)	(-0.032)
PPVT raw z-scores R2	0.122	0.119
	(4.992)***	(4.864)***
CDA raw z-scores R2	0.118	0.118
	(2.745)***	(2.746)***
Height-for-age z-scores	0.028	
	(1.471)	
Weight-for-height z-scores	0.052	
	(1.978)*	
Life-threatening morbidity	0.024	
	(0.921)	
Recent sickness	-0.024	
	(-0.812)	
EMPI z-scores		-0.029
		(-0.905)
Constant	0.664	0.688
	(0.884)	(0.911)

Observations	1,331	1,331
R-squared	0.189	0.184
Number of communities	36	36
Adjusted R-square	0.162	0.160

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Standard errors clustered at community level ; community fixed effects included in all regressions

Appendix C9. Robustness check, second research question (selected covariates)

ETHIOPIA

VARIABLES	(1) MATHS	(2) PPVT R3	(3) EGRA
Male	0.014	-0.007	-0.015
	(0.365)	(-0.142)	(-0.295)
Long-term illness or health problem	-0.072	0.152	0.109
	(-1.051)	(1.538)	(1.283)
Amharic is child’s mother tongue	0.017	0.304	-0.152
	(0.201)	(1.598)	(-1.470)
First-born	-0.053	-0.072	-0.049
	(-0.830)	(-0.988)	(-0.542)
Child born in health facility (hospital or other)	0.239	0.307	0.108
	(2.099)**	(1.851)*	(0.578)
No vaccinations	-0.047	-0.125	0.026
	(-0.758)	(-2.363)**	(0.393)
Attended pre-school	0.314	0.287	-0.037
	(3.059)***	(1.816)*	(-0.338)
Rural	-0.611	-0.426	-0.353
	(-5.534)***	(-2.238)**	(-2.767)**
Carer’s education: none	-0.026	-0.136	-0.035
	(-0.385)	(-1.041)	(-0.388)
Carer’s education: primary	-0.019	-0.159	-0.041
	(-0.299)	(-1.637)	(-0.613)
Carer’s education: secondary	-0.045	-0.241	-0.024
	(-0.392)	(-1.619)	(-0.275)
Housing quality index	0.112	0.104	0.534
	(0.849)	(0.589)	(1.805)*
Access to services index	0.349	0.164	-0.130
	(2.483)**	(1.135)	(-0.870)
Hours doing chores, domestic tasks, care	0.013	0.014	-0.039
	(1.147)	(1.116)	(-1.903)*
Hours in school or studying	0.090	0.087	0.052
	(4.219)***	(4.247)***	(1.920)*
PPVT raw z-scores R2	0.073	0.121	0.044
	(2.165)**	(3.759)***	(1.025)
CDA raw z-scores R2	0.054	0.090	0.041
	(1.963)*	(3.182)***	(0.995)
Stunted	0.014	-0.042	0.009
	(0.396)	(-1.001)	(0.208)
Wasted	-0.064	0.047	-0.094
	(-2.520)**	(1.200)	(-1.640)
Life-threatening morbidity	0.011	-0.007	-0.048
	(0.362)	(-0.148)	(-0.663)
Recent sickness	-0.013	-0.059	0.023
	(-0.364)	(-2.299)**	(0.675)
Stunted*wasted	-0.027	-0.057	-0.025
	(-1.060)	(-1.943)*	(-0.869)
Stunted*morbidity	0.021	0.037	0.104
	(0.488)	(0.557)	(1.260)
Stunted*sickness	0.009	0.052	0.005
	(0.240)	(1.389)	(0.110)
Wasted*morbidity	-0.001	-0.050	0.018
	(-0.028)	(-1.165)	(0.614)

Wasted*sickness	0.057	-0.000	0.112
	(1.740)*	(-0.002)	(1.932)*
Morbidity*sickness	0.020	0.026	0.008
	(0.482)	(0.479)	(0.117)
Stunted*morbidity*sickness	-0.093	-0.058	-0.147
	(-1.758)*	(-0.824)	(-2.124)**
Constant	-1.100	-2.362	-0.415
	(-2.777)**	(-4.366)***	(-0.614)
Observations	1,140	1,014	1,021
R-squared	0.333	0.261	0.180
Number of communities	27	24	25
Adjusted R-squared	0.304	0.225	0.141

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

INDIA			
	(1)	(2)	(3)
VARIABLES	MATHS	PPVT R3	EGRA
Male	0.179	0.262	0.087
	(4.295)***	(4.537)***	(2.036)**
Long-term illness or health problem	0.100	0.147	0.135
	(1.107)	(0.913)	(1.277)
Child from scheduled tribe	-0.133	0.007	0.001
	(-1.824)*	(0.072)	(0.016)
Child from backward caste	-0.175	-0.029	-0.152
	(-2.442)**	(-0.295)	(-1.573)
Child from non-Hindu background	-0.216	0.057	0.140
	(-1.626)	(0.254)	(1.291)
Child's first language is Telugu	0.125	0.023	0.201
	(1.705)*	(0.248)	(2.529)**
First-born	-0.022	0.058	0.096
	(-0.501)	(0.954)	(2.319)**
No vaccinations	0.034	-0.031	0.021
	(0.811)	(-0.467)	(0.469)
Attended pre-school	-0.019	-0.050	-0.039
	(-0.340)	(-0.699)	(-0.514)
Rural	0.134	-0.099	0.072
	(1.301)	(-0.541)	(0.600)
Carer’s education: none	-0.272	-0.087	-0.190
	(-2.911)***	(-0.518)	(-1.794)*
Carer’s education: primary	-0.128	-0.124	-0.102
	(-1.238)	(-0.644)	(-0.869)
Carer’s education: secondary	-0.122	-0.027	-0.111
	(-1.524)	(-0.160)	(-1.127)
Housing quality index	0.165	0.034	0.085
	(1.649)	(0.331)	(0.852)
Access to services index	0.425	0.628	0.276
	(3.050)***	(3.254)***	(1.865)*
Not enrolled	-1.032	-0.369	-0.888
	(-13.557)***	(-3.625)***	(-8.624)***
Enrolled in first grade	-0.768	-0.253	-0.738
	(-11.498)***	(-2.857)***	(-9.283)***
Enrolled in second grade	-0.321	-0.105	-0.353
	(-5.615)***	(-1.204)	(-4.888)***
Hours doing chores, domestic tasks, care	0.043	-0.043	0.068
	(1.519)	(-1.617)	(2.398)**
Hours in school or studying	0.091	0.088	0.063
	(4.834)***	(2.895)***	(3.102)***
CDA raw z-scores R2	0.141	0.083	0.098
	(5.941)***	(3.427)***	(3.751)***
PPVT raw z-scores R2	0.075	0.145	0.100
	(2.445)**	(3.593)***	(4.301)***
Public school	-0.134	-0.061	-0.040
	(-2.351)**	(-0.683)	(-0.664)
Stunted	-0.068	0.029	-0.021
	(-2.523)**	(0.871)	(-0.694)
Wasted	-0.005	-0.006	0.041
	(-0.221)	(-0.125)	(1.065)
Life-threatening morbidity	-0.006	-0.017	0.001

	(-0.199)	(-0.467)	(0.036)
Recent sickness	0.004	0.001	-0.011
	(0.130)	(0.025)	(-0.283)
Stunted*wasted	-0.045	-0.063	-0.079
	(-1.758)*	(-1.953)*	(-2.830)***
Stunted*morbidity	0.003	-0.006	-0.034
	(0.102)	(-0.153)	(-0.898)
Stunted*sickness	0.012	-0.048	0.015
	(0.376)	(-1.039)	(0.385)
Wasted*morbidity	0.005	-0.005	0.011
	(0.248)	(-0.195)	(0.501)
Wasted*sickness	-0.010	0.013	-0.025
	(-0.470)	(0.374)	(-0.836)
Morbidity*sickness	0.014	0.025	0.008
	(0.419)	(0.528)	(0.178)
Stunted*morbidity*sickness	-0.044	-0.012	-0.004
	(-1.171)	(-0.256)	(-0.086)
Constant	-0.913	-0.618	-0.579
	(-1.989)**	(-0.923)	(-0.878)
Observations	1,671	1,383	1,641
R-squared	0.347	0.170	0.221
Number of communities	101	101	101
Adjusted R-squared	0.326	0.137	0.196

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

PERU			
	(1)	(2)	(3)
VARIABLES	MATHS	PPVT R3	EGRA
Male	0.175	0.134	0.034
	(17.192)***	(16.778)***	(3.810)***
Long-term illness or health problem	-0.076	-0.013	-0.077
	(-4.362)***	(-0.961)	(-2.619)**
Child is either native amazon, black or Asiatic	0.133	0.406	0.156
	(4.230)***	(14.933)***	(5.072)***
Child first language is Spanish	0.185	0.234	0.439
	(12.919)***	(19.108)***	(21.510)***
First-born	0.122	0.021	0.015
	(6.752)***	(1.747)*	(0.931)
No vaccinations	0.063	-0.047	-0.061
	(5.679)***	(-4.220)***	(-3.680)***
Attended pre-school	-0.040	0.070	0.092
	(-3.281)***	(6.166)***	(3.571)***
Attended crèche before 3yrs of age	-0.029	0.060	0.026
	(-1.311)	(4.942)***	(1.774)*
Rural	-0.177	-0.196	-0.270
	(-33.527)***	(-27.509)***	(-37.496)***
Carer’s education: none	-0.314	-0.526	-0.320
	(-12.355)***	(-24.368)***	(-14.264)***
Carer’s education: primary	-0.280	-0.392	-0.244
	(-6.184)***	(-37.046)***	(-13.930)***
Carer’s education: secondary	-0.192	-0.250	-0.254
	(-3.954)***	(-13.338)***	(-12.811)***
Housing quality index	0.056	0.108	0.106
	(1.860)*	(4.368)***	(4.492)***
Access to services index	0.490	0.636	0.369
	(16.191)***	(44.622)***	(13.123)***
Not enrolled	-1.555	-1.457	-2.145
	(-56.031)***	(-70.562)***	(-61.446)***
Enrolled in first grade	-1.171	-0.690	-0.982
	(-30.801)***	(-22.854)***	(-59.898)***
Enrolled in second grade	-0.460	-0.091	-0.163
	(-45.734)***	(-10.296)***	(-11.033)***
Hours doing chores, domestic tasks, care	0.018	-0.019	-0.011
	(2.671)***	(-4.157)***	(-2.787)***
Hours in school or studying	0.059	0.021	0.015
	(6.884)***	(6.373)***	(4.081)***
PPVT raw z-scores R2	-0.012	0.057	0.026
	(-0.846)	(10.125)***	(4.519)***
CDA raw z-scores R2	0.125	0.162	0.160
	(11.131)***	(29.536)***	(8.854)***
Public school	-0.243	-0.159	-0.060
	(-13.562)***	(-6.554)***	(-5.378)***
Stunted	-0.114	-0.073	-0.123
	(-9.354)***	(-4.201)***	(-10.106)***
Wasted	-0.024	0.031	-0.007
	(-1.518)	(1.547)	(-0.275)
Life-threatening morbidity	-0.084	-0.056	-0.068
	(-9.433)***	(-7.231)***	(-4.693)***
Recent sickness	-0.026	-0.005	-0.012

	(-3.161)***	(-1.030)	(-1.660)
Stunted*morbidity	0.151	0.054	0.111
	(25.866)***	(3.717)***	(9.418)***
Stunted*sickness	0.003	-0.010	0.021
	(0.223)	(-0.626)	(1.427)
Wasted*sickness	-0.017	-0.032	-0.024
	(-0.986)	(-1.870)*	(-0.802)
Morbidity*sickness	0.036	0.031	0.017
	(3.520)***	(2.549)**	(0.821)
Stunted*morbidity*sickness	-0.080	-0.024	-0.041
	(-10.855)***	(-1.963)*	(-2.875)***
Constant	-2.940	-2.898	-1.110
	(-7.917)***	(-9.925)***	(-4.283)***
Observations	1,702	1,573	1,570
R-squared	0.434	0.488	0.328
Number of communities	62	60	59
Adjusted R-squared	0.419	0.472	0.308

Robust t-statistics in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$.
Standard errors clustered at community level ; community fixed effects included in all regressions

VIETNAM			
VARIABLES	(1) MATHS	(2) PPVT R3	(3) EGRA
Male	0.004	0.014	-0.089
	(0.108)	(0.376)	(-2.037)**
Long-term illness or health problem	-0.086	0.063	-0.010
	(-1.690)*	(0.916)	(-0.135)
Child does not belong to Kihn group	-0.185	-0.124	0.056
	(-1.195)	(-0.572)	(0.676)
Child's mother tongue is Vietamese	0.258	0.050	0.156
	(1.508)	(0.271)	(1.207)
First-born	0.051	0.017	0.011
	(1.339)	(0.343)	(0.251)
No vaccinations	-0.050	-0.075	0.018
	(-0.891)	(-1.628)	(0.381)
Attended pre-school	-0.176	-0.025	0.091
	(-1.581)	(-0.353)	(0.861)
Attended crèche before 3yrs of age	0.061	0.068	-0.014
	(1.297)	(0.903)	(-0.298)
Rural	0.065	-0.193	0.109
	(0.632)	(-1.767)*	(0.537)
Carer’s education: none	-0.433	-0.623	-0.586
	(-2.635)**	(-5.035)***	(-4.513)***
Carer’s education: primary	-0.249	-0.270	-0.193
	(-2.646)**	(-3.331)***	(-2.123)**
Carer’s education: secondary	-0.091	-0.104	-0.036
	(-1.129)	(-1.316)	(-0.527)
Housing quality index	0.047	0.027	0.276
	(0.300)	(0.180)	(1.536)
Access to services index	0.188	0.046	0.117
	(0.956)	(0.245)	(0.809)
Not enrolled	-1.760	-0.349	-1.254
	(-4.115)***	(-0.896)	(-2.924)***
Enrolled in first grade	-1.218	-0.353	-0.633
	(-5.689)***	(-1.078)	(-3.505)***
Enrolled in second grade	-0.245	-0.165	-0.290
	(-1.189)	(-0.517)	(-1.790)*
Hours doing chores, domestic tasks, care	-0.030	-0.027	-0.028
	(-1.389)	(-0.962)	(-1.393)
Hours in school or studying	0.028	-0.005	-0.001
	(2.095)**	(-0.295)	(-0.075)
PPVT raw z-scores R2	0.060	0.194	0.119
	(2.478)**	(5.375)***	(4.902)***
CDA raw z-scores R2	0.111	0.113	0.121
	(3.900)***	(4.163)***	(2.856)***
Stunted	-0.080	0.004	0.009
	(-2.322)**	(0.144)	(0.303)
Wasted	-0.032	-0.012	-0.059
	(-1.642)	(-0.422)	(-2.306)**
Wasted	0.001	-0.003	0.007
	(0.043)	(-0.094)	(0.174)
Recent sickness	-0.030	-0.029	-0.032
	(-1.461)	(-0.845)	(-0.973)
Stunted*morbidity	0.021		-0.011
	(0.666)		(-0.217)
Stunted*sickness	0.034	0.022	-0.014
	(1.128)	(0.583)	(-0.362)
Morbidity*sickness	0.032	0.007	0.024

	(0.934)	(0.144)	(0.497)
Stunted*morbidity*sickness	0.002	-0.017	0.021
	(0.057)	(-0.337)	(0.367)
Constant	0.666	-0.006	0.776
	(1.048)	(-0.008)	(1.032)
Observations	1,343	1,259	1,331
R-squared	0.396	0.194	0.189
Number of communities	36	36	36
Adjusted R-squared	0.374	0.163	0.160

Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1.
Standard errors clustered at community level ; community fixed effects included in all regressions

Appendix C10. Synoptic table of the coefficients and predictive power of the baseline and hybrid value added model with interactions. Only statistical significant coefficients are reported (Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1

	Ethiopia					
	Maths		**PPVT**		**EGRA**	
	Baseline	Robustness	Baseline	Robustness	Baseline	Robustness
Stunted	/	/	/	/	/	/
Wasted	-0.061**	-0.064**	/	/	/	/
Life-threatening morbidity	/	/	/	/	/	/
Recent sickness	/	/	-0.058**	-0.059**	/	/
Stunted*wasted	/	/	/	-0.057**	/	/
Stunted*morbidity	/	/	-0.056**	/	/	/
Stunted*sickness	/	/	/	/	/	/
Wasted*morbidity	/	/	/	/	/	/
Wasted*sickeness	/	0.057*	/	/	0.119**	0.121**
Morbidity*sickness	/	/	/	/	/	/
Stunted*morbidity*sickness	-0.076*	-0.093*	/	/	-0.142*	-0.147*
Adjusted R-square	0.299	0.304	0.192	0.225	0.144	0.141

India						
	Maths		PPVT		EGRA	
	Baseline	Robustness	Baseline	Robustness	Baseline	Robustness
Stunted	-0.084***	-0.068**	/	/	/	/
Wasted	/	/	/	/	/	/
Life-threatening morbidity	/	/	/	/	/	/
Recent sickness	/	/	/	/	/	/
Stunted*wasted	/	-0.045*	-0.063*	-0.063*	-0.073**	-0.079***
Stunted*morbidity	/	/	/	/	/	/
Stunted*sickness	/	/	/	/	/	/
Wasted*morbidity	/	/	/	/	/	/
Wasted*sickeness	/	/	/	/	/	/
Morbidity*sickness	/	/	/	/	/	/
Stunted*morbidity*sickness	/	/	/	/	/	/
Adjusted R-square	0.303	0.326	0.113	0.137	0.179	0.196

Peru						
	Maths		**PPVT**		**EGRA**	
	Baseline	Robustness	Baseline	Robustness	Baseline	Robustness
Stunted	-0.111***	-0.114***	-0.083***	-0.073***	-0.108***	-0.123***
Wasted	/	/	0.04*	/	/	/
Life-threatening morbidity	- 0.078***	-0.084***	-0.052***	-0.056***	- 0.065***	-0.068***
Recent sickness	- 0.023***	-0.026***	-0.008*	/	- 0.015***	/
Stunted*morbidity	0.149***	0.151***	0.040***	0.054***	- 0.09***	0.111***
Stunted*sickness	/	/	/	/	/	/
Wasted*sickeness	-0.034**	/	-0.049***	-0.032*	-0.045*	/
Morbidity*sickness	0.036***	0.036***	0.036***	0.031***	/	/
Stunted*morbidity*sickness	-0.083***	-0.08***	/	-0.024*	/	-0.041***
Adjusted R-square	0.413	0.419	0.449	0.472	0.289	0.308

Vietnam

	Maths		PPVT		EGRA	
	Baseline	Robustness	Baseline	Robustness	Baseline	Robustness
Stunted	-0.078**	-0.080***	/	/	/	-0.123***
Wasted	/	/	/	/	-0.045*	-0.059**
Life-threatening morbidity	/	/	/	/	/	/
Recent sickness	/	/	/	/	/	/
Stunted*morbidity	/	/	/	/	/	/
Stunted*sickness	/	/	/	/	/	/
Morbidity*sickness	/	/	/	/	/	/
Stunted*morbidity*sickness	/	/	/	/	/	/
Adjusted R-square	0.360	0.374	0.124	0.163	0.139	0.160